REAL TIME INTEGRATION AND COLLABORATION FOR SUSTAINABILITY MANAGEMENT IN METALLURGICAL COMPLEXES.

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ABSTRACT

The lack of integration information with sufficient detail for analysis causes inefficient operation in metallurgical complexes. It is not the lack of information. It can said it is avoidance to define right context for the use of information for sustainable operations. Having said that, what are we doing for the people to act upon information and be aligned to optimize the use of the resources raw material, energy, water and consumable for an entire metallurgical complex?

Collaboration between all the different entities in the company is a key component of improving efficiency of energy and water use. Evolution of Web technology and object modeling of the enterprise enables collaboration across the whole business and troubleshooting of the operation to more quickly act on issues to reduce wasteful operation. This paper presents a real time software infrastructure with people tools that gives the users the ability to sift through available data, transform data into information for business continuous improvement and optimization. We will introduce a simple collaborative tool to add context to business areas or assets for getting things done in an industrial complex. Two examples from the industry will presented and their benefits highlighted.

Keywords: Dynamic Performance Management in Metallurgical Complexes, Dynamic Performance Notifications for Action, Mass and Energy Balances, Enterprise Asset Management, Equipment Availability, Overall Process Effectiveness.

INTRODUCTION

One of the main challenges to the mineral processing plants is the efficient management of water and energy. These represent a major part of the cost in the mining and mineral processing. Rising costs of water and energy have a direct impact on the profitability of the operation, especially as the grade of the ore is reduced over time. An example of the effect of grade and recovery on energy use in copper production, from work by D. Fuerstenau [9] is shown in Figure 1. Comminution uses over 50% of the energy used to produce copper and as grade decreases the energy requirement increases sharply and can make the operation unprofitable. The other processes such as smelting and refining are not dependent on the ore grade.

An example of the typical water consumption in milling is 125 – 200 gallons per ton of rock in a SAG mill and 150 – 300 gallons per ton of rock in a ball/rod mill. The use of water also impact the energy consumption since the water has to be pumped. So optimizing the water use not only reduces water use per ton but will also reduce energy consumption in the entire process. The energy consumption is also huge, and opportunities for savings are not only in Comminution, but in the extraction operation (blasting, drilling, etc.) and in the material handling operations (diesel powered equipment, conveyers, pumps, etc.) According to the US Department of Energy study about 25% of the current energy use in the US mining industry can be saved by going from current operation to best practice operation, and over 50% to practical minimum operation.

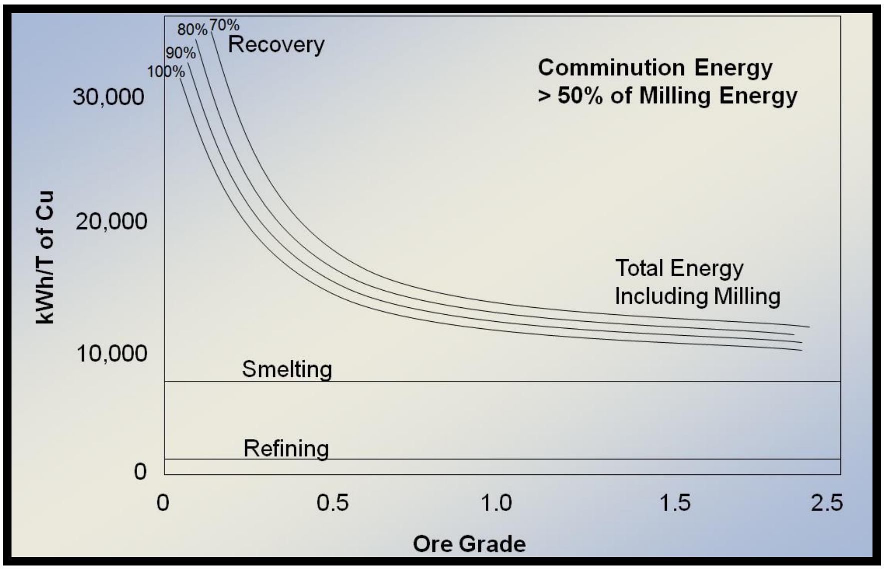


Figure 1- Energy Use versus Ore Grade and Recovery

A couple of examples of the potential savings are (the numbers are for year 2007 for the US mining industry) US DOE, 2007:

- Grinding – Current consumption 124 TKcal/yr, Best Practice consumption 106 TKcal/yr, and Practical Minimum consumption 35 TKcal/yr
- Material Handling (Diesel) – Current consumption 54 TKcal/yr, Best Practice consumption 35 TKcal/yr, and Practical Minimum consumption 26 TKcal/yr

The current challenge is that a large amount of data is available, but it is in information and application islands. What is lacking is the unification of the data in a common platform and collaboration between different groups to address the business objectives of the corporation. Most of the real-time data gathered from the equipment is usually filtered and aggregated resulting in possible loss of information that was encapsulated in the raw data [12].

What is needed to enable reductions water and energy consumption is the availability of the necessary real-time data and tools to process and analyze, collaboration between different groups in the company, immediate feedback for actions taken, and lots of small focussed projects instead of a few mega projects. To do this effectively in a scalable manner, a software infrastructure needs to be set up, with models of assets embedding standards and calculation logic in templates for easy maintenance and collaboration. Lastly, it is imperative to provide total visibility of this whole process to the enterprise. Presenting the performance metrics, KPIs, and other integrated information relevant to the operation provides immediate feedback to the enterprise and allows users to see the impact of their actions in real-time.

To enable achieve these results a continuous improvement and innovations management strategy is imperative [3, 10]. Bascur and Hertler [7] discussed the requirement to build a collaborative enterprise environment to enable collaboration between the operational and strategic teams. These strategic teams currently transcribe the information but they do not have access to the detailed information to identify long term initiatives and recommend new strategies (innovation) for changing. The collaborative strategy and benchmarking strategy is fuelled by a dynamic performance monitoring and notification environment. Early adoption and incorporation of the operational design can be incorporated in the process object information models [8].

This paper highlights the implementation of a software infrastructure and a reliable data unification and analysis system. This provides the structure that is needed for any process plant to maintain optimum operational levels and more efficient use of energy and water.

METHODOLOGY DESCRIPTION

The importance of real-time information cannot be overstated. The faster you have the information the faster you can react to it. When integrating mining and metallurgical information into a common platform it is important to keep the enterprise goals of the company in mind. So the first step is to link all the data sources that need to be historized to the PI Server and store the raw data in the necessary fidelity. A common tool set can now be used to access the time-series data and also non time-series data from external sources [13]. This gives visibility on the plant floor to the performance of assets and the process and allows the operators and engineers to trend, correlate, and analyze important operational factors. To make this scalable and visible to the enterprise it is necessary to create an asset data directory.

An asset framework infrastructure to treat real time information

Recent advances in software technology enable the scalable use of objects template to organize real time data into many contexts as required. A key development in OSIsoft PI System infrastructure is the PI Asset Framework (PI AF) allows users to create templates of their assets, embed calculation logic and methodology into these templates, and create an asset structure [6, 7]. This application provides a standardized object model of the corporate assets and a data directory allowing the building of the business intelligence processes. It also enables the maintenance of assets from a centralized library of templates and the combining of real time data, events and non-real time data in a common toolset. PI AF isolates the client applications from the data sources allowing the continuous improvement of the underlying and embedded knowhow, and the easy maintenance of the assets from the templates. It also integrates the process and equipment data, the “Application Models” (logical, plant, physical, organizational, etc.), and the scheduling of calculations and procedures, providing a scalable and evolving infrastructure for the implementation of client applications. Plant models are time referenced, including specific business rules as defined from the event frames.

All the assets need to be classified and categorized by creating templates of the same types, like crushers, grinders, concentrators, conveyors, etc. The templates contain the links to data in the PI Server and external data as well as any calculations for KPIs and metrics for that type of equipment. Figure 2 shows a sample asset structure for a concentrator. In this example, the assets are organized by production line with monitoring of consumables. Real-time statistics are used to calculate the minimum, maximum, and standard deviation of each consumable by asset, by production line, and by mill. The users modify the time range they are interested in from say 1hour to a shift or a day. The statistics are recalculated in real-time based on this time range. This way the operations and plant floor are using the same assets as the business systems are, but have different views of the same data for their own purposes and needs.

Once this in place, it creates a structured environment that allows for much easier maintenance, creation of assets structure, unit metallurgical process templates to organize the measurements and calculations, and then presentation to the business systems using the Web.

This process classifies and consolidates the measured values and provides information which correlates the state of the assets for energy and water conservation. These results are then used to focus on erroneous measurements so that they can be fixed. It is important to use validated numbers in evaluating performance of a process otherwise wrong conclusions can be derived. The validation process is performed over many shifts together with real-time statistical quality control (SQC) performed on the meters. The key validation is the classification of the assets operational state during each shift.

After the measurements have been classified the analysis of the asset performance and the process can be performed. The information on these performance metrics must be made visible not only to the operators and unit engineers, but to the entire enterprise. Visibility of the data in real time is the key to continuous improvement and collaboration. This is best achieved using portal technology such as Microsoft Sharepoint or SAP NetWeaver displaying the results in a WEB environment for access by management, personnel and external resources. This way the real time performance indicators, inventories, yields, etc. can be made visible to a wider audience and provides immediate feedback for the operation of the facility. This creates a collaboration environment with a feedback process for creating small focused projects for more efficiently using energy and water for the operation.

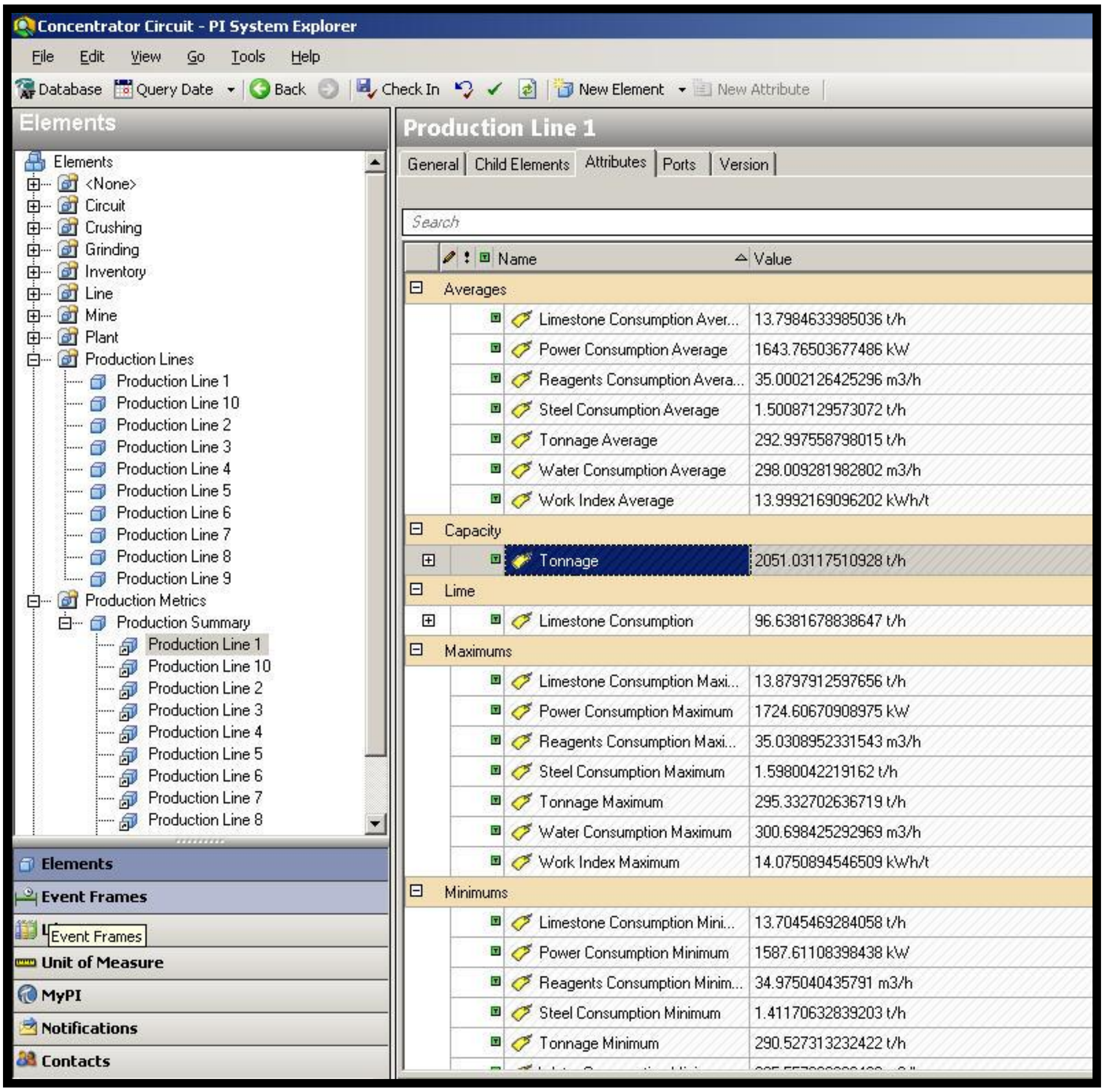


Fig 2 – Concentrator Asset Structure and Consumables Consolidation Statistics

RESULTS AND DISCUSSION

The real time information accesses the associated variables during the period of time (context interval) when this ore type was processed. Analysis of the metallurgical performance can be performed linking the grade/recovery with the grinding/blast strategies in a mineral processing plant. 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. The operating 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.

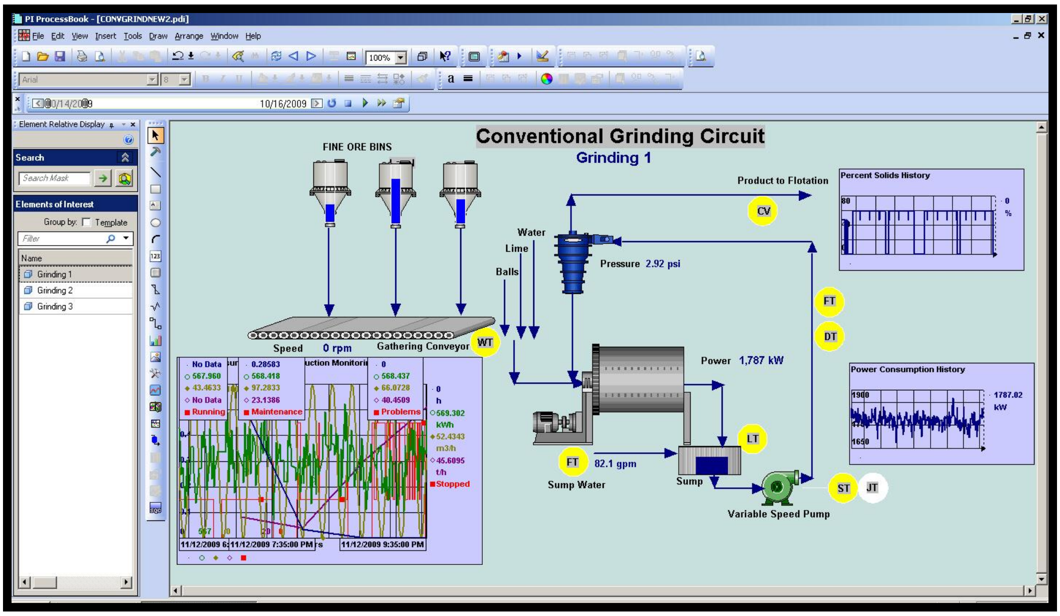


Figure 3: Grinding Circuit Dynamic Performance Monitoring and Notification

A view created by an engineer to analyse a grinding circuits section is shown in Figure 3. Consumables, such as power and water, are monitored in real-time as well as the average, maximum, and minimum for each shift. The variability of consumption is therefore monitored and gives the engineer information to investigate abnormal consumption and identify the root cause for this occurrence. The status and availability of the assets in the grinding circuit are also monitored to give vital information on the events whether an asset is in running correctly, idling, in maintenance, down, or having trouble, how often it has been in these states and for how long. Correlating this information with the production and consumables information gives feedback to the engineer so that corrective action can be taken to prevent sub-optimal operation, and hence the wasting of water and energy.

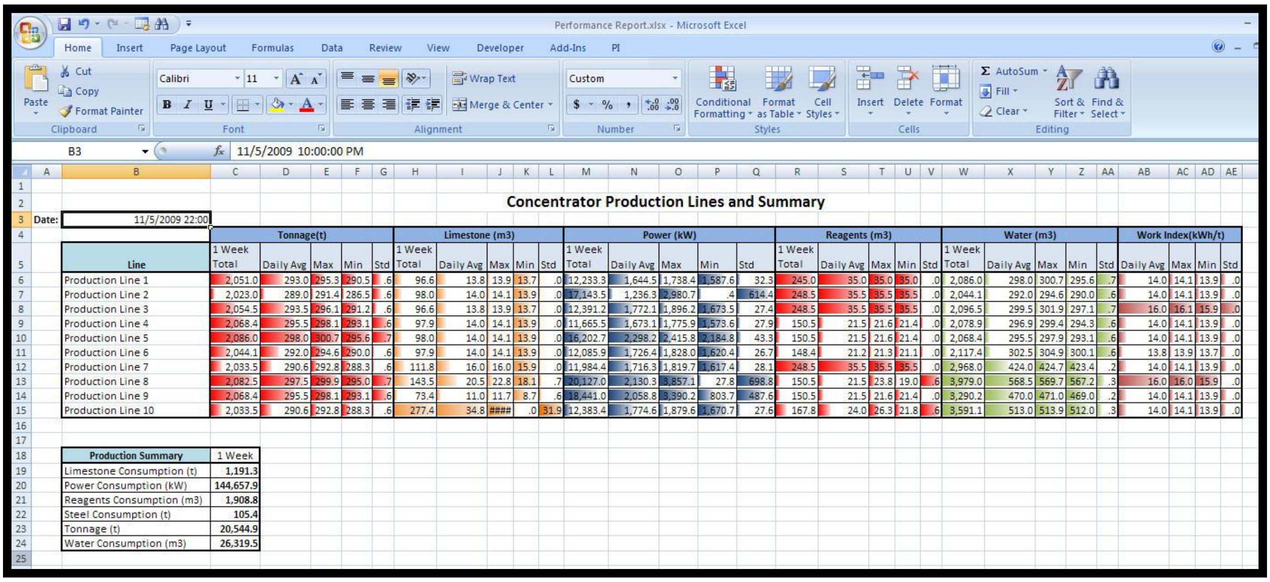
In addition to monitoring the grinding line from an operator's point of view, notifications are set up to watch for abnormal or deteriorating operational performance over time. The automatically generated notification alert the appropriate party (Managers, Maintenance, Support Center) when the mill is using more than the average consumables and when the availability drops below a minimum threshold. The notifications are set to notify based on business rules managed by the contact engineers or using real-time statistical quality control. Providing this feedback enables operations and asset availability personnel to quickly assess the problem and take corrective action. This makes a more efficient operation preventing waste of consumables and increasing throughput. As such, the operating, maintenance, enterprise competence centres can collaborate and work on the local tactics (root cause analysis) and on long term strategic initiatives for business improvements and innovation.

The KPIs are used for Dynamic Performance Management analysing the different operational states when running well, in troubles, down, stopped or in maintenance. In each of the operating states the overall operating costs (energy, water, steel, reagents) are consolidated and reported based on ore type, hardness, mineralogy on the effect final recovery and grades. This type of implementation has been reported by [15] with saving of more than US$ 30 million per year.

Getting things done in large metallurgical complexes

David Allen book entitled Getting Things [1] done clearly identifies that Managing Action is the PRIME CHALLENGE. As such, as we pointed out the people has to engage in the creation for the business rules defined to transformed data into information for business action [4]. Data can be reused several ways for action. Operating staff can define the filters to be in line with their knowledge of the process and equipment.

They can define the classification and filter rules prior to action. This classification is related to tactical and strategic decisions in an operating environment. The tactical are related to finding the root causes of the problem and the strategic loop is focus on asking the question: Are we satisfied with the results, how can we improve or reduce costs?. Allen suggests that what you do with your time, what you do with information, and what do you do with your body and your focus relatives to your priorities. These are the real options to which you must allocate your limited resources. As such, you need to be involved in applying the tools for yourself and your team to simply your function as an individual. The real issue is how to make the appropriate choices about what to do at any point in time. It is extremely difficult to manage actions you haven't identified or decided on. As such, the way to people assign context to their data is a vital activity for them to become better actor. They have to close the loop. This was discussed with many examples in [5]. Dr. Malhotra discussed the key design of the process engineer activities using the 7 Habits of Highly Effective People [11]. As such, the urgent (pump repair, cyclone plugged, daily metallurgical balance) as compared to the important activities (plant auditing based on ore type, preparation of metrics, operator training, preventative maintenance or condition based maintenance) and other less important activities such as urgent and not important (weekly report, order reagents, reagent salesman call, mail, meeting mine people) and not urgent and not important (mail, time wasters).



Concentrator Production Lines and Summary

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Line	Tonnage(t) 1 Week Total	Daily Avg	Max	Min	Std	Limestone (m3) 1 Week Total	Daily Avg	Max	Min	Std
Production Line 1	2,051.0	293.0	295.3	290.5	.6	96.6	13.8	13.9	13.7	.0
Production Line 2	2,023.0	289.0	291.4	286.5	.6	98.0	14.0	14.1	13.9	.0
Production Line 3	2,054.5	293.5	296.1	291.2	.6	96.6	13.8	13.9	13.7	.0
Production Line 4	2,068.4	295.5	298.1	293.1	.6	97.9	14.0	14.1	13.9	.0
Production Line 5	2,086.0	298.0	300.7	295.6	.7	98.0	14.0	14.1	13.9	.0
Production Line 6	2,044.1	292.0	294.6	290.0	.6	97.9	14.0	14.1	13.9	.0
Production Line 7	2,033.5	290.6	292.8	288.3	.6	111.8	16.0	16.0	15.9	.0
Production Line 8	2,082.5	297.5	299.9	295.0	.7	143.5	20.5	22.8	18.1	.7
Production Line 9	2,068.4	295.5	298.1	293.1	.6	73.4	11.0	11.7	8.7	.6
Production Line 10	2,033.5	290.6	292.8	288.3	.6	277.4	34.8	####	.0	31.9

Line	Power (kW) 1 Week Total	Daily Avg	Max	Min	Std	Reagents (m3) 1 Week Total	Daily Avg	Max	Min	Std
Production Line 1	12,233.3	1,644.5	1,738.4	1,587.6	32.3	245.0	35.0	35.0	35.0	.0
Production Line 2	17,143.5	1,236.3	2,980.7	.4	614.4	248.5	35.5	35.5	35.5	.0
Production Line 3	12,391.2	1,772.1	1,896.2	1,673.5	27.4	248.5	35.5	35.5	35.5	.0
Production Line 4	11,665.5	1,673.1	1,775.9	1,573.6	27.9	150.5	21.5	21.6	21.4	.0
Production Line 5	16,202.7	2,298.2	2,415.8	2,184.8	43.3	150.5	21.5	21.6	21.4	.0
Production Line 6	12,085.9	1,726.4	1,828.0	1,620.4	26.7	148.4	21.2	21.3	21.1	.0
Production Line 7	11,984.4	1,716.3	1,819.7	1,617.4	28.1	248.5	35.5	35.5	35.5	.0
Production Line 8	20,127.0	2,130.3	3,857.1	27.8	698.8	150.5	21.5	23.8	19.0	.6
Production Line 9	18,441.0	2,058.8	3,390.2	803.7	487.6	150.5	21.5	21.6	21.4	.0
Production Line 10	12,383.4	1,774.6	1,879.6	1,670.7	27.6	167.8	24.0	26.3	21.8	.6

Line	Water (m3) 1 Week Total	Daily Avg	Max	Min	Std	Work Index(kWh/t) Daily Avg	Max	Min	Std
Production Line 1	2,086.0	298.0	300.7	295.6	.7	14.0	14.1	13.9	.0
Production Line 2	2,044.1	292.0	294.6	290.0	.6	14.0	14.1	13.9	.0
Production Line 3	2,096.5	299.5	301.9	297.1	.7	16.0	16.1	15.9	.0
Production Line 4	2,078.9	296.9	299.4	294.3	.6	14.0	14.1	13.9	.0
Production Line 5	2,068.4	295.5	297.9	293.1	.6	14.0	14.1	13.9	.0
Production Line 6	2,117.4	302.5	304.9	300.1	.6	13.8	13.9	13.7	.0
Production Line 7	2,968.0	424.0	424.7	423.4	.2	14.0	14.1	13.9	.0
Production Line 8	3,979.0	568.5	569.7	567.2	.3	16.0	16.0	15.9	.0
Production Line 9	3,290.2	470.0	471.0	469.0	.2	14.0	14.1	13.9	.0
Production Line 10	3,591.1	513.0	513.9	512.0	.3	14.0	14.1	13.9	.0

Production Summary	1 Week
Limestone Consumption (t)	1,191.3
Power Consumption (kW)	144,657.9
Reagents Consumption (m3)	1,908.8
Steel Consumption (t)	105.4
Tonnage (t)	20,544.9
Water Consumption (m3)	26,319.5

Figure 4 – Monitoring Concentrator Production Lines

He points out using the new tools that have to strategically be involved in more analysis and deployment of Performance Management activities. It is not the writing daily reports that provide no results, today they have to select what is going to make a different and exploit the generation and identification of predictive performance, analisis of the asset availability optimization, reduction of downtimes and process in troubles. They should be running statistical process control to indentify the root cause and capital investment for reduction of causal problems.

Allan suggest to clarify things on the front end, when opportunities appear on the radar, rather than on the back end, after trouble has developed, these activities allows people to reap the benefits. He suggests focusing on a Greek proverb... The beginning is half of every action... In our context we can say: early identifications of alerts based on the analysis of the historical information, and focussing in implementing and managing notifications and workflows to collaborate within the enterprise.

The integration of metallurgical complexes starts by developing a center of excellence to enable the implementation of the overall energy consumption starting from the blasting and the quality of it, ore transportation, crushing and milling energy and water resources are now monitored in real time for identification of process opportunities for costs reduction.

This integration results in view of the entire process from a business and maintenance point of view. The consumables are monitored by asset, production lines are compared, operations based on shifts are compared, and the status of the assets is monitored. The overall energy consumption can now be analysed by ore type and mining strategy initiative, this resulting in a best strategy for each type of ore. Figure 4 shows the results from the PI AF exercising the analysis for a given case in an Excel spreadsheet. The use of Excel is for presentation purpose all the analysis and process calculation are done within the analysis tools stored in MS SQL.

Enterprise Dynamic Performance Management

For 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 consolidate the set of inventories, flows, compositions and transactions. 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. Metal losses are calculated based on the set of data provided. It is interesting to note that for this to work collaboration between accountants, process engineers, laboratory measurement and plant management is the key. The real time performance management infrastructure supports this type of activity. In the implementation of applications the collaboration between the instrumentation people, plant engineers, accountants and management has been a crucial part of the success.

The creation of the asset structure and the use of templates to enforce the standards, calculation methods, and KPI determination provide the ability to create different views into the process. Maintenance of the templates enables any modifications or changes to be automatically propagated to the individual assets. It is also important to be able to cross correlate the status of individual equipment with the production data. The equipment status can be defined as [2, 7]):

- Running – operating correctly
- Down – unscheduled maintenance due to equipment failure
- In Maintenance – scheduled maintenance
- Trouble – operating but indications equipment is abnormally possibly leading to failure
- Idle – not operating but not in maintenance

It is important to monitor the status of the assets to make sure a conveyor isn't left running when there is no material to transport; water isn't left running when a mill is in idle, etc. Scenarios like these are easy to fix and hence prevent wasting of power and water. A real-time dynamic performance is required for adequate feedback and notification. A simple example is real-time monitoring of a pump and its motor. A pump has performance curves that determine the pump discharge pressure based on the flow rate, based on the pump type, the pump speed in RPM and impeller size. The pump template is configured in the PI AF with the appropriate attributes gathering data from PI System, relational databases, and formulas. The individual pumps are then created from the template; each pump's discharge pressure is compared in real-time to the design discharge pressure based on the pump curves. Notifications are set when the deviation starts exceeding a user defined tolerance. This way the pump degradation is monitored in real-time and maintenance can now be performed on just-in-time basis instead on a predefined schedule. Running the pumps efficiently optimizes the use of energy and prevents unscheduled downtime resulting in lost production. This same strategy is now used for all rotating equipment (trucks, drills, grinding mills, conveyors, valves, flotation cells, thickeners, mixers, etc.).

Figure 5 shows an actual example for an industrial iron and steel complex. A basic template for an area is defined and configured with the production, consumables, and energy and water metrics. The template is implemented with the necessary calculations, time derived variables (Min,Max Std, Totals) and organized by production areas. The performance analysis is aggregated for the required time interval and all the metrics rolled up by productions areas. As such, all the information by productions areas and the assets times used to consolidate the information for any time interval, raw materials, and production types to dynamic performance analysis. This is power of using a temporal data base and not a relational data base.

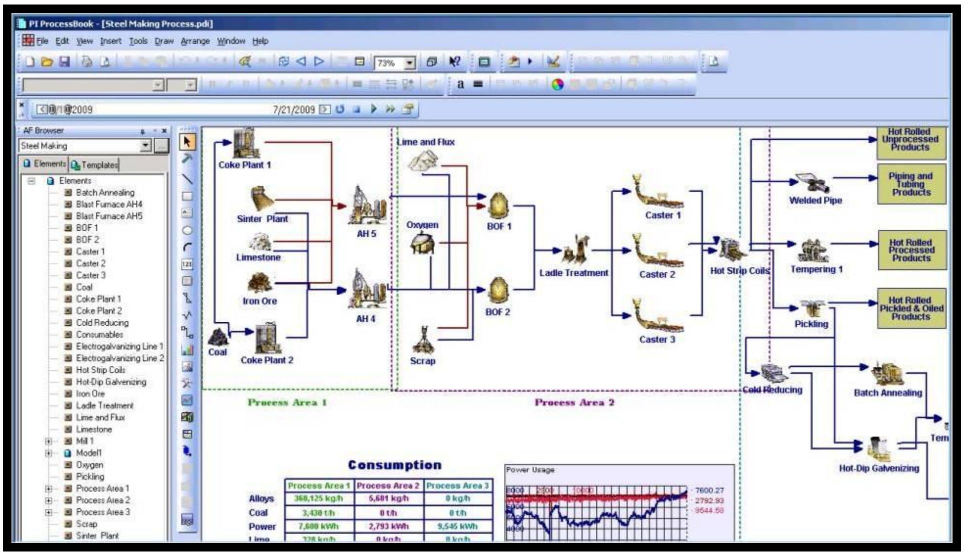
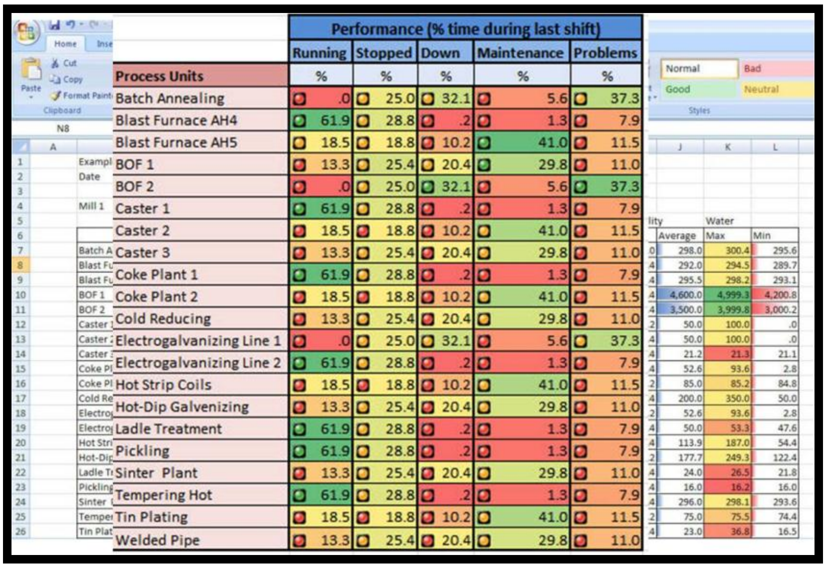


Figure 5: Context Information Production, Consumables, Energy and Water for a Metallurgical Complex.

Following, Figure 6 shows a real time data analisis of asset time analisis for each of the metallurgical complex areas. The data is validated and filtered without programming identifying the opportunities to focus on extending the asset operating time on a sustainable performance. The consolidation of the consumables, energy, water and environmental metrics can be grouped in optimal utilization of the assets and the time wasted by the assets of for improvement shift to shift. The transitions from lower performance to higher performance to satisfy the metallurgical production schedule are enabled.



	Performance (% time during last shift)				
	Running	Stopped	Down	Maintenance	Problems
Process Units	%	%	%	%	%
Batch Annealing	.0	25.0	32.1	5.6	37.3
Blast Furnace AH4	61.9	28.8	.2	1.3	7.9
Blast Furnace AH5	18.5	18.8	10.2	41.0	11.5
BOF 1	13.3	25.4	20.4	29.8	11.0
BOF 2	.0	25.0	32.1	5.6	37.3
Caster 1	61.9	28.8	.2	1.3	7.9
Caster 2	18.5	18.8	10.2	41.0	11.5
Caster 3	13.3	25.4	20.4	29.8	11.0
Coke Plant 1	61.9	28.8	.2	1.3	7.9
Coke Plant 2	18.5	18.8	10.2	41.0	11.5
Cold Reducing	13.3	25.4	20.4	29.8	11.0
Electrogalvanizing Line 1	.0	25.0	32.1	5.6	37.3
Electrogalvanizing Line 2	61.9	28.8	.2	1.3	7.9
Hot Strip Coils	18.5	18.8	10.2	41.0	11.5
Hot-Dip Galvenizing	13.3	25.4	20.4	29.8	11.0
Ladle Treatment	61.9	28.8	.2	1.3	7.9
Pickling	61.9	28.8	.2	1.3	7.9
Sinter Plant	13.3	25.4	20.4	29.8	11.0
Tempering Hot	61.9	28.8	.2	1.3	7.9
Tin Plating	18.5	18.8	10.2	41.0	11.5
Welded Pipe	13.3	25.4	20.4	29.8	11.0

Figure 6: Information for ACTION, Asset Timed Optimization

The following example of a balance a water distribution system is shown in Figure 7 below for a large metallurgical complex in the western USA. This model is used for mass and component balances from the mine to the mineral processing to validate the water consumption and the contaminants in the water. These models integrate the whole metallurgical mining and metallurgical complex. It includes the power plants and additional services using energy and water. The savings of water intake to the metallurgical complex and the tailings impoundment management has been very successfully implemented.

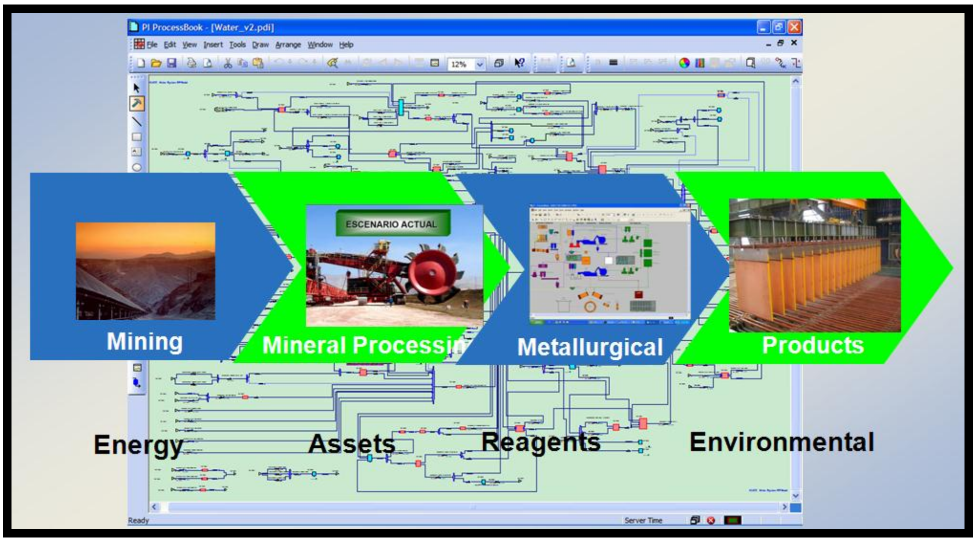


Figure 7: Mine and Metallurgical Complex Water Distribution Model

CONCLUSIONS

Despite the advances in automatic data collection and archiving, operators and engineers to the business decision makers face the problem of exploiting the information that is relevant for the plant operation and the profitability of the business enterprise. Visibility and transparency of the information is necessary for an efficiently run business. This improves collaboration and gives real time feedback on the different decisions made at any level in the organization. The efficient use of water and energy is related to running the business in an efficient manner. The best approach is to have the infrastructure in place to be able to conduct small focused projects, collaboration between different groups in the organization, and understanding that this is a continuous improvement process.

There is a critical need to integrate legacy systems into real time information management infrastructures. This environment should enable users to transform process data into actionable information. 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 to defining the operational management database for implementation of variable cost management; yield accounting, dynamic process and equipment performance monitoring, downtime analysis and asset monitoring.

The technologies are available today to rethink plant operations and to increase the performance of current production systems. Data unification simplifies the integration of information from the process, laboratory, receipts and manual data entry. It generates high quality performance information from process data. The synergy of combining process data with transactional data provides a deeper understanding of the data for continuous improvement and innovation.

The key to re-engineering is linking people, business processes, strategies and the best enabling technologies. It is important to recognize that the cleaning data is a process. As such, several groups (instrumentation, maintenance, process engineering, accounting and managers) collaborate in the data unification process. This team effort should be rewarded.

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