MINE 432: Industrial Automation and Robotics in Mining

Lecture 9B

Process Control Strategies in Mineral Processing

A mineral processing plant contains a myriad of control systems that range from simple on-off alarm signals to complex adaptive control strategies that work within a dedicated DCS (Distributed Control System). These systems generally focus on a centralized control room into which all data in the mill are fed for viewing by an operations supervisor. Out on the mill floor there will be a number of operators and helpers responsible for monitoring and supervising specific unit operations either in response to signals on local control loops or to commands from the centralized system or supervisor.

Crushing Plants

The mill system will begin with a comminution circuit that consists of crushers, screens, feeders, conveyor belts, magnets, metal detectors, chutes, hoppers and bins, pumps and sumps, pipes and water flow rate controllers, grinding mills, classification units such as cyclones or classifiers, and assorted head tanks and pressure control systems. See Fig. 9B-1.

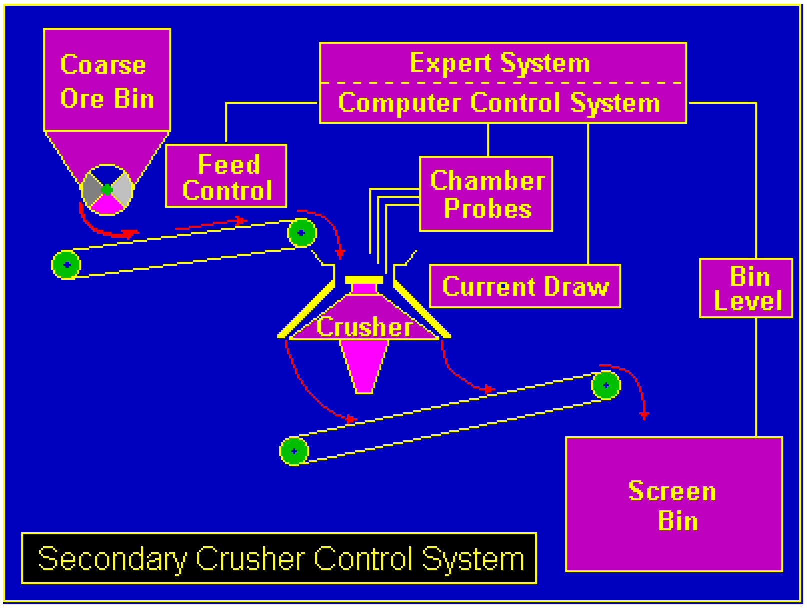


Figure 9B-1. Typical Secondary Crushing Plant with Controls.

Crushing circuit control involves one or more of the following control systems:

1. Control of the feed ore using a vibratory feeder or rotating feeder which responds to weight scale signals from a load cell mounted on the main feed conveyor.
2. The set point to the system derives from the power draw from the crushing unit or form a level sensor mounted within the crusher chamber. Generally a combination of these two signals is used to ensure "high-level" current draw does not occur and that the chamber level remains well below "Full" while maintaining a choked-feed condition.
3. Within the crushing plant, one finds vibrating screens that are used to control the product size

and ensure material that is too coarse is retained within the circuit for re-processing. The feed to these units is generally controlled so as to match the overall feed within the plant and maintain steady conditions with respect to bin levels and power draw.

4. All conveyors have metal-detecting sensors which trip out the belt in order to protect the crusher mantle and bowl from receiving uncrushable (steel or wood) material that could jam or break a crusher liner.
5. Recent cone crusher developments include the ability to change the crusher closed-side setting "on the fly" by raising or lowering the mantle as the chamber level and/or amperage level decreases or increases. In this way, the gap setting of a crusher now becomes a control variable rather than a design one.

The major loads to which these control systems must respond are as follows:

- changes in ore conditions (feed size and hardness)
- changes in the amount of fines and/or moisture – clay minerals are problematic
- presence of wood and/or metal (proper protection leads to trip-outs)
- trip-outs of other equipment
- hang-up of material within bins and chutes
- high and low level alarms on bins and on power draw

Grinding Circuit Control

Grinding circuits in industry today range from simple ball-mill/cyclone circuits through to more complex rod-mill/ball-mill two-stage grinding and all the way to semi-autogenous and fully-autogenous mills that may or may not include a crusher in closed circuit. See Fig. 9B-2a and b.

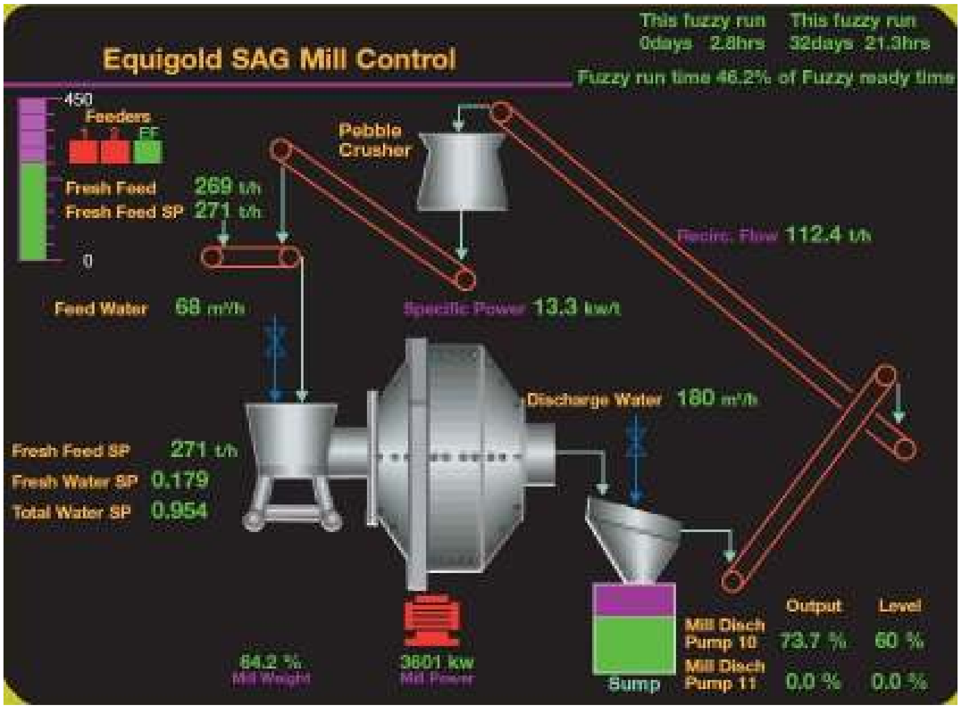


Figure 9B-2a. Grinding circuit showing control systems in use with a SAG mill circuit and a downstream second stage ball-milling.

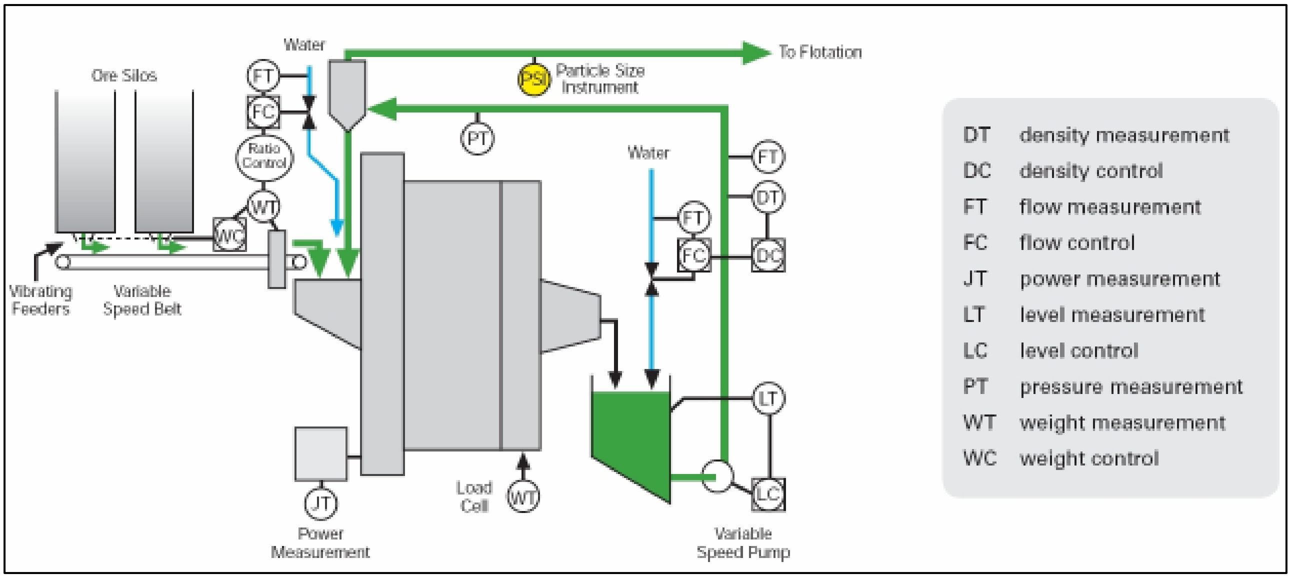


Figure 9B-2a. Grinding circuit showing control systems in use with a Single-stage ball-mill circuit with a cyclone classifier.

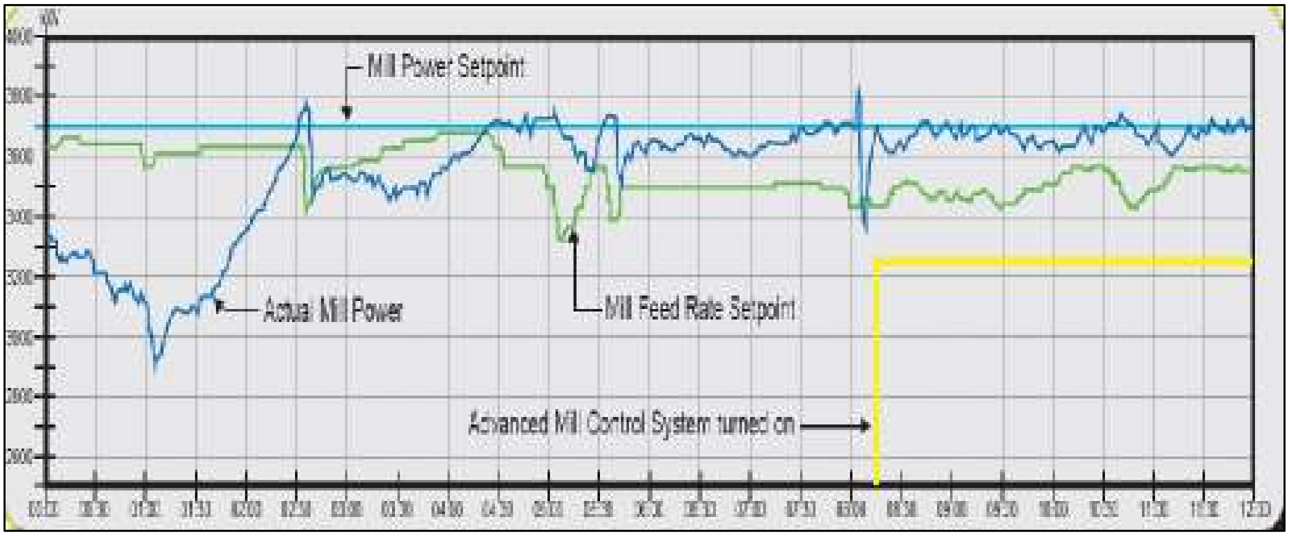


Figure 9B-2c. Control of grinding circuit in Fig. 9B-2a with advanced control OFF and ON.

The feed belt is generally controlled by changing the motor speed in response to set-point changes in tonnage required together with a feedback signal from a weight scale (weightometer). Water addition to the primary mill is generally metered using a ratio-controller that attempts to maintain the water flow rate in proportion to the solids feed rate – this ensures that the pulp density within the primary mill stays relatively constant – at least that is the goal.

As the ground pulp exits from the mill, water is added to aid in pumping and provide better and more stable rheological characteristics (i.e., slurry viscosity). The addition of this water is done to maintain adequate and stable pumping conditions. These conditions can be measured or indicated in a number of ways:

- measurement of pump speed (or power draw)
- measurement of pulp flowrate
- measurement of pump sump level
- measurement of downstream unit pressure
- measurement of pulp density
- measurement of particle size (direct measure)

Material that leaves a primary mill must be classified according to its size to ensure that the ore is properly prepared for the separation stage of the plant. The coarse fraction is sent to a secondary milling circuit or returned to the primary mill, while the fine material is delivered to the separation circuit (usually a flotation circuit, but not always).

Control of the classifier or cyclones is aimed at maintaining conditions that produce effective size separation – to minimize the return of fine material which would otherwise be over-ground and to minimize misplacement of unliberated coarse material into the separation process feed. Generally, variables such as pressure and pulp density are controlled by adding water to the classifier feed to maintain conditions to achieve a good split between coarse and fine particles.

The types of loads (or disturbances) suffered by a grinding circuit include the following:

- ore hardness changes
- feed size changes (when crushing circuit upsets occur)
- water conditions (line pressure and chemical conditions)
- circuit upsets (overflowing sumps, rod charging, clogged mill grates, etc.)
- set-point changes of the "grind" or of the "tonnage"

As a result of these changes, it is necessary to vary the water addition and the tonnage rate to suit the current needs of the overall mill situation and/or react to the ore changes.

Flotation Circuit Control

The most interesting process to control in a mill involves flotation. There are numerous variables available for use in process control, and so it is difficult to generalize – every mill develops its own approach since the ores are different and the chemicals used are different and often the particular constraints are different.

The goal of flotation is to concentrate the valuable minerals into a concentrate product with as little misplacement of gangue minerals as possible and as little loss as possible of valuable mineral to the plant tailings. Success is measured in terms of product quality/product quantity data – the so-called concentrate grade/recovery curve.

A flotation circuit consists of different stages – roughers, scavengers, and cleaners – a regrind circuit may also be featured within these circuits. Each stage has its own set of goals and constraints that come together to provide an overall metallurgical performance target for the plant. Both quality and quantity targets and constraints must be met.

Flotation Process Loads:

- Ore mineralogy
- Feed grade
- Mineral association (liberation size)
- Ore "grind" (particle size distribution
- Water chemistry conditions (recycle and fresh)
- Circuit upsets
- Reagent flowrate changes (delay times)
- Sampling problems (delays and accuracy)
- Surges in flowrates
- Distribution of material between parallel units

The first step is to describe the goal of each flotation stage. For example, in dealing with a **cleaner stage**, the main **objective** is to upgrade the circuit feed (generally rougher concentrate) to **final concentrate grade**. A set-point is established based on smelter contracts and on mineralogy (e.g., for a chalcopyritic copper ore, the concentrate grade set-point would be between 25 and 30% (certainly never much over 30, nor under 25). If bornite or chalcocite is present in any abundance, then the concentrate grade set-point could be much higher (perhaps as low as 40% or as high as 50%). If cubanite is present or the chalcopyrite is intimately associated with pyrite then the lower limit of 25% is typical. For a cleaner stage, the grade of the cleaner tailing is determined by the constraint of allowable recycle quantity. This constraint also plays an indirect role in determining the maximum value of the concentrate grade.

Alternatively, the **goal of the scavenger stage** is to recover every last bit of copper possible within the constraint of limiting the quantity of scavenger concentrate produced. The focus is on the grade of the tailing product which determines the **overall recovery** achieved by the plant. A set point can be chosen for the tailing grade to be as low as possible. The amount of scavenger concentrate that can be tolerated is the limiting issue with how low the grade of tailings can be set and this will vary depending on many ore parameters such as mineralogy and liberation.

With the rougher stage, the goal depends on the overall circuit configuration and current operating constraints. If sufficient cleaning capacity is available, the focus is on rougher circuit recovery to ensure the scavenger cells are not overloaded and the scavenger concentrate load does not increase too much. If cleaning capacity is limited, then the roughers can be used to increase the grade of the cleaner feed to reduce this constraint. The limiting constraints change based on the amount of material to be treated and on ore grade changes. With cleaner cells, feed grade and/or mineralogy can affect capacity requirements. The flow rate of pulp to a bank of flotation cells can vary considerably as the feed grade and/or mineralogical make-up changes (the goal is usually to obtain a target residence time of about 1 minute per flotation cell – it should never fall below 0.5 minutes and should never go above 1.5 minutes to ensure good performance). The scavenger stage is generally sized to be able to handle fluctuating feed grades. However in some cases, the recycling of middlings from the scavengers back to the roughers can lead to too high a flowrate.

pH Control

The control of pH in a mill is required in a number of different types of flotation circuits, particularly with ores that contain multiple valuable commodities such as copper and zinc, copper and lead, lead and zinc, copper and nickel, copper and cobalt, copper, lead, and zinc, etc. Alkali pH control is generally the major requirement with pH levels ranging from 9.0 to as high as 12.0 (for iron ores). Lime is generally the modifier used to achieve control, but soda ash, caustic soda, and ammonia may also be used. There can be considerable difficulty in controlling pH because of non-linearities in the pH vs. reagent concentration curve and from sanding (plugging) of the reagent valve (particularly problematic with lime). Solutions to these problems require advanced multi-variable algorithms, gain scheduling, and various fault detection methods.

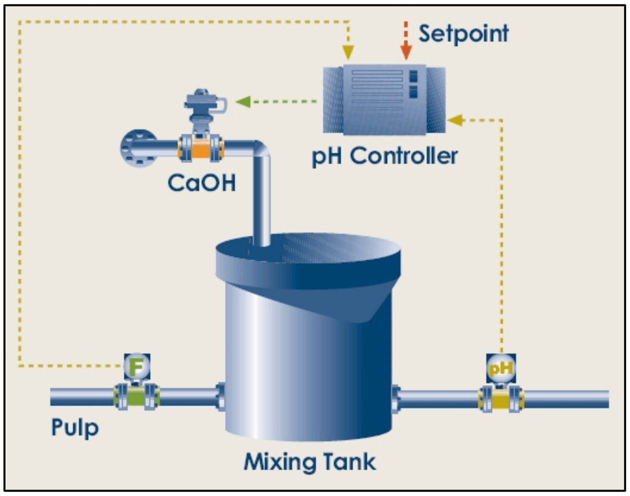


Figure 9B-3: Control system to meter lime into a flotation circuit stream to control pH.

Fig. 9B-3 shows mixing of lime and flotation pulp taking place in a dedicated mixing tank. While this is sometimes the case, often required control can be achieved by adding the lime slurry directly into a sump or even into the grinding mill. This may produce a larger delay time or process lag into the system, however the loads on pH control in these types of applications are usually not severe unless the water pH is variable or contaminated with metals and other reactive species.

Flotation Circuit Stability

A flotation circuit can be considered a multivariable, strongly-interacting process. The control actions taken in one stage (or even bank of parallel cells), can have significant impact on downstream processes. If these disturbances are not handled quickly and effectively they can rapidly propagate through and around the overall circuit. The main control variables in flotation involve reagent (of different kinds) addition rates and flotation cell levels in each flotation stage.

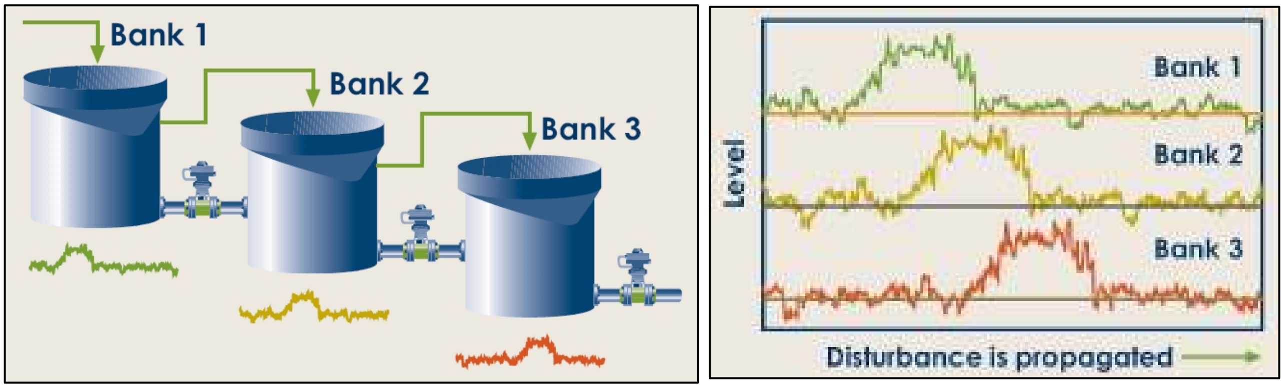


Figure 9B-4: Propagation of a disturbance through downstream processes.

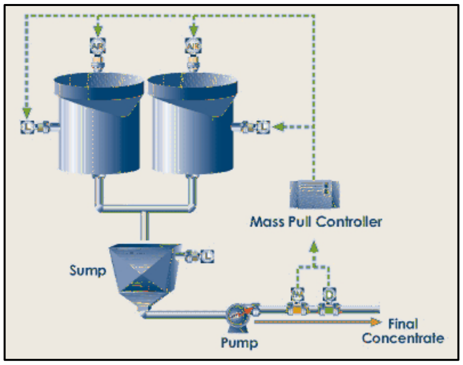


Fig. 9B-5: Massflow control of flotation cells using air flow and cell level as the manipulated variables.

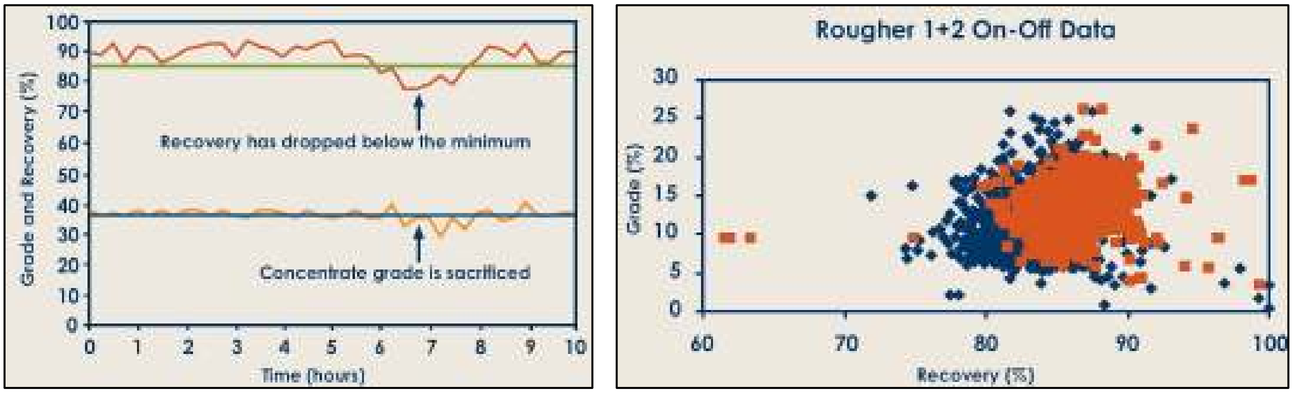


Figure 9B-6: The control strategy biases recovery over concentrate grade. **Left:** when recovery falls below a set minimum value, the system sacrifices concentrate grade to restore recovery to an acceptable level. **Right:** blue data refers to periods under PID control while red data shows a multi-variable optimization program to keep recovery above minimum. Conc. grade variation is lower under multi-variable control while recovery is higher.

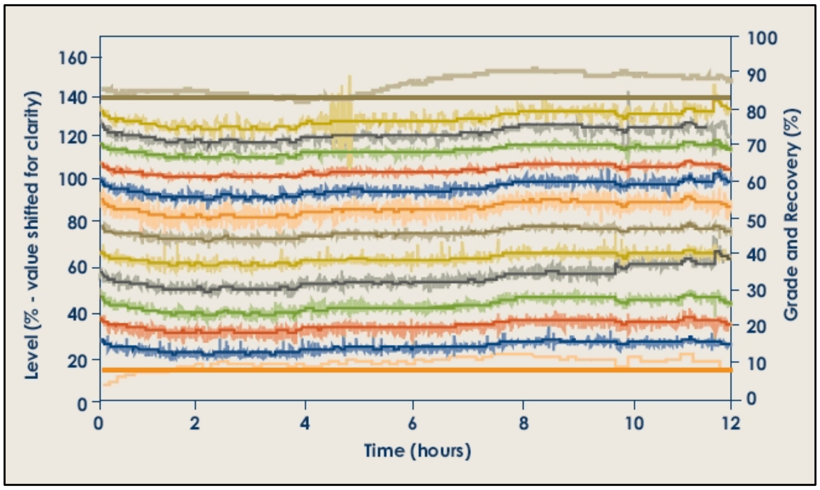


Figure. 9B-7: Time series data from Cu concentrator showing outputs in different flotation stages with recovery (top curve) and concentrate grade (bottom curve). The optimizer objective is to maximize rougher recovery while maintaining concentrate grade above minimum. Air control was not available since machines were self-aspirating.

Table 9B-1: Comparison of plant results under PID control of local loops and under a multivariable optimizing control strategy.

Metallurgical Variable	PID Control	Optimizing Control	Difference (%)
Average Recovery (%)	86.36	88.35	+1.99
Average Feed Grade (%)	1.632	1.634	Equivalent
Average Concentrate Grade (%)	37.51	37.32	Equivalent
Average Tailing Grade (%)	0.226	0.197	- 0.029

Reagent Optimization

Reagents play very important roles in flotation by maintaining selective hydrophobicity between valuable and gangue mineralization and in keeping froth conditions stable. Reagents strongly influence metallurgical performance of the circuit, and contribute significantly to plant operating costs. Selection of the "best" reagent suite is complex and often involves many contra-indicative rules and analyses. A reagent optimization process can automate this analysis process to provide consistent 24-7 adjustments to reagent additions tailored to current plant operating conditions.

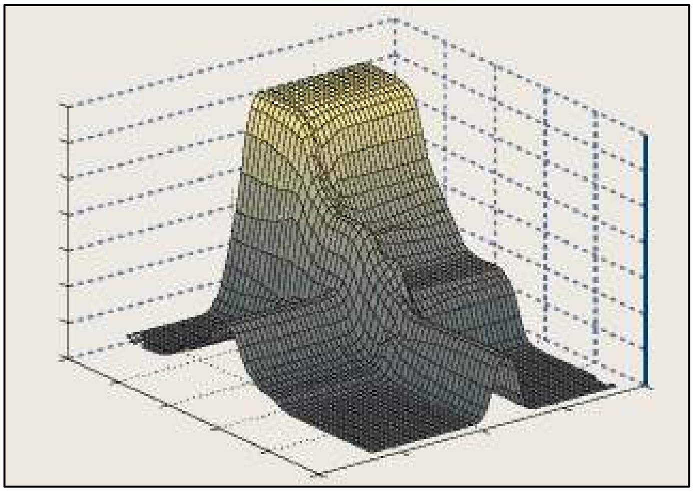


Fig. 9B-8: Representation of how reagent addition can vary as a function of the tailings and concentrate grades.

The optimization routine may consist of a fuzzy rule base with plant feedback of non-linear process outputs and feed-forward of multiple inputs. The system must have an effective user interface so both operators and metallurgists can work in real-time to assess current performance and implement new ideas. The system must be able to identify false readings or invalid assay values. It must be able to work with other optimization techniques that may be in use in other parts of the plant or in related processes.

Fault Detection and Alarms

A control system must be able to detect faults in data and keep the system from reacting to data errors. Fig. 9B-7 shows two types of faults – spikes and frozen signals. Spiky data clearly can result in wide swings in manipulated variables that could introduce greater variations than actually exist. Similarly, "dead" signals need to be quickly identified to attempt to repair the problem – likely a blockage in a line or a disconnected wire.

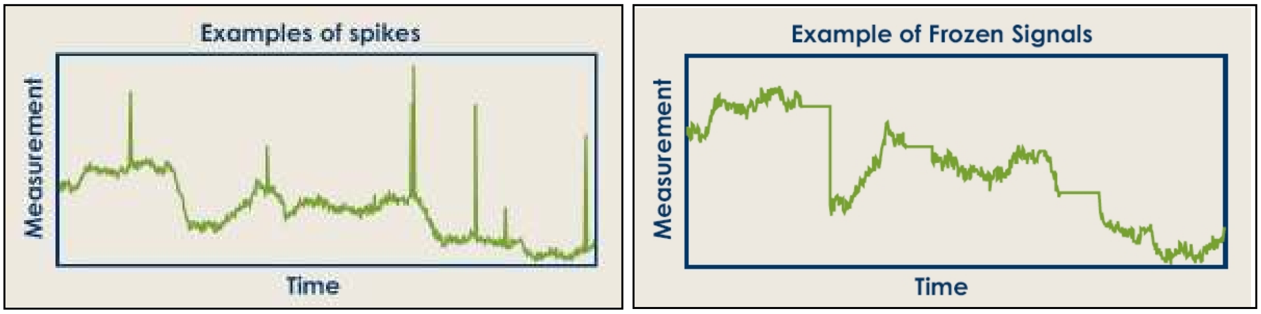


Figure 9B-9: Detection of faulty data in measurements taken within a concentrator. On the left, "spikes" can be seen in data that are artifacts or sensor failures. On the right, the output shows signs of "frozen" signals in which an output remains unchanged over a period of time indicative of a sensor or sampling failure.

The detection of upset conditions that exceed limits or process constraints is also a very important feature of a distributed control system (DCS). An example of such a limit violation is shown in Figure 9B-10 – these minimum and maximum levels could represent ore in a bin, pulp in a sump, water pressure in a line, reagent solution in a mixing tank, etc. These alarms can be just as significant to detect as faults in data since they can result in a "permanent" upset condition that will require considerable time and effort to rectify.

Figure 9B-10: Generation of process alarms in which a monitored variable exceeds a minimum or maximum limit established by operating conditions or by equipment constraints.

Reference: MinTek, 2006. StarCS: FloatStar – Flotation Control and Optimization
http://www.starcs.co.za/FloatStar.pdf#search=%22%22flotation%20control%22%22

On-Stream Analysis

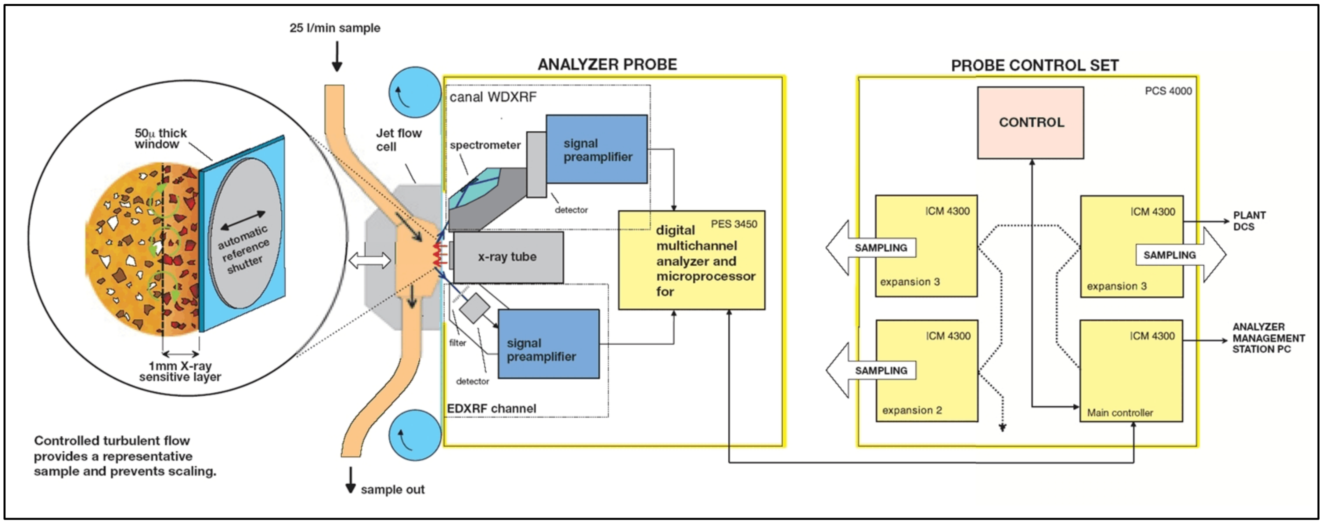


Figure 9B-11: Basic Components of the Courier-6SL On-stream XRF Analyser.

The Courier-6SL is the high-performance version of the Courier On-stream XRF Analyzer systems marketed by Outotec (formerly Outokumpu Oy) for real-time elemental assaying of slurry process streams. This high-power analyzer offers the best sensitivity and shortest cycle times for process management, monitoring, and control in all sizes and types of minerals processing plants. An alternative system is the Courier 3 SL analyzers for distributed applications and remote sampling.

What can a Courier analyzer do?

- Sampling and analysis are automatically done in a consistent way 24-7 creating savings in assay costs and metallurgical sampling;
- Recoveries are increased since process upsets are detected early and solved rapidly;
- Frequent assays are necessary for real-time process monitoring and control;
- Concentrate quality is controllable and undesired variations minimized;
- Plant operation is optimized with lower circulating loads resulting in higher throughput.
- Assay accuracy compares with high-quality manual sample laboratory procedures;
- Courier on-stream analyzers use Wavelength Dispersive X-ray fluorescence (WDXRF) technology similar to high-performance laboratory analyzers;
- Results from process tests and changes are readily available motivating and speeding-up process development;
- Courier analyzer systems are modular so they can be upgraded and expanded as plant requirements change.

Sampling

Outotec primary samplers have been in use for over 25 years and can sample all process flows. A representative 70-300 L/min primary sample is circulated through a fast loop to the secondary sampler and back to a convenient return point in the process. The height loss of the sample is only 1m. Primary samples are not mixed with each other.

A smaller secondary sample is split out for accurate analysis. The secondary sample stream is sampled by a calibration sampler for lab assaying during calibration. When basic sampling design rules are followed, the primary sample streams can be used to collect representative composite samples for metallurgical accounting. Composite sample collection is built into the Courier 6SL sample multiplexers.

Representativeness of Samples

In considering sample assay representativeness, each step in the process stream to XRF analysis must be accounted for. X-ray fluorescence radiation only penetrates the sample slurry for a short distance, typically < 1 mm. The sample at the surface of the analyzer window must represent the entire process flow for accurate on-stream process assays this is achieved by using a specially-designed jet-nozzle to mix the sample as it enters the presentation chamber.

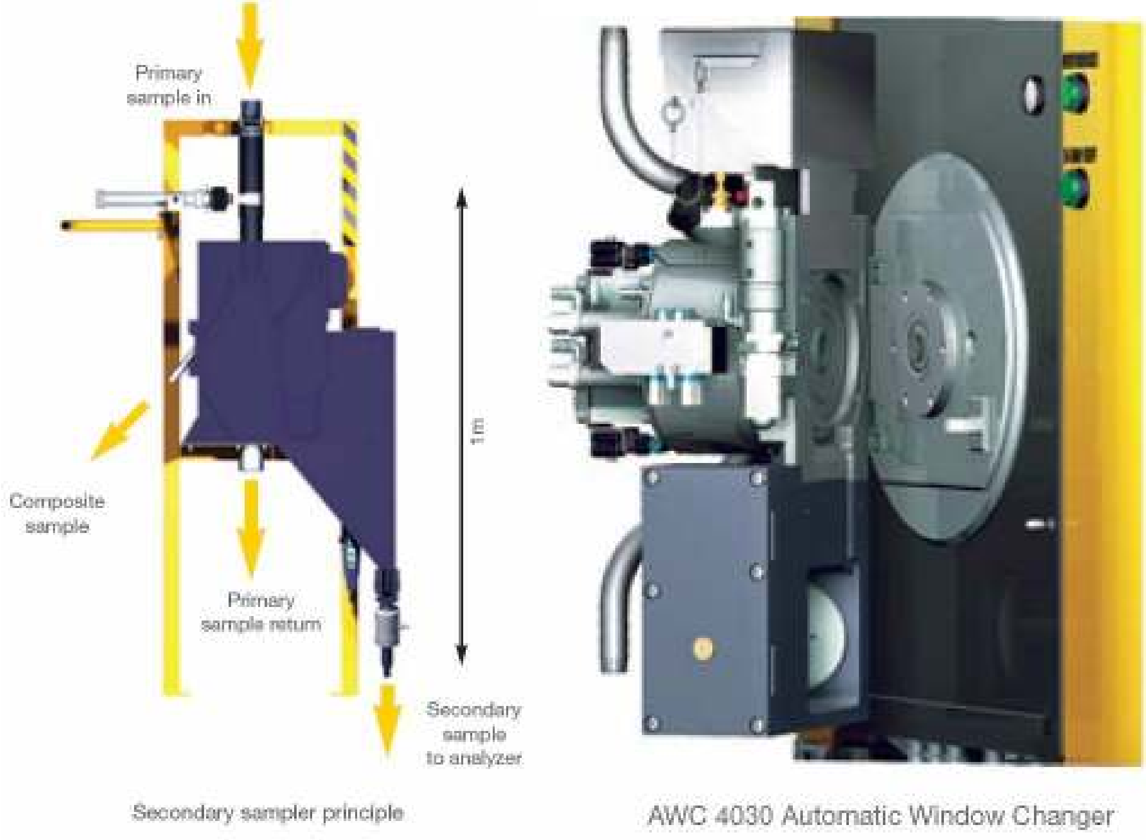


Figure 9B-12: a. Secondary sampling system for the Courier XRF Analyser.
b. Automated Mylar Window Changer.

Timeliness of assays

The major benefit in using a Courier on-stream analyzer is the frequency and speed of accurate assaying. This allows for fast reaction to changes in the metallurgical behavior of the flotation circuit. The cost of frequent laboratory assays required by proper process control is prohibitive. If the assays are based on strongly-filtered or averaged measurements over a long period of time, the assays are not useful for process control. Long time delay from actual process changes to control action makes feedback control unstable and the process trends become misleading.

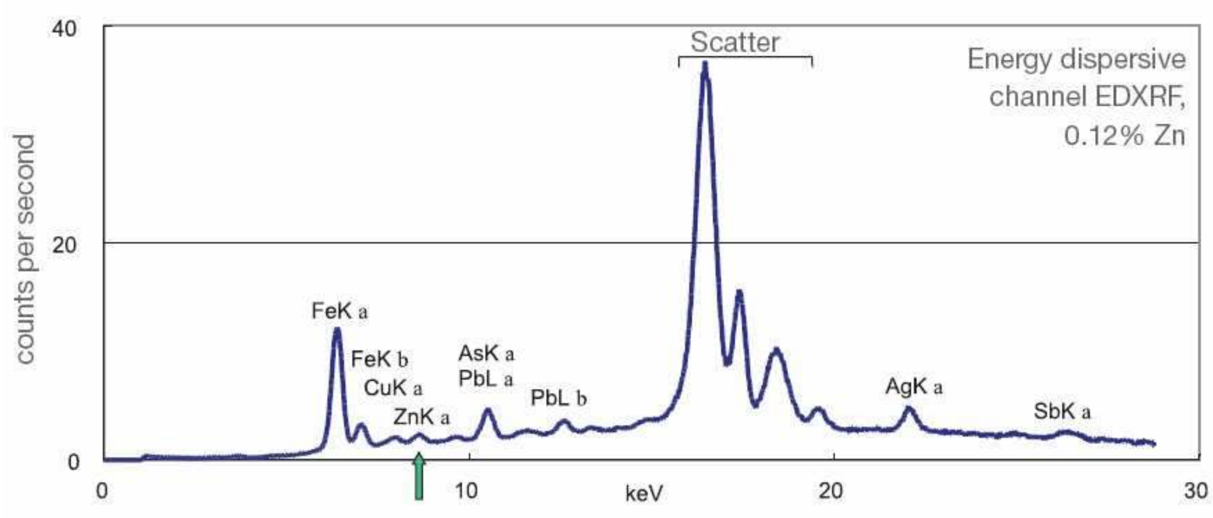


Figure 9B-13: Wavelength dispersive XRF plot for the Courier 6 Analyser.

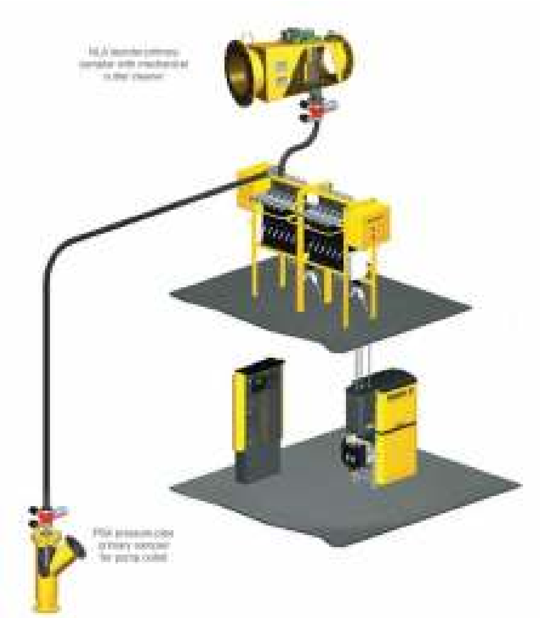


Figure 9B-14: Multiplex secondary sampling system for the Courier XRF Analyser.

Flash Flotation Control

Monitoring a flash flotation cell within the grinding circuit by sampling the concentrate grade helps produce high-grade concentrate, which is then easier to clean or may not even require cleaning. Significant overall recovery improvement can be obtained in this way since valuable free mineral particles can be removed from the grinding recycle stream avoiding unnecessary regrinding and so, decreasing valuable mineral losses to final tailings in the -10 micron fraction.

Primary Rougher Flotation Control

Monitoring the primary rougher concentrate grade is critical to produce high-grade concentrate that can often be added to the final concentrate.

Rougher Control

If the rougher stage runs properly, the rest of the circuit is much easier to operate. The roughers should produce a good grade rougher concentrate with acceptable recovery. Rougher tailing should be monitored for recovery control but often this sample cannot be taken and so its assays must be inferred. If the rougher tailing grade is too high, there may not be enough scavenger circuit capacity to prevent losses. Concentrate grade is controlled by air flow, cell level and reagent addition rate. Concentrate grade is affected by feed grade, mineralogy, circulating loads, water quality, and other circuit parameters. On-stream analysis is vital to control rougher concentrate production. Direct measurements of froth depth can also be used to complement the on-stream analyzer information for better rougher stage control.

Cleaner Control

Achieving final product quality, while closely watching circulating loads in the cleaner stage, is a critical element in operating a flotation process. The Courier system can also measure low assays of "penalty elements" in the presence of high main element grade to provide data for control of overall concentrate quality.

Scavenger Control

The job of the scavenger stage is to lower the final tailing assay to as low a value as possible. Accurate assay is important to allow accurate monitoring of recovery. This requires high analyzer sensitivity and accuracy. The scavenger concentrate assay is watched to keep recirculation to a controllable.

Basic Flotation Circuit Control Loops

Typical basic control loops used for flotation control are illustrated in Fig. 9B-15. Successful assay control requires that all key operating parameters of a flotation machine are under control. The set-points of the basic control loops are determined by the process operator or by an expert system. The Outotec Proscon Advanced Control Tools package (ACT) can be used to optimize plant operation. An example of a typical grade-recovery optimization scheme is shown in Fig. 9B-16.

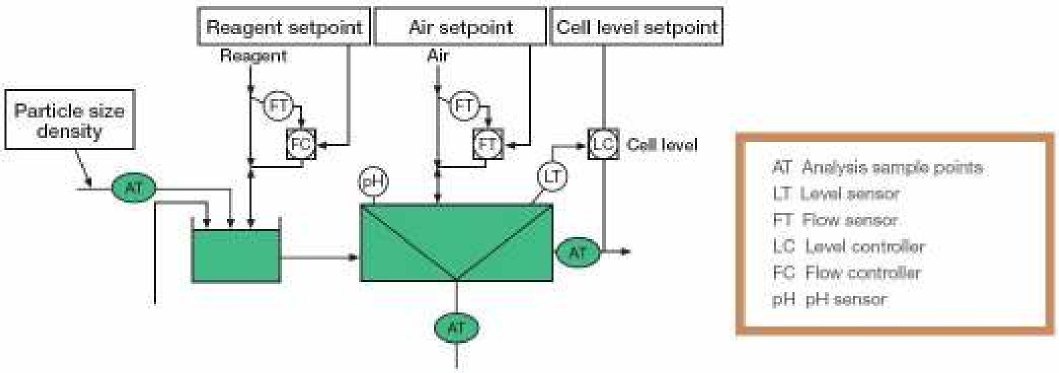
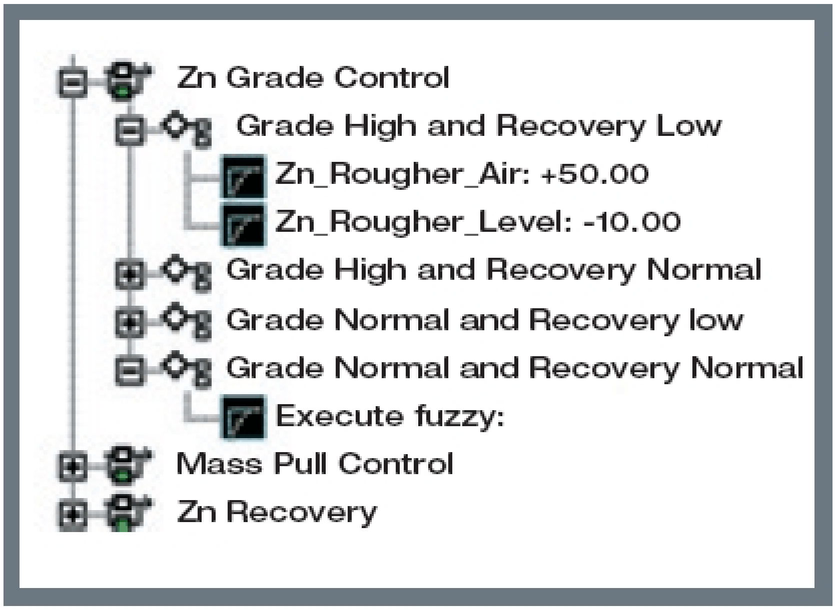


Figure 9B-15. Example of a control system for a flotation circuit. Four manipulated variables are shown: ore "grind", reagent addition, air flowrate, and cell level. Feed grade is a load variable while the control variables (outputs) are concentrate and tailing grades.



- Zn Grade Control
  - Grade High and Recovery Low
    - Zn_Rougher_Air: +50.00
    - Zn_Rougher_Level: -10.00
  - Grade High and Recovery Normal
  - Grade Normal and Recovery low
  - Grade Normal and Recovery Normal
    - Execute fuzzy:
- Mass Pull Control
- Zn Recovery

Figure 9B-16. Example of an optimization control algorithm for a zinc flotation circuit. Note the system divides the concentrate grade-recovery curve into 4 regions, each of which implements a different "crisp" strategy except when things are "Normal", then a fuzzy strategy is used to attempt to improve the process. After following the strategy for Zn concentrate grade, the system moves to a mass flowrate strategy and then activates a Zn recovery strategy.

Primary Sampling

The primary sampler directs part of the process stream to a multiplexer for secondary sampling. A range of proven Outotec primary samplers is available for various situations. The low head required by the Courier. 6SL analyzer allows sample flows to be handled by gravity without need for pumping. Small process flows can be passed through the analyzer secondary sampling system without sampling if there is no need to reduce the flow rate to the analyzer. Depending on process requirements, the primary sample flow can be continuous with or without automatic periodic flushing. Alternatively, sample flow can be stopped and the delivery line flushed automatically between samples. Controlled sampling features offer great flexibility.

Analyzer Control

The Courier 6SL analyzer probe control panel has a graphic terminal complemented by control switches and indicator lamps. Most recent assays and analyzer status are shown on the display. The cabinet houses both the interface modules and control modules for the primary and secondary sampling system.

De-multiplexing

Optional de-multiplexing can be used to divert a small slurry flow through the analyzer flow cell to its appropriate point. This flexibility is particularly useful when a sample stream has a high value content.

Assaying

The Courier 6SL analyzer probe combines high-performance wavelength-dispersive XRF with economic energy-dispersive XRF methods in a unique and cost-effective way. The analyzer has an automatic reference measurement for instrument stability and self-diagnostics. The analyzer probe contains the core analytical components of the analyzer in a protective IP56 (designed to meet NEMA 4X radiation safety standards) stainless steel enclosure.

Calibration Sampling

A built-in calibration sampler helps operators take representative and repeatable samples from the measured slurry for comparative laboratory assays. The calibration data can be read from the analyzer into the management station calibration program.

Secondary Sampling

The full primary sample flow is cut by an air-cylinder-actuated sample hose. The same cylinder moves the hose in the other direction across a cutter at programmed intervals to collect a representative composite sample. Trash is removed from the sample by a self-cleaning screen and entrained-air is minimized by sending the stream through in a level-controlled constant head tank. The tank provides a stable sample flow to the analyzer flow cell. Primary sample availability and flow rate are monitored for diagnostic purposes. The presence of entrained-air provides erratic and unreliable assays, so the removal of as much of the air bubbles as possible is a necessity.

The multiplexer is designed to reduce sample changeover times that were evident in earlier Courier systems. While a sample in one multiplexer is being measured, the next sample is being conditioned in the second multiplexer unit providing a faster measurement cycle for all streams. The measurement sequence is fully programmable so that critical streams can be measured more frequently and/or more measurement time can be assigned to tailings streams. Composite sample collection of all streams is a standard feature of the multiplexer. An optional filter dries the composite samples.

Analyzer Management

Courier 6SL analyzers can be networked together to share a common analyzer management station PC. Calibration and diagnostic data are available for on-site service requirements and remote support. The management station displays the assays, trends and analyzer status information. It is also used for setting up the functions and parameters of the Courier 6 SL analyzers. The analyzer management station collects analyzer system calibration and diagnostic data for local and remote support.

The calibration program can be run on the same PC to access calibration data and use the best models for assay calculations. Only one connection to the plant process control (DCS) system is required. The Outotec automation product range has compatible PROSCON. 2100 process control and management systems for metallurgical applications.

Sample Presentation

Outotec's patented Jet CellTM technology ensures that a representative fresh sample is always presented for assaying at the window surface. The flow cell window is kept cleaned by the flowing slurry but it also is slowly abraded. Windows are changed manually or automatically by Outotec's AWC 4030 Automatic Window Changer option.

Analysis

The sample in the flow cell sensitive layer is excited using a high-intensity X-ray tube. Atoms in the sample react by emitting fluorescence radiation, which has a characteristic wavelength for each individual element in the sample. A high-resolution wavelength-dispersive analyzer technology is used for critical assays. Energy-dispersive technology complements this more accurate method to increase the range of elements that can be analyzed. This also extends the system capability to measure up to 12 assays per stream.

Analyzer System Control

The primary and secondary sampling system and analyzer measurements are controlled by the Probe Control Set. The scalable modular system has several ICM 4300 Interface and Control Modules connected by a fast serial bus. Each multiplexer unit is controlled by its own module. Primary sampling is controlled by available I/O in the multiplexer control modules or a dedicated unit in case of a large analyzer system.

Wavelength Dispersive Technology

The wavelength dispersive detection channel measures only the narrow element peak (blue). A high-resolution spectrometer separates the peak before the detector. Nearby element peaks do not overlap and the background signal is minimal. Since the full capacity of the detector is dedicated to the relevant peak, a high-power X-ray tube can be used so analyzer speed and sensitivity are increased. Wavelength dispersive detection is used in high-performance laboratory analyzers. Several element-specific wavelength dispersive channels are used for simultaneous measurement of the critical elements to be assayed.

Energy dispersive technology

The energy dispersive detection channel (Si(Li), Si-PIN or proportional counter) measures the whole spectrum (blue). Measuring a small Zn peak (green arrow) is a challenge, since most of the detected counts cannot be used for the specific assay. Loss of resolution and its deterioration above 10k counts per second count rate seriously limit the usefulness of the X-ray intensity. Analyzer speed and sensitivity are reduced considerably over the wavelength-dispersive method. So the energy dispersive detectors can be used to measure high-grade assays for less critical measurements as a cost-effective complement to wavelength dispersive detectors. One energy dispersive detector can measure many element peaks at the same time.

Analyzer Specifications

Analysis Method

Wavelength dispersive X-ray fluorescence method uses X-ray tube excitation. Energy dispersive channels are available. No radioactive isotope sources are used, minimizing fire and disposal risks.

Number of Sample Streams

One Courier 6SL analyzer system can measure up to 24 sample streams. Each multiplexer module handles up to 6 sample streams.

Number of Simultaneous Assays

A Courier 6SL analyzer can provide up to 12 simultaneous assays for elements from calcium to uranium (atomic numbers 20 to 92) and solids content from each process sample. Multiple models can be used for assay calculation.

Sample Measurement Time

Sample measurement time is selectable for each sample. Typical time is 15 0 seconds.

Analysis Cycle

Normal analysis cycle for 12 samples is 9 minutes and for 18 streams 12.5 minutes depending on the measuring time required for each sample. Assays are calculated and updated from fresh measured data for each cycle.

Measurable Concentration Range

Typical measurable concentrations range from 0.002% - 100% by weight for slurries.

Stability

Short-term stability of the analyzer under the specified conditions is better than 0.1% relative. Automatic internal reference measurements compensate for long-term drift.

Minimum Detection Limit

For most elements in a slurry, the detection limit is 30 ppm with the WDXRF-measurement channel. With the EDXRF-measurement channel, the minimum detection limit is 3,000 ppm.

Accuracy

Outotec accuracy specification is based on flowing slurry samples using measurement times of real applications. Briquette measurements and long measurement times give unrealistic results. Measurement accuracy is a function of sample parameters such as matrix composition, mineralization and particle size. Under normal operating conditions, 3% relative standard deviation for minor concentrations and 1% relative standard deviation for major concentrations is achieved for individual slurry sample measurements of concentration levels, well above the minimum detection limit.

Analyzer Calibration

Optional integrated calibration sampler takes a repeatable and representative sample for the analyzer calibration. Outocal™ software is available for interactive calibration model design.

Maintenance

The Courier 6SL analyzer is designed for minimal maintenance. The analyzer probe window change is automatic, with an Automatic Window Changer option. The analyzer has built-in self and remote diagnostic capabilities.

Flushing Water

Sand-filtered raw water, 2 bar (30 5 psi)
Average 30 L/min (8 gal/min)
Peak 100 L/min (26 gal/min)

Shipping and installed weight

Typical total shipping weight is 1000 kg (2200 lbs) for a 12-stream system, 1250 kg (2750 lbs) for an 18-stream system. One 6-stream multiplexer unit weight is 225 kg (500 lbs).

Outotec (previously Outokumpu) has a long history and broad experience in the recovery and refining of base metals. Over the years, the company has developed a comprehensive line of metallurgical processes and related advanced equipment, from grinding to metal production. These include:

The Outokumpu Flash Smelter for Copper and Nickel
The Outokumpu Flash Flotation Cell
The OK Flotation Machine
The Courier On-stream Analysis System
The Proscon Process Control System

Outokumpu TankCell technology is used by major mining companies around the world. State of- the-art on-stream analyzers and automation systems have been used in Outokumpu concentrators and refineries since the late 1960s. The company is the market and technology leader with more than 700 on-stream analyzer systems delivered to minerals processing and metallurgical applications.

SCADA Systems

Supervisory Control and Data Acquisition Systems consist of communication networks and information management methods to interface with most processing plants.

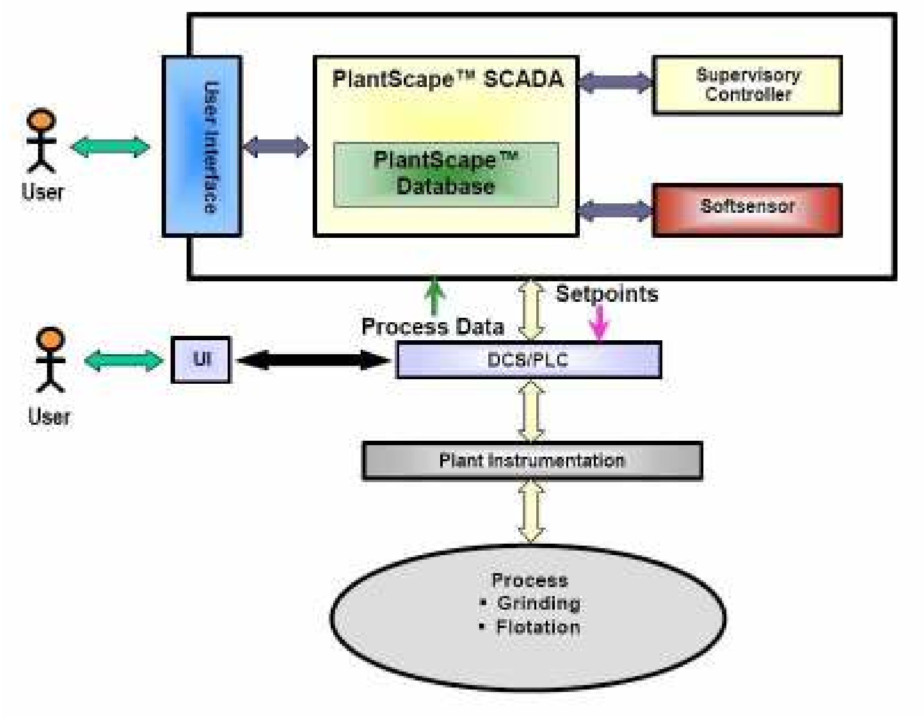
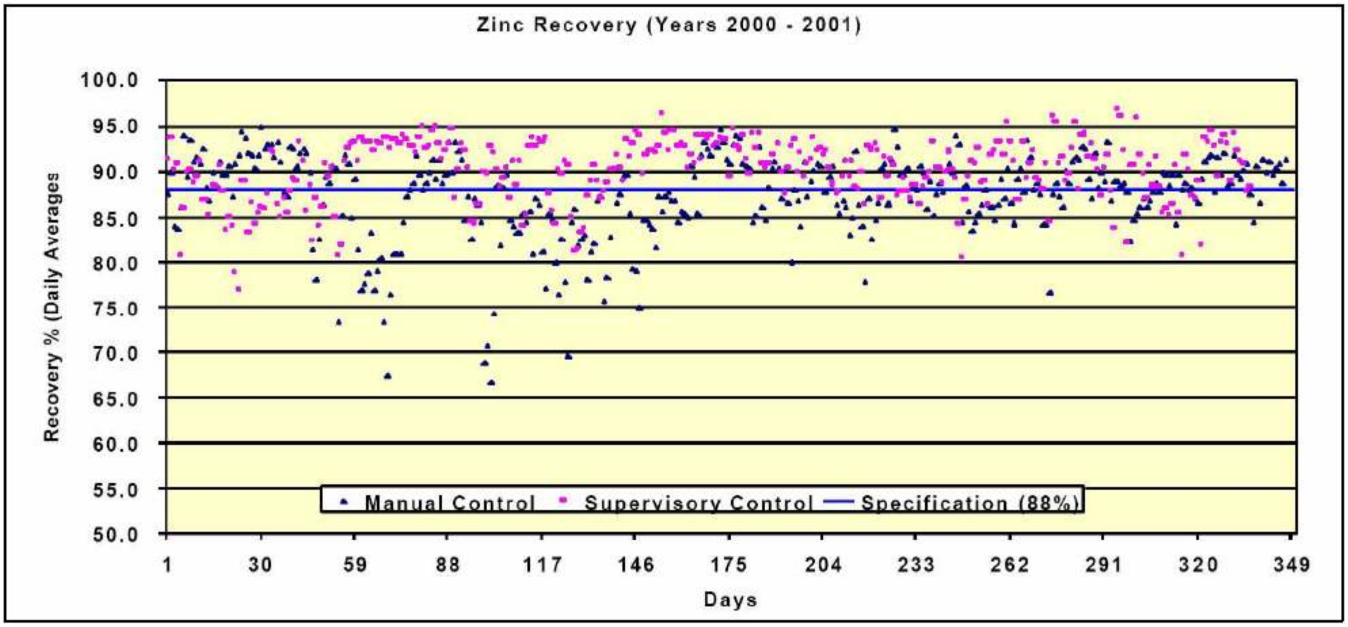


Figure 9B-17: Example of a Supervisory Control and Data-Acquisition System.

Example of Process Control Results Comparison

In the example data shown on the last page, the manually-operated process results for recovery and concentrate grade match that of the automated control system at the high level of the range for both. However, significant excursions to lower results occur much more frequently for the manual system than for the automated one. This leads to an overall lower average result for manual in comparison to automated. [Ravi Gopinath, 2002. Plant-Wide Advanced ProcessController and Optimizer for Hindustan Zinc Ltd., Manufacturing Practice, Tata Consultancy Services, Mumbai, India. http://www.scribd.com/doc/27129235/Plant-wide-Advanced-Process-Controller-and-Optimizer-For]



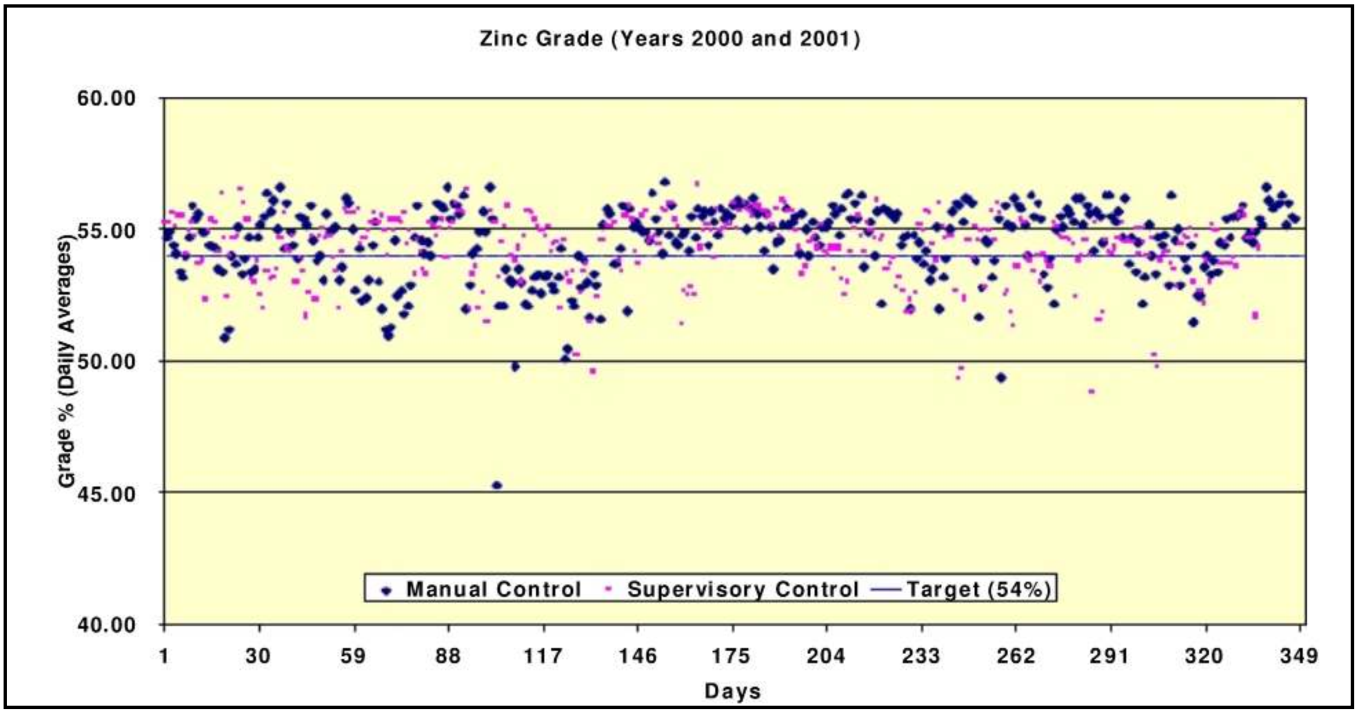


Figure 9B-18: Hindustan Zinc Ltd. Recovery and Concentrate Grade using a SCADA system.