Design for operability

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Synopsis

The design metallurgist is often faced with a challenge of quantifying the benefit of allowing for operability in the plant design. This paper attempts to summarize the points that need to be considered in improving the plant operability. The paper considers some of the challenges that the design metallurgist faces in designing the plant, and looks at how technology has developed in aiding the operator to control the plant.

The introduction of control systems and improved instrumentation has increased the need for more intense training in the empowerment of the workforce. A delicate medium must be considered in how much of the control can be wrested from the operator, and how much should be handed to the expert systems.

Quantifying the benefits of considering operability in the plant design remains a challenge, however, we are fast approaching the solution given the amount of information that is being collected on existing operations.

This paper is a summary of a paper presented at the SAIMM Design Workshop of August 2005 in Cape Town. Although many of the examples mentioned in this paper are relevant to metallurgical concentrators, the principles can be applied to process plants in general.

Introduction

Plant operability is of paramount importance to the practising metallurgist, and in many cases describes the capability of the plant of achieving design efficiencies. The phrase 'design efficiencies' is used to describe not only the metallurgical recovery that is achievable, but also the availability of the plant, and most importantly, the safety of the workforce that have to operate, maintain and optimize the plant.

And yet, in the design process, operability is often the most difficult criterion to motivate and defend. Many of the points discussed in this paper are often classified as being 'nice to have', and for that reason, are the first items that are removed from the design when the capital cost estimate is reviewed.

This paper attempts to define and describe 'operability' and the benefits of prioritizing 'operability' in the design process. The paper attempts to highlight the challenges that are faced by the metallurgist in producing an operable design, and gives examples of how technology has advanced to address the challenges.

Operability in design

A number of points have to be considered when assessing the operability of a plant design.

- Of paramount importance in defining the operability of the design is the safety of the operations staff and affected parties. Safety cannot be compromised, no matter the cost of introducing measures to minimize the risk, or the introduction of alternate technology
- Plant layout is very important in determining the operability of the plant, and the layout must be both well defined and logical
- The need for the transportation of man or machinery must be minimized
- The ease of operation, supervision and maintenance must be considered
- Security risks must be minimized with the introduction of measures to reduce the likelihood of a threat to property and staff
- In the event of potential plant expansion, the design engineer should consider how the expansion would least influence ongoing operations.

Safety considerations in designing for operability

As mentioned above, the safety of staff and affected parties cannot be compromised. A metallurgical plant is often fitted with equipment or processes that present the following risks to safety:

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- Moving parts that may result in physical injury
- Equipment that is operated under pressure
- Equipment that is operated at high temperature
- Processes that make use of potentially harmful substances
- Processes that produce potentially harmful substances in the form of gas or liquid.

In the design of the process every effort is made to introduce measures to minimize the risk. Many times the focus is directed at the process and in ensuring that the process is inherently safe. From an operability perspective the design engineers need to consider the following points:

- The plant layout must be such as to allow for the ease of access, and egress
- Travelling ways in and around the equipment must be unobstructed
- Good lighting
- Equipment must be visible and the layout must be such that the operator can scan his work area and identify potential faults
- There must be adequate ventilation
- Access must be provided for emergency vehicles.

Ease of operation

In designing the plant consideration must be given to the fact that the plant operation will be controlled by teams of operators working long hours and, depending on the nature of the operation, in demanding working conditions.

In order to ease their task and indirectly improve their efficiency, a few points need to be considered.

- When designing the process flow, consider the simplest yet efficient flowsheet. Overcomplicating the flowsheet may appear to address potential process inefficiencies; however, the process engineer must critique the need, and try to identify simpler alternatives
- Make all access points for monitoring, sampling and control accessible to the operator. Inaccessible areas will most certainly not be visited on a night shift
- Keep the plant compact, and minimize distances between areas
- In the layout keep separate areas of the plant in demarcated areas
- Provide adequate surge capacity to minimize the effect of process instability in one section affecting other sections of the plant
- Use simple, easy to control, robust, well-engineered plant and processes
- Provide good lighting and ventilation in the work area
- Provide adequate spillage containment areas
- Provide a well-ventilated and visible rest area that is isolated from the noise, dust and fumes of the operation.

No matter how robust a process, the influence of the operating staff is critical in maintaining efficiencies, plant availability and the safety of the workforce and affected parties. Some of the points mentioned may be considered to be luxuries but the plant will be operating for twenty-four hours a day for at least the next twenty years. Although the benefits of addressing these points may never be quantifiable, experience has shown that they are often the differentiator between an average operation and a true success.

Maintenance considerations

Proper effective maintenance not only affects the plant availability but also affects the mineral recovery. Minimizing unplanned stoppages reduces plant instability and the recovery losses resulting from plant start-up and shutdown. Furthermore, effective maintenance will ensure that the equipment is properly tuned and in a condition to produce optimum results.

In order to facilitate effective maintenance, the following points must be considered in designing the plant.

- The maintenance crews must be provided with safe access routes to the equipment
- Adequate access to pipelines and cables must be provided
- Cranes and lifting equipment must be provided. This is particularly important for routine jobs such as mill relining and the replacement of pump casings
- Adequate headroom must be allowed for in the design
- Good lighting and ventilation
- Workshops and lay-down areas for equipment, machinery and tools.

Supervision

Supervision in any process plant is crucial and raises awareness and improves communication. The location of the plant control room is very important and there must be good visibility from the control room to all parts of the operation. Locating the control room on the periphery of the plant is not recommended.

The location of the shift supervisor's office and metallurgist's office should also be within the plant, and should be close to the control room.

The control room must also be located in such a position to allow ease of access for the shift supervisor to the various areas. Relying on radio contact and closed-circuit television cameras for supervision is not enough. Timely identification of a problem may save plant downtime and potential equipment failure.

Challenges in designing an operable plant

The design metallurgist is faced with a number of challenges when attempting to introduce operability into the design of the plant.

- The most daunting challenge is the capital constraint. Inevitably the capital estimate for the plant will exceed expectations and the design team will be tasked with finding ways and means of reducing the capital cost. The metallurgist is instructed to remove the 'nice-to-haves' from the design. In many cases this includes the surge capacity that the metallurgist has so carefully included in the design. Unfortunately removing the

surge capacity is the most common pitfall of the capital rationalization and results in an inoperable plant that will forever yield low recoveries and suboptimal performance.

- The design philosophy is often challenged when the planned throughput is increased based on the outcome of the latest iteration of the 'financial model'. Redesigning of the plant for the increase in tonnage is often not an option due to time constraints, and the original design is used. This phenomenon reappears during the life of the operation when the operating philosophy is revised from that of maximizing efficiency to maximizing throughput. This can, however, not be catered for in the design stages.
- A critical phase in the plant design process is the development of the process design criteria. Primary data such as throughput and ore source are provided by the client. This is supplemented with information generated by metallurgical test work combined with experience of the design team. Shifting of the goalposts during the design process destroys the natural design methodology and results in a plant that is not fit for purpose. A typical example of such a situation is where the mining plan is changed and a different ore blend is sent to the plant.
- Technology has also introduced its challenges and the increase in equipment size has made the task of plant design from an operability perspective more challenging. The introduction of run-of-mine (ROM) milling has introduced instability into the comminution circuits that was not evident in the times of crushing and ball milling. The ROM approach has its advantages from a capital cost and operating cost perspective, and very few new plants will be found today that do not process ROM ore in their mills.
- An evergrowing challenge facing the industry is the lack of skilled operators, and this is made even more difficult with the introduction of more hi-tech equipment. It is not uncommon to find examples of where technology has 'failed' and the underlying cause is later identified as a lack of attention by suitably qualified personnel.

Recent developments in the search for operability

Some of the challenges mentioned above are being addressed in one way or another. Developments in technology and a strengthening of the knowledge base have provided the design metallurgist with tools and information to the challenges.

- Many of the points that were discussed in the above sections considered access and layout as being important. Developments in three-dimensional computer aided design (CAD) technology have allowed the design engineers to visualize the product of their endeavours. The designer is now in the position to view the plant from every angle and consider the concerns of access, visibility, etc. The latest CAD packages have the facility to walk a virtual operator/crane/vehicle through the plant and thereby identify potential problem areas for access
- A better understanding of the processes and the effect of various parameters on the metallurgical performance have allowed the design metallurgist to include facets into the design that would previously have been regarded as being 'nice-to-haves'.
- The metallurgist is now more capable of quantifying the benefits of improved operability. This is facilitated by developments in recent years in the field of instrumentation and control. More measurements are being taken, the data is being collected and collated, and the pitfalls and benefits can be identified on existing operations.
- The technological advances in instrumentation and control have also helped to improve plant operability. Designing the plant such that the available technology is utilized to its fullest extent has allowed the metallurgist to address many of the challenges highlighted above. Some of the latest developments are discussed in the next section.
- The development of computer systems and computer networks has also improved the operator's arsenal in operating troublesome plants. The design engineer must utilize the latest technology within the control philosophy of the plant.

This does introduce an added challenge in that the workforce must be developed to appreciate and utilize the technology. Many a plant today is fitted with equipment and instrumentation that is not being used due to a lack of appreciation.

Examples of recent developments in technology

Online analysers have been in use on metallurgical concentrators for at least thirty years, and have been successfully applied in optimizing performance. Recent developments in systems integration and the facility to import the information into a plant control system have increased the potential for improved control. Unfortunately the application of this technology has often failed due to the lack of suitably qualified resources to maintain the instruments.

A challenge that has faced the metallurgical fraternity has been to capture the skills that have been acquired by the operators over the years and translate that knowledge into rules for the manipulation of process parameters. A typical example is the examination and interpretation of flotation froth. The experienced operator will be able to decide what actions need to be taken when visually examining the froth. A number of projects are ongoing in the development of a froth imaging system to quantify the observations and automate the reaction to changes in the criteria.

A system that is currently being supplied by Outukumpu is illustrated in Figure 1.

The system measures a variety of parameters through a video camera and provides a series of 4–20 mA signals to provide information to a control system. The system is being utilized by concentrators to control reagent dosage. In Figure 2 we can observe the effect of aeration rate on froth speed in a Outukumpu 160 m^3 flotation cell.

In Figure 3 we can observe the effect of collector flow rate on the bubble size in a flotation cell.

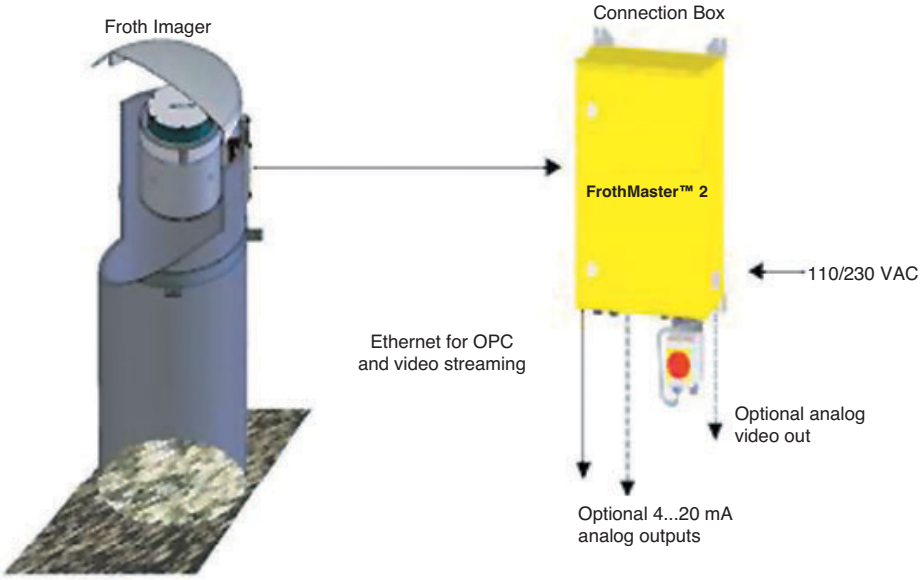

Figure 1—Outukumpu Froth Master froth imaging system

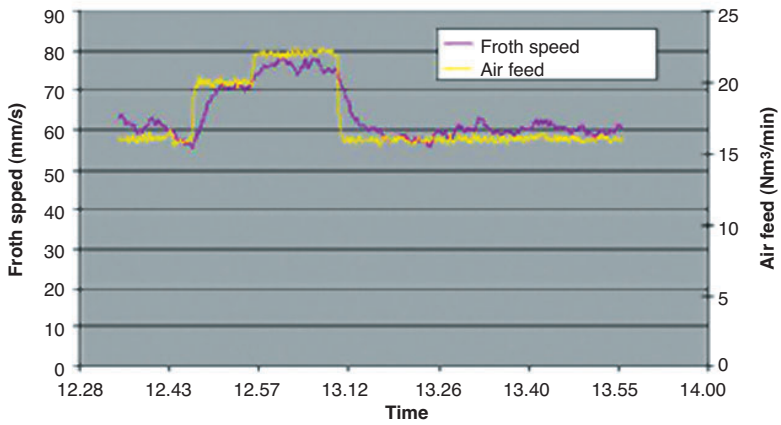

Figure 2—Chart indicating the effect of aeration rate on froth speed on an Outokumpu Tank Cell 160

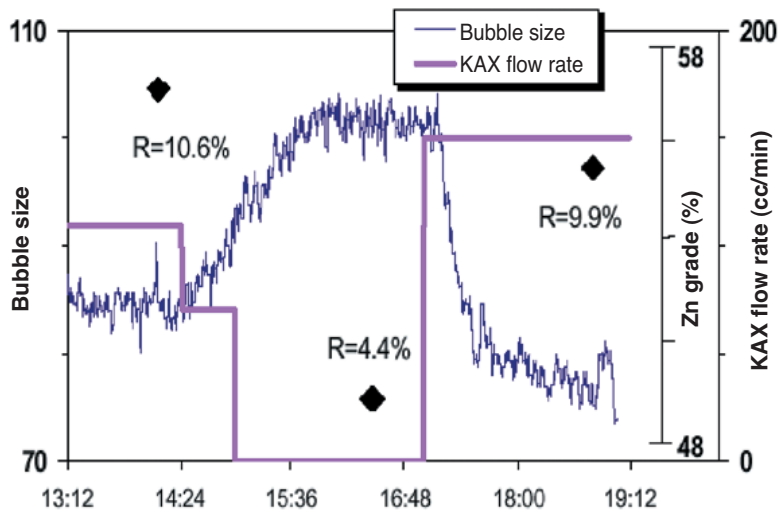

Figure 3—The effect of collector flow rate on the bubble size in a flotation cell

Figure 4—Outukumpu PSI 500 particle size analyser

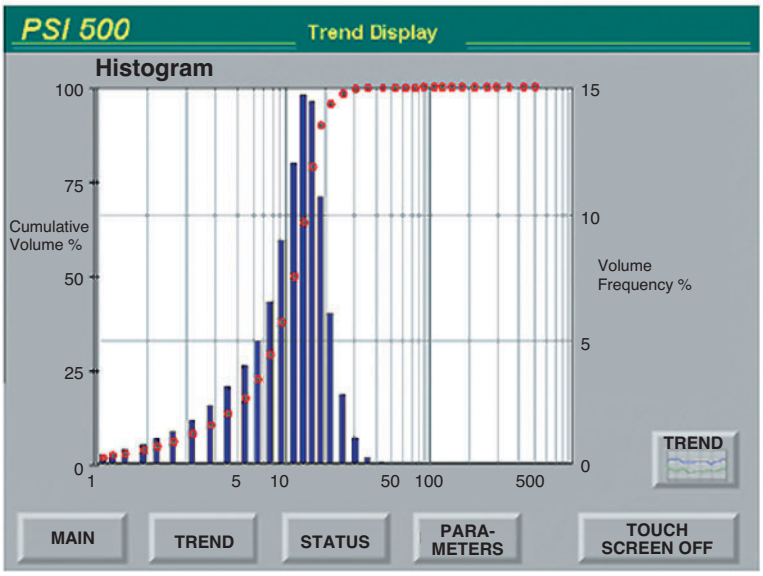

Figure 5—Particle size distribution determined by the PSI500

Particle size analysers have also been used in the metallurgical industry and recent developments in technology and network integration have increased the utilization of the equipment in mill control. The Outukumpu PSI500 illustrated in Figure 4 utilizes laser diffraction to provide a particle size distribution to the control system as illustrated in Figure 5.

Utilizing the data provided

A challenge that faces the operations metallurgist today is not necessarily the lack of data, but the lack of useful data. What options are there for the metallurgist in the plethora of data that are being provided?

The two options are to either empower the workforce or introduce an 'intelligent' control system that will be able to make rational changes to the operating parameters.

Empowering the workforce

The first option is to provide the information to the operators in such a format that the information empowers the workforce and they can make changes to the operating parameters according to a predetermined set of rules. Examples of such data are illustrated in Figures 2, 3 and 5.

This process will require training and continual reinforcement with the operators. At the same time the

metallurgists' understanding of the metallurgical processes will be enhanced and this has to be conveyed in a formal training procedure to the operators.

Empowering the workforce will also mean designing the plant so as to minimize laborious work that would otherwise distract the operator from the task at hand. This would include the introduction of systems such as an automatic reagent mixing facility, automatic mill media addition, properly designed spillage containment areas, automatic sampling, conveyor scrapers and properly designed chutes.

The presentation of the information is critical in providing the operator with data that can be used in a timely fashion. This includes the introduction of terminals on the shop floor, or displaying the data on strategically located displays that are being continually updated, and can be seen from a distance. It is a waste of time for the operator to walk to the control room to study the bubble size trend on his flotation plant, and he will do it infrequently.

It is important to provide the operators with key data that address the key issues, and not to flood them with too much data. An example of a group of charts for the operators indicating trends is illustrated in Figure 6. The system can also highlight critical problems as illustrated in Figure 7.

Empowering the workforce and concentrating the effort on controlling the plant will allow the operation to rationalize the workforce. Large plants with multiple parallel streams are being operated by far fewer operators than in the past through the introduction of systems to maximize the contribution of the operators and minimize manual labour.

Introduction of expert systems

Expert systems have been in use on metallurgical operations for a number of years. To the layman the term expert system describes a system that is programmed with a set of rules for the interpretation of data from the operation. The rules are generated from metallurgical expertise and the experience base of plant personnel.

The complexity of the system may vary and may be as simple as density control through the adjustment of a water valve. Expert systems can become very complex and may involve the optimization of reagent dosage based on the information provided by a froth imaging system.

The influence of the Mintek Millstar control system on mill power control is illustrated in Figure 8.

A system that has attracted much interest of late is the Mintek Flotstar system that is used to control flotation cell levels within a flotation circuit (Figure 9).

Use of an expert system and the elimination of operator intervention does introduce an additional risk. The expert system is programmed to interpret a set of data in isolation and make necessary adjustments to the process parameters.

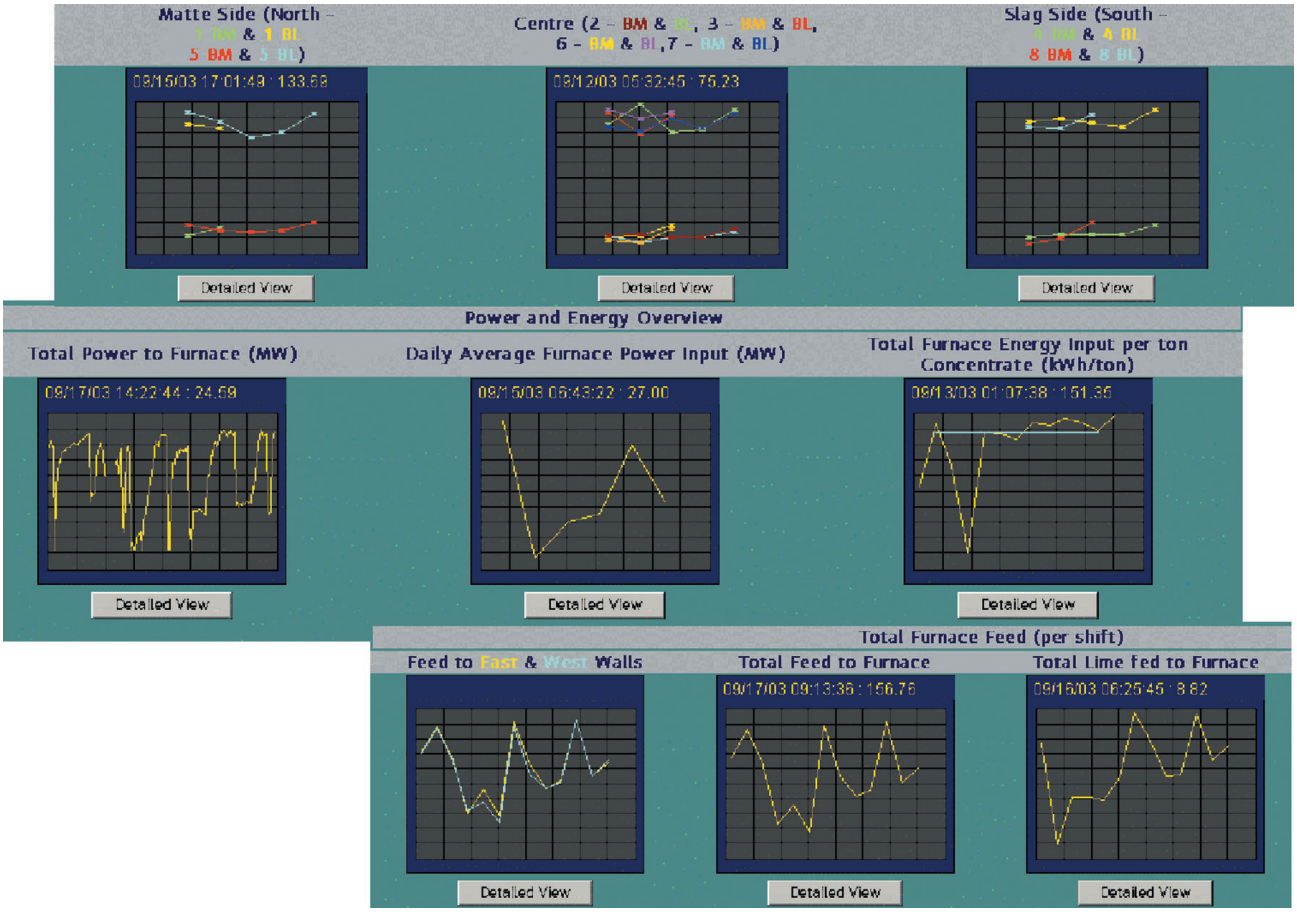

Figure 6—Example of charts for the operators

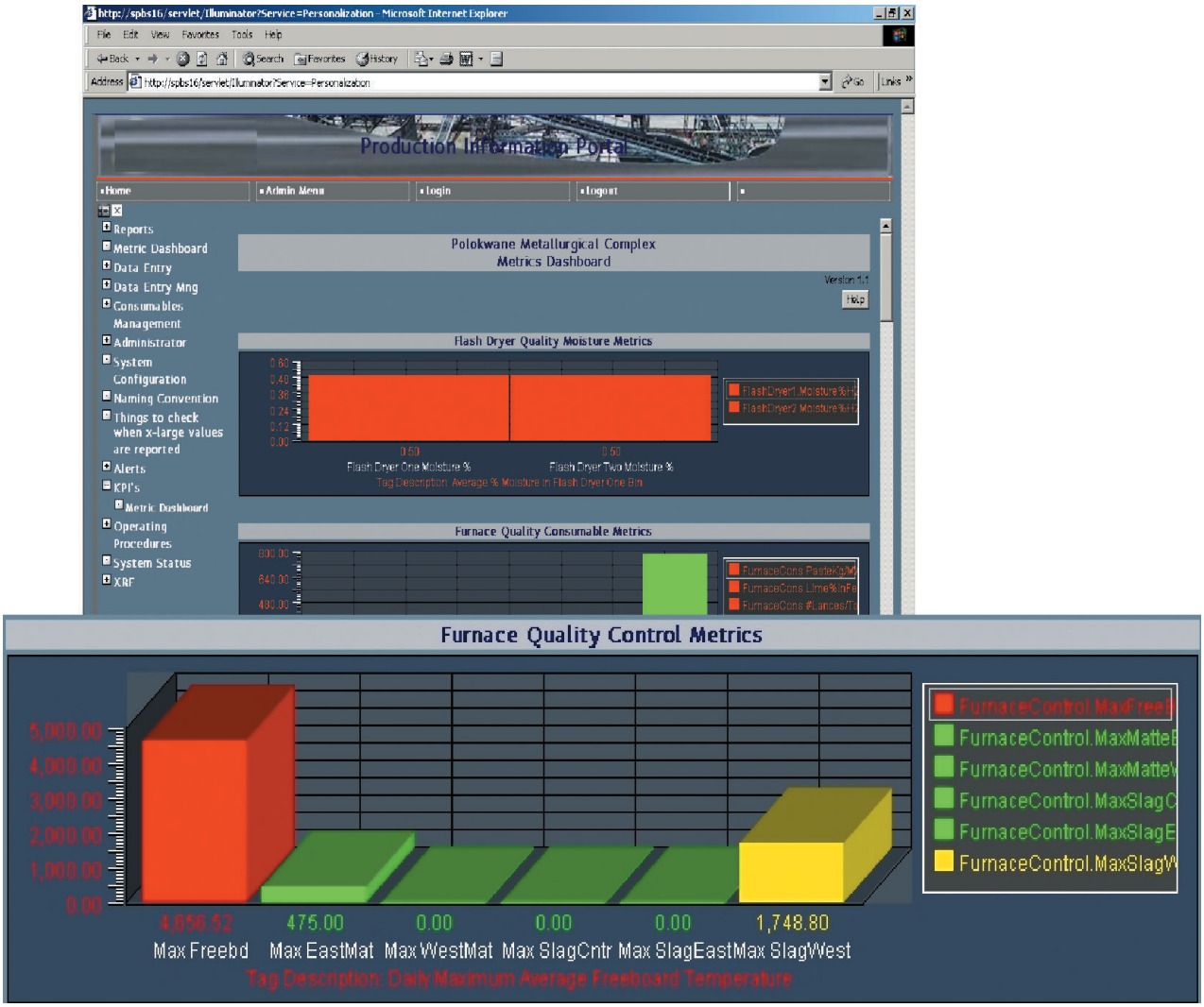

Figure 7—Furnace control system highlighting problem areas

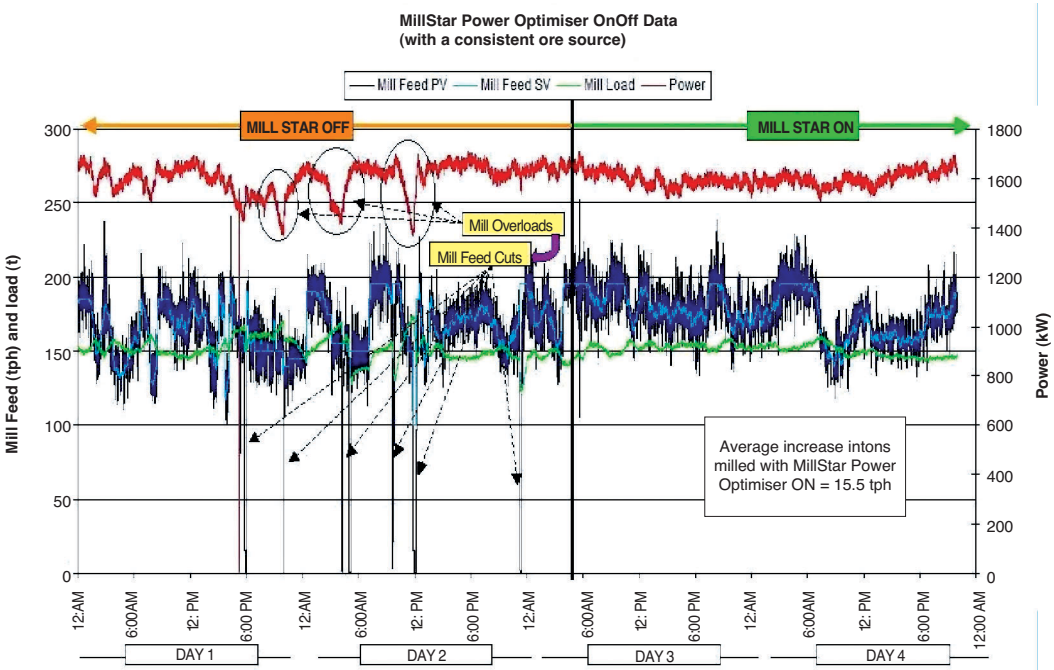

Figure 8—Mill power optimization using the Mintek Millstar system

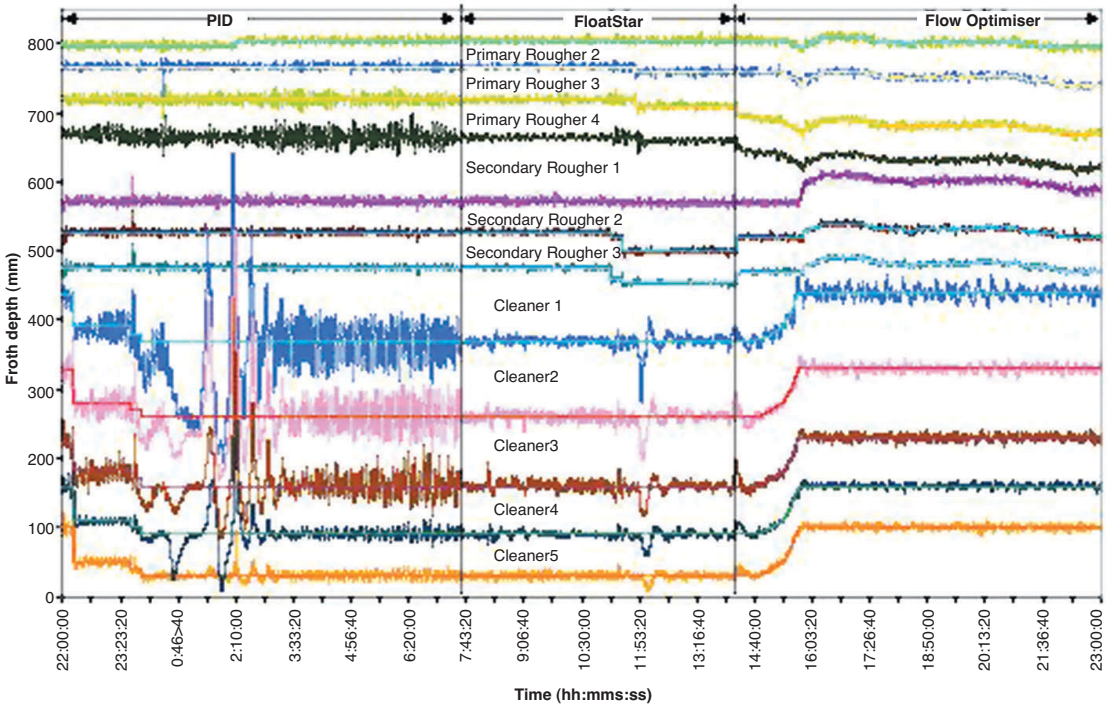

Figure 9—Flotation level control using the Mintek Flotstar system

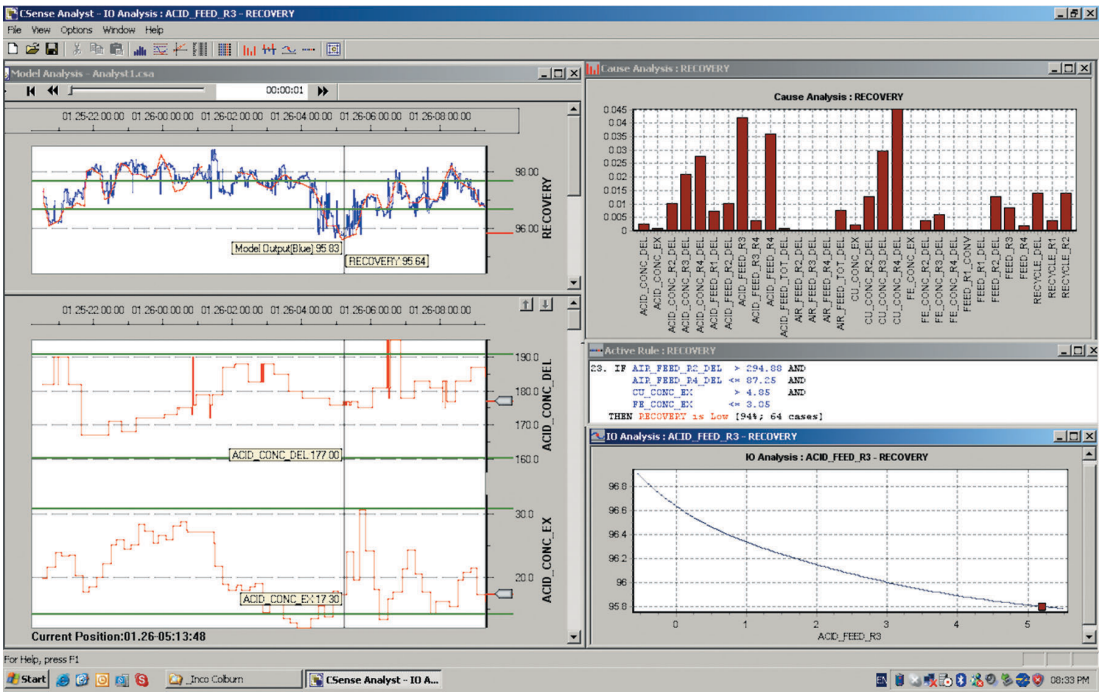

Figure 10—CSense data fault-finding system

The system depends on the accuracy of the data that are being provided. This implies that the system may in fact make inappropriate changes to the parameters based on faulty data.

This has resulted in the development of systems for the interrogation of data to identify faulty instrumentation/equipment. Such a system is the CSense system that is being provided by Crusader Systems. The output of the system is illustrated in Figure 10.

The system is an 'intelligent' system that develops trends and relationships from the data-set and identifies when sensors fail. The system has the facility to take over the function of the sensor and allow the plant to continue operating. This is illustrated in Figure 11 where a sensor has failed and the system has continued to control the plant. The system continues to develop rules and relationships and updates the rules within the expert system on a regular basis.

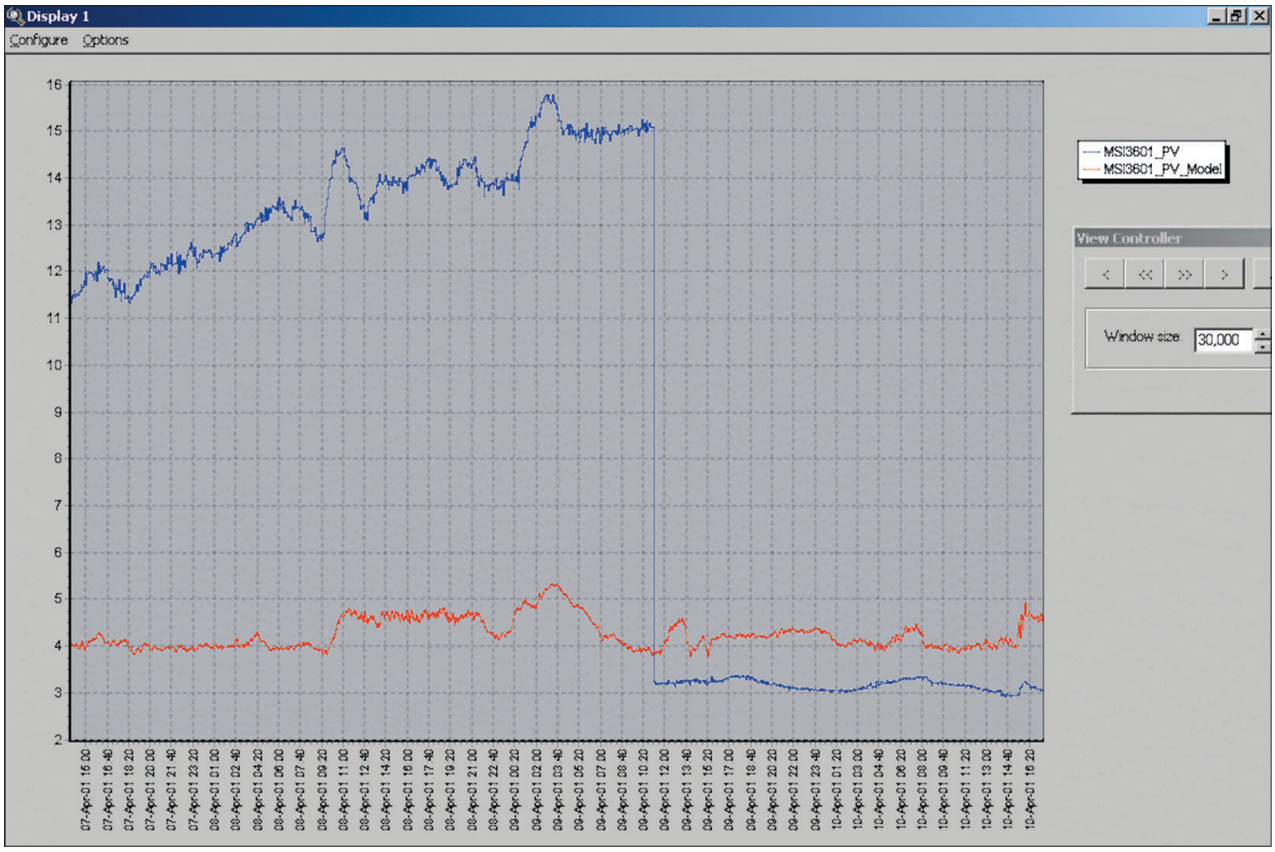

Figure 11—CSense control chart indicating the failure of a sensor and subsequent control

Summary

The benefit of improved operability is difficult to quantify, and an experienced metallurgist will argue that improved operability in the design of a plant will result in the following:

- Improved plant availability
- Increase in recovery
- Improved product quality
- A safer operation
- A happier and more productive workforce.

The design metallurgist will include many of the points that we have considered into the design. Unfortunately many of these items are removed from the design due to constraint on capital, as the apparent benefit cannot be quantified.

More information is becoming available to the metallurgist with the introduction of production information systems on the existing operations, and the task of motivating the operability items in the design is becoming less arduous.

Considering the points that have been discussed, it is evident that access and movement about the plant are important. It is also important to separate plant areas with regard spillage and with the introduction of surge capacity. The impact of adequate surge capacity has not been discussed in sufficient detail, and analysis of data from existing plants will reveal how significant adequate surge capacity is on the performance of the plant.

The development in instrumentation and process equipment has been staggering and the information that is being made available to the metallurgist is more than some of us can deal with. Networks and system integration have developed with the instrumentation and the type of data that is being presented to the operator and/or the expert system is more functional.

Expert systems have developed in the past few years and the need for such systems has resulted from the increase in the complexity of the control of circuits such as the ROM circuits that have become popular of late.

The risk does exist in removing control from the operator; however, systems have been developed to identify faults and take over control.

There is a happy medium in terms of how much responsibility can be taken from the operator and passed to an expert system. Nonetheless, the size of the modern plant and the complexity of the operation will require empowerment of the workforce and more intense training of the operators in understanding the process and the systems that we are employing for process control.

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