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Centralised Process Control of the Metallurgical Operation at Rössing, South West Africa/Namibia

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A Honeywell TDC 2000 central process control system was installed at Rössing in 1984. The system controls the metallurgical operations from crushing to the finished product of uranium oxide and manufacture of sulphuric acid. The operation was previously controlled from nine separate local control rooms.

The paper briefly reviews the design and commissioning of the control system on an operating plant and discusses the impact on manpower organisation and training needs.

Development of the process control system during its first two years of operation is reviewed and a summary is given of the current status of computer control at Rössing. The impact of the new system on overall plant operation and performance efficiency is also briefly described. In conclusion, future developments of computer control and overall optimisation of metallurgical operations are reviewed.

Introduction

Rössing has operated one of the world's largest uranium mines in the Namib desert since 1976. The mining and metallurgical operations have been described in detail elsewhere [1] and will not be repeated in this paper. A simplified flow diagram of the metallurgical process operations is given in Figure 1. The various stages of the metallurgical operation consist of primary crushing, three stages of fine crushing, rod milling, leaching, washing, tailings disposal, continuous ion exchange, solvent extraction, ammonium diuranate precipitation and roasting to the final product of uranium oxide. There is also a 720 tonne per day capacity pyrite roasting acid plant which supplies sluphuric acid for leaching.

Milling capacity is in excess of 45 000 tonnes per day, and many technological innovations were introduced during Rössing's first ten years of operation to improve efficiency and maintain cost effectiveness. [2,3] A major innovation was the installation of a central process control system early in 1984. This resulted in increased manpower productivity, improved metallurgical efficiency and a steady move towards optimisation of the total operation. The following sections briefly review the implementation of central process control at Rössing and give specific examples of the development and application of advanced computer control strategies.

Process control systems

The metallurgical plant was constructed

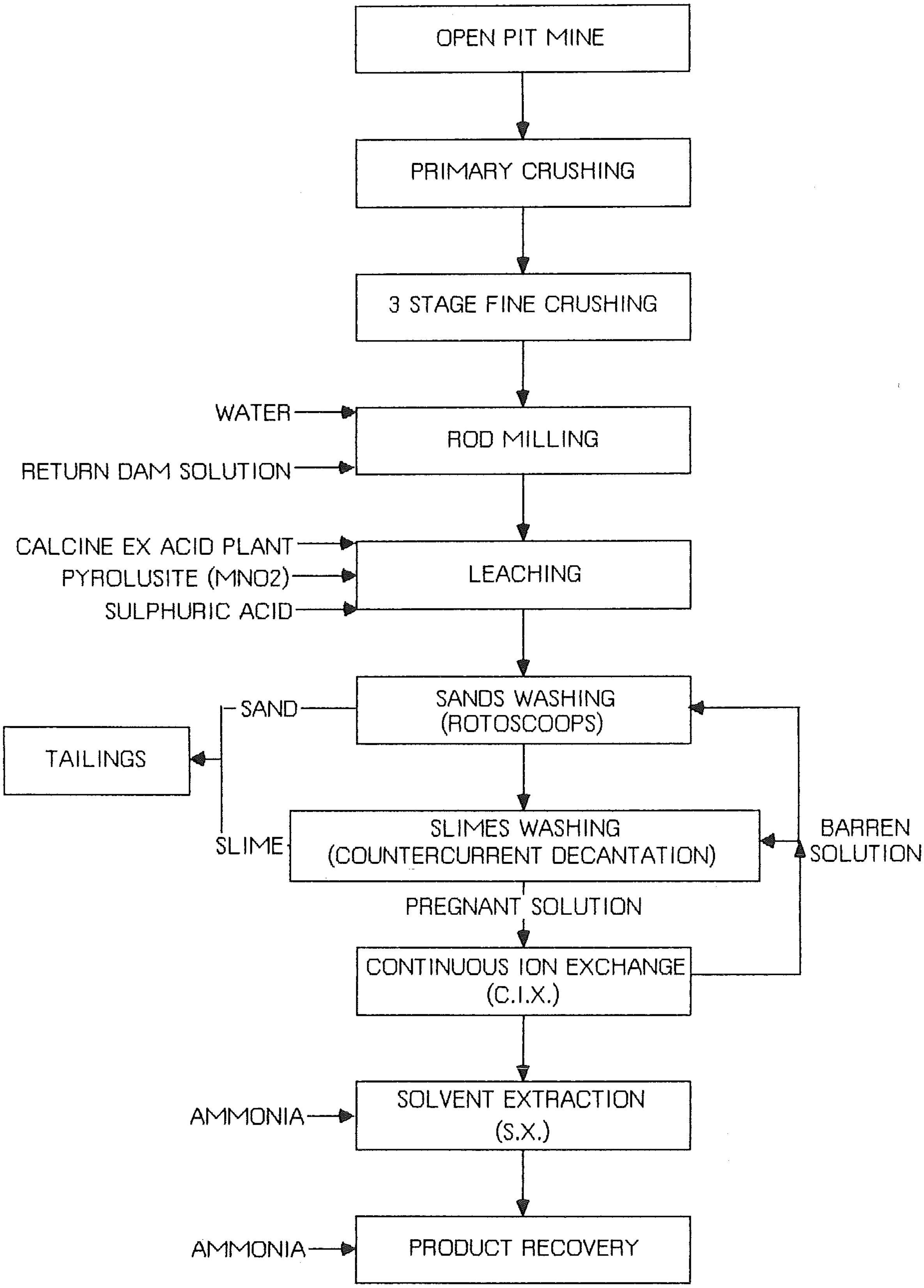

FIGURE 1. Flow diagram of Rössing metallurgical plant

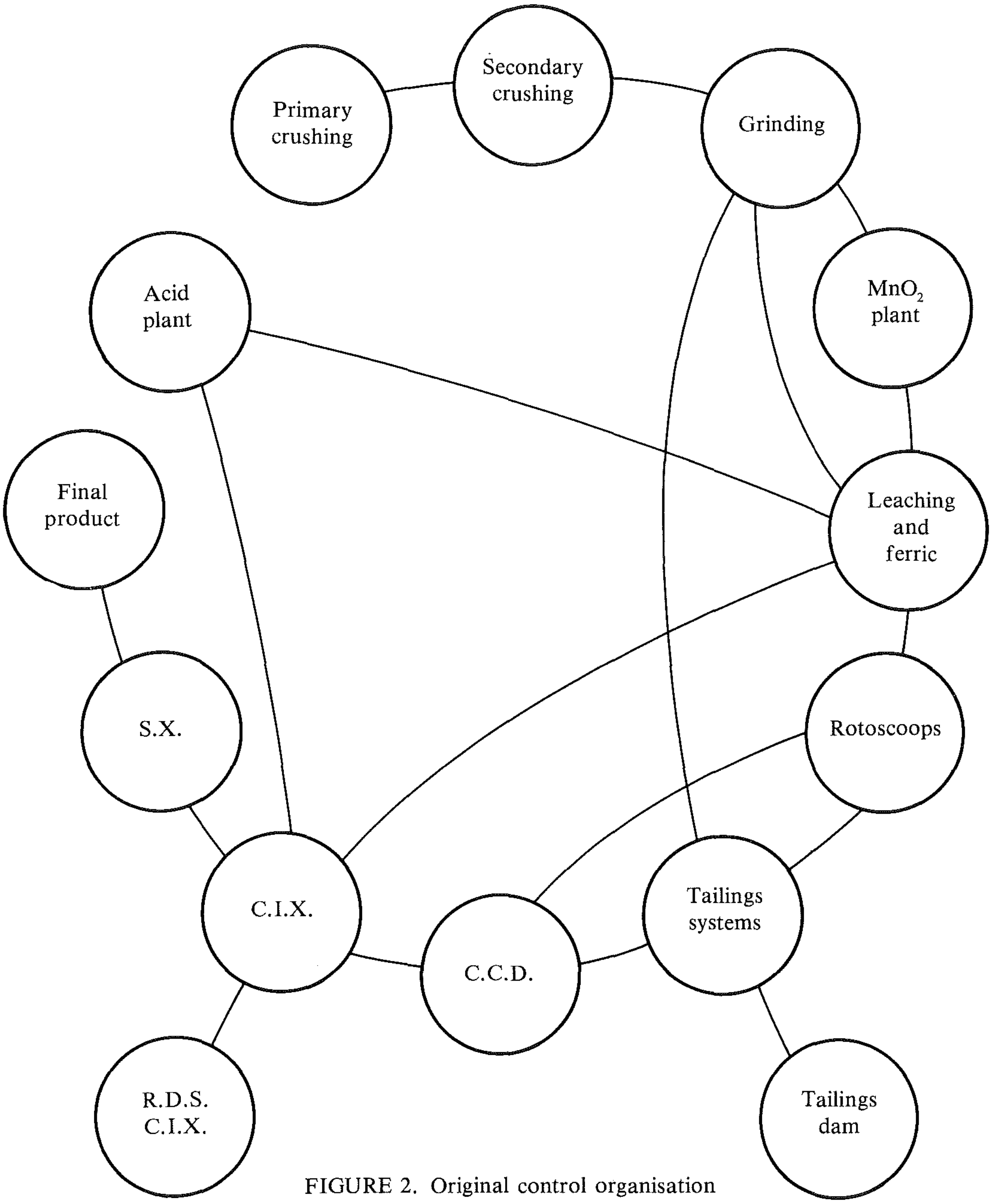

FIGURE 2. Original control organisation

with a comprehensive level of instrumentation, each area of plant having its own manned control room with a hierarchy of operators and supervisory personnel responsible for control of operations.

From Figure 2 it can be seen that optimisation of overall operations was difficult owing to the large number of people involved in process control decision-making and the complexity of communications between various areas of plant. Despite the complexities of this control system, performance of the metallurgical plant was impressive. However, there remained significant benefits to be achieved by centralisation of control and decision making.

A Honeywell TDC 2000 central control system was successfully commissioned early in 1984. This system controls all operations from fine crushing to the finished product of uranium oxide and sulphuric acid manufacture. The original nine local control rooms were replaced by one central control unit (Figure 3).

It should be emphasised that all control

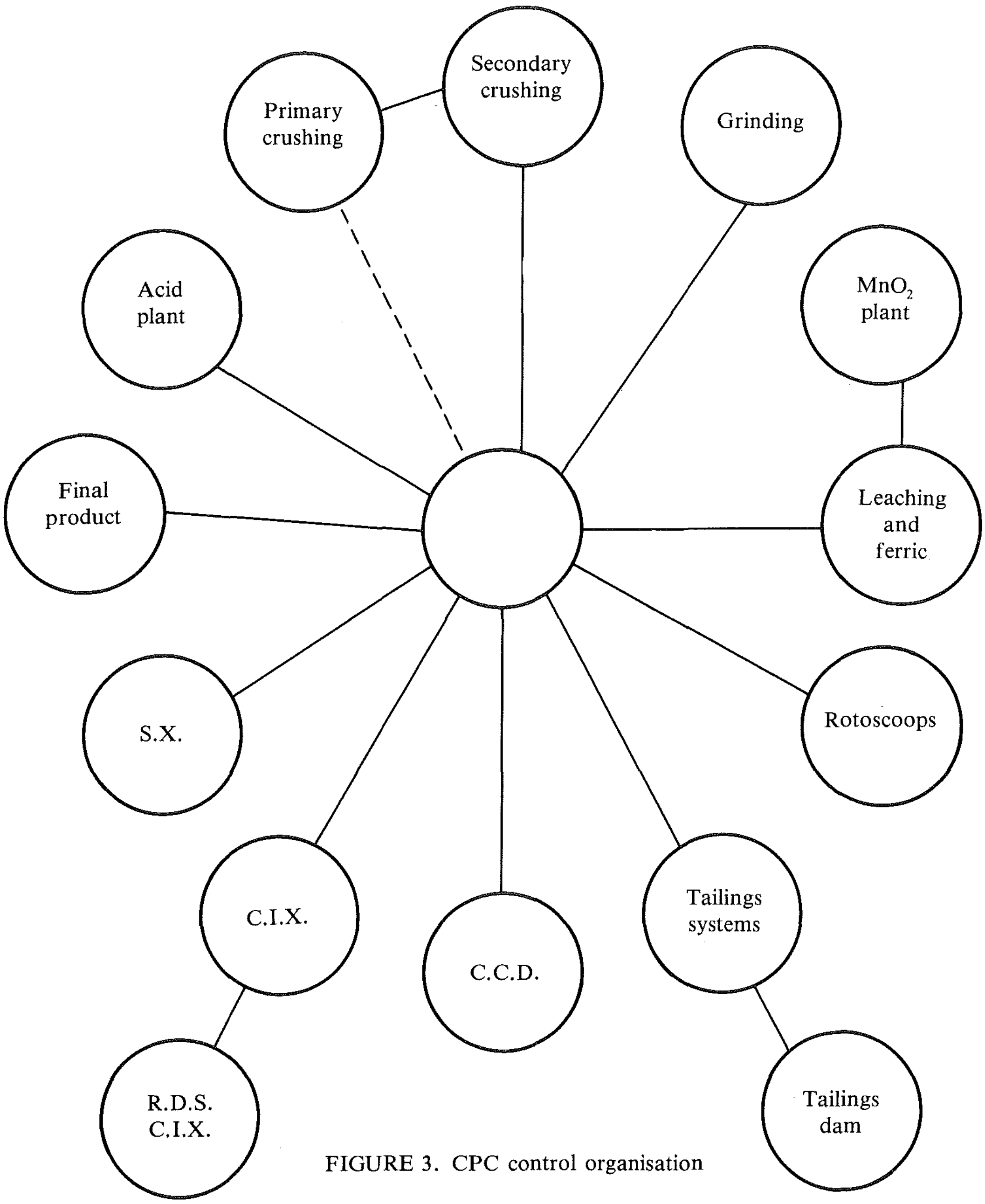

FIGURE 3. CPC control organisation

actions and decision-making are now the responsibility of central process control (CPC). The original control rooms remain only as sealed areas housing the hardware which communicates between the plant instrumentation and the central control room. All process control actions, including start-up and shut-down of all areas of the plant, are carried out from the central control room.

Details of the Rössing CPC system have been published previously [2], and only a brief summary will be given here. The current control room hardware comprises:

(a) 4 Honeywell basic operator stations.
(b) 1 Honeywell 4 500 processor with two supervisory operator stations.
(c) A variety of peripherals, printers etc.

Each basic station is a standalone micro-processor with a capacity to monitor and control up to 1 500 digital or analog process points. The basic stations are configured for control over specific areas of the metallurgical plant. Control actions are largely manual at the operator stations, but the basic stations do have

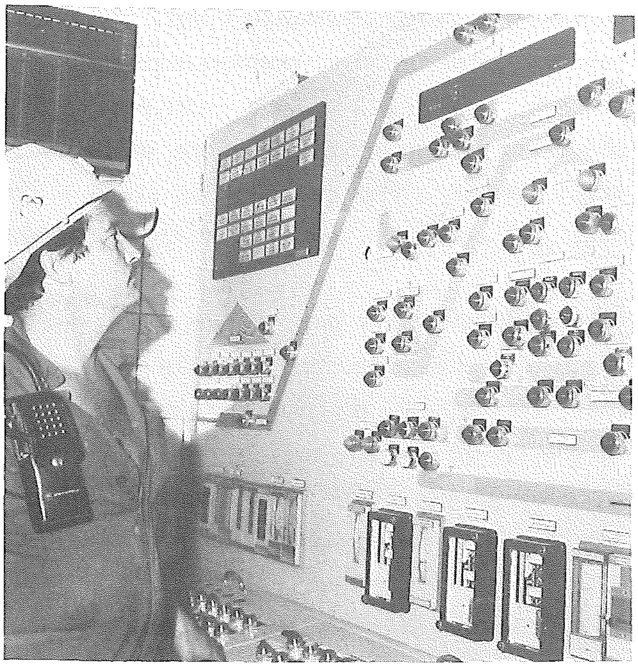

FIGURE 4. Typical original control on plant

limited software capacity for automatic control of certain operations.

The supervisory stations are linked to the process via the 4 500 computer, and each station can monitor and control up to 5 000 digital or analog process points. Each supervisory station overviews the entire metallurgical operation which currently has a total of ± 3 000 points. The supervisory stations can duplicate the basic station functions and have comprehensive software facilities to allow development and application of advanced automatic control.

The implementation of new process control technology on an operating plant had a major impact on people at all levels. This is perhaps most dramatically illustrated by comparison of the original working environment (Figure 4) with the present control room (Figure 5).

The central process control system was successfully commissioned on an operating plant whilst maintaining production and performance targets. In the first two years of operation there were significant developments in control strategy, which have resulted in improvements in the efficiency of metallurgical performance.

The success of the project can be largely attributed to the full involvement and participation of technical and operations personnel.

FIGURE 5. CPC control room

Prior to commissioning, a project team was established, comprising relevant engineering, metallurgical and operations personnel. Particular emphasis was placed on the inclusion of experienced plant operating personnel in the project team.

Control of metallurgical operations is now the responsibility of a CPC controller who is the senior person on each shift and responsible for all metallurgical plant operations. These individuals were selected after exhaustive testing, using various techniques, such as Assessment Centres, from experienced operating personnel, and became an integral part of the project team. Following further intensive technical and process training and a series of personal development courses, these CPC controllers made a major contribution to the design, commissioning and development of the Central Process Control system. Of particular interest is that the operations personnel played a major role in the system software development, and the control system, as a result, has been tailor-made to suit operational requirements. This successful approach has continued, with all development of the control systems being done in conjunction with, and to suit the needs of, operations personnel.

The CPC system as originally commissioned duplicated the facilities previously available in the local control rooms. Initially control remained a series of manual actions, but considerable software development has taken place and many control actions are now performed automatically by the computer systems. The following section gives a brief summary of process control developments successfully achieved to date.

Development of control systems

The primary objective of CPC was to centralise all controls and decision-making. The initial commissioning of the central control system achieved this objective but all controls were effectively still manual. For example, to start a rod mill an operator called up the relevant screens on a VDU and sent signals to valves, motors and pumps. He then checked the electronic feedback signals to ensure that the correct actions occurred. A high intensity of manual actions and short-term decision-making was therefore needed to maintain effective control over the entire metallurgical complex. Subsequently, however, there has been considerable on-site software development which has led to successful application of more advanced computerised control.

Control system developments can be grouped into various categories, e.g.

(a) Automatic start-up/shut-down of sections of plant - to reduce the level of repetitive operator tasks and free control room personnel for more rewarding aspects of process control and optimisation.

(b) Automatic control algorithms - continuous on-line computer control on a section of plant. This can vary from a simple algorithm for control of a tank level to application of complex process optimisation models.

(c) Management information - a wide variety of process information is automatically captured and can be made available as required by all levels of management. While not strictly process control, the CPC management information systems provide a significant contribution to overall decision-making and optimisation of process operations.

Developments in each of the above areas are briefly reviewed below.

Automatic start-up and shut-down

The Rössing metallurgical plant is a continuous 24-hour operation, but certain plant areas are shut down on a regular basis for planned maintenance. When performed manually at a control room operator station, shut-down and start-up involve a complex sequence of keystrokes (e.g. approximately 60 keystrokes for one line of the fine crushing plant). These repetitive sequences have been programmed step-by-step into the system and can now be activated with two or three keystrokes. This approach ensures that the item of equipment is always stopped or started in a safe manner and according to an established standard procedure.

After each step, checks have to be carried out, in software, to acertain whether the required actions have occurred. Branch instructions for any abnormal situation are also incorporated into the program, i.e. re-try, abandon or continue sequence. This program and similar ones for other areas of plant relieve the operators of repetitive tasks, giving them more time to concentrate on other aspects of operational control.

Automatic control algorithms

This category covers programmed algorithms which are permanently on-line as opposed to start-up and shut-down sequences that are activated only when necessary. Control algorithms of varying complexity are in use, although a comprehensive description of the full range of automatic control applications at Rössing is beyond the scope of this paper. A few typical control algorithm applications are listed below, however, which give some indication of the variety and scope of computer control.

Bin level control

This is a simple example of a type of control strategy extensively implemented. This particular algorithm prevents a surge bin at the crushing plant from either overflowing or emptying.

Seven feeders underneath a coarse ore stockpile discharge onto a conveyor belt which in turn feeds into a surge bin. Continuous signals from sonar level indicators at the top of the bin are sent to CPC. The feeders under the stockpile can be stopped and started to maintain the bin level within specified limits. The algorithm allows operators to select feeders which will then automatically stop and start to maintain the level in the bin.

This is a trivial example of automatic control but it demonstrates the power of the CPC system. Many similar applications have been possible with only minor software development. More traditional instrumentation can achieve similar results but normally only at significant hardware cost.

Rod mill discharge density

Fine ore from the crushing plant is mixed with water and recycled tailings dam solution. The resultant pulp is fed to an open circuit rod milling operation. Maximum discharge density commensurate with smooth rod mill operation is required as this minimises water consumption and maximises leaching efficiency.

Ore to water ratio was traditionally controlled to a set point which was manually adjusted to maintain smooth mill operation. Set point adjustments were necessary at irregular intervals of time owing to the variable physical nature of the pulp being handled. Considerable disruptions to milling operations were caused through limitations of the mill discharge pumping systems and pulp viscosity changes. In practice this caused overflowing mill discharge sumps and resultant loss of mill throughput.

Control algorithms now continuously monitor mill discharge sump level and adjust ore to water ratio as necessary to maintain smooth mill operation and maximum achievable pulp density.

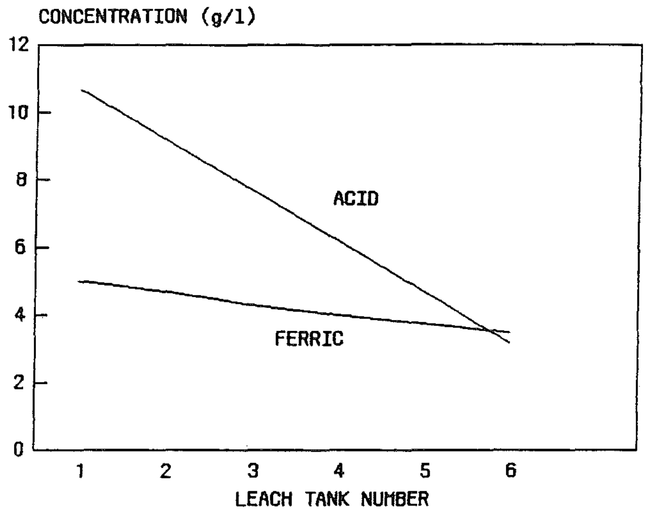

FIGURE 6. Acid and ferric profiles — leaching

Leach profile control

There is major potential for cost saving by optimisation of leaching conditions. Considerable effort has been devoted to control algorithm development in this area. Uranium is leached in an acid medium with ferric iron as an oxidising agent, i.e.

$UO_2 + 2\ Fe^{3+} \rightarrow UO_2^{2+} + 2\ Fe^{2+}$ [1]

$UO_2^{2+} + 3\ H_2SO_4 \rightarrow [UO_2\ (SO_4)_3]^{4-} + 6H$ [2]

Sulphuric acid provides the acidic medium and ferric iron concentration is controlled by addition of manganese, i.e.

$2\ Fe^{2+} + Mn^{4+} \rightarrow 2\ Fe^{3+} + Mn^{2+}$ [3]

The concentration of Fe^{3+}, Fe^{2+} and H^+ in leach discharge solution has a strong influence on the efficiency of the downstream ion exchange plant. Overall optimum targets for concentrations of Fe^{3+} and free acid in leach discharge have been established from metallurgical testwork (typically $\pm$ 3,5 g/litre for Fe^{3+} and $\pm$ 3,2 g/litre for free acid) and provide the basis for leach control.

The Rössing leach plant consists of two identical modules of six tanks in series, with sulphuric acid and manganese dioxide being added to the first three tanks. Typical concentration profiles are shown in Figure 6 which give an indication of the rate at which acid and ferric iron are consumed in the process.

The total retention time in the tanks is dependent on tonnage throughput, but is normally about 10 hours.

A control algorithm has to take into consideration the fact that the gradients of the leach concentration profiles vary with differing ore types. Figure 7 shows a typical range of acid concentration profiles. Concentrations

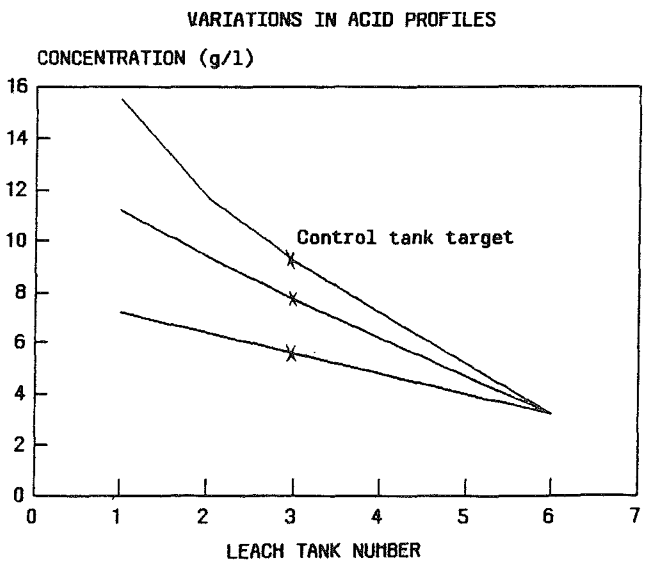

FIGURE 7. Leach acid concentration profiles

in the early tanks must vary considerably to maintain terminal tank targets.

The algorithm used for acid profile control continuously monitors acid concentration profiles. Variations in consumption rate (i.e. gradient) are immediately noted and acid addition rate is altered accordingly. The algorithm takes account of throughput variations depending on the number of mills on-line and makes provision for bypassing of leach tanks for maintenance.

Ferric iron control is based on a similar strategy and incorporates control over total iron concentrations as the Fe^{3+} / Fe^{2+} ratio is the driving force for the uranium oxidation reaction. Iron is obtained in the form of calcine (Fe_2O_3), a waste product from Rössing's pyrite-burning sulphuric acid plant.

The leach control algorithms currently in use are limited as on-line sampling and analysis are not yet available. Conductivity probes and redox probes provide the basis for short-term leach profile control, and hourly concentration values for all leach tanks are manually determined and entered into the computer system. The control algorithms use the hourly analyses as a basis for continuous recalibration of conductivity and redox probes and adjustment of set points to control reagent addition.

On-line sampling and analysis systems are under development and should lead to further improvements in control. The current control algorithms, while limited, have provided significant improvements over the previous manual control of set points. For example, terminal acid targets are consistently achieved within $\pm$ 10% of target compared with $\pm$ 25% for manual control.

The financial benefits of improved leach control are difficult to quantify as leach performance is not purely a function of control actions but is also strongly influenced by variations in ore properties. However, in the first full year of CPC control there was a total saving in excess of one million rand owing to lower acid consumption alone, and up to 70% of this saving has been attributed to improved control. This saving alone represents a significant contribution towards the return on the total CPC capital investment of $\pm$ 2 million rand, and is only one facet of the savings achieved.

Management information

The 4 500 processor continuously monitors process parameters and maintains a history data base for the entire plant. Information can be recalled to a screen or printer in a variety of forms including shift, daily or monthly averages. Report formats are custom-built to suit user requirements, and routine hard copy reports are automatically generated as required for all levels or supervision and management.

The processor also retains minute by minute readings of process variables for a period of thirty hours. This feature, together with an alarm history for the latest 5 000 process alarms, is an invaluable trouble-shooting tool. Metallurgists and engineers can now reconstruct in detail a series of events that preceded an abnormal plant condition, for example, then identify the problem and take corrective action.

Future developments

Development of control system software is a dynamic, ongoing process; a variety of control algorithms are in various stages of development and application. Items of interest include the following:

(a) Wash circuit control : continuous on-line optimisation of wash circuit parameters to minimise soluble losses and maximise uranium recovery.

(b) Ion exchange and solvent extraction optimisation : on-line control of flow-rates to achieve overall optimisation between the two processes.

A comprehensive technical model of the metallurgical process has been developed and is currently used off-line as a management planning tool. Control algorithms based on subsets of this model are is use in an on-line environment; the ultimate objective is continuous, on-line optimisation of the entire metallurgical plant.

This ultimate objective remains some years in the future but process control development is proceeding at a rapid pace and will make a significant contribution towards cost-effective production of uranium at Rössing in the years ahead.

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