Impact of plant upgrade and DMS on the processing capability of the Tati Nickel concentrator—a case study

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Transaction Paper

Synopsis

This paper describes DRA's involvement with the expansions at Tati Nickel, Phoenix Mine, that have taken an initial plant design of 3.6 Mtpa (originally built by Murray & Roberts), up to 5 Mtpa, and eventually 12 Mtpa capacity.

Initially, the plant could not achieve the design nameplate capacity for the first few years of operation, as a consequence of the notoriously hard and abrasive nickel ore affecting primarily the operation of the crusher circuit. In order to extend the life of mine, Tati' assessed and then redefined the mining plan, choosing to increase the Phoenix mine reserves to a lower cut-off grade. In order to increase nickel units produced, the concentrator had to therefore treat additional tonnage at lower head grades.

Site investigations and field tests around the comminution circuits are outlined, indicated that the milling circuit could be increased to 650 tph, from the initial design of 470 tph, for a similar feed grade and recovery.

A project was initiated to debottleneck the crusher circuit and achieve the new target throughput. (Project 5M).

This was followed by a feasibility study of the impact of pre-concentration by DMS, which after promising laboratory tests, was followed up with the installation of a 200 tph 'demonstration' plant. The success of this demonstration plant provided the impetus to expand the supply to the 5 Mtpa mill from a large preconcentration stage.

A gyratory crusher (one of the largest and most powerful) will receive ore directly from the open pit operation, feeding into a secondary-tertiary crushing plant followed by a modular DMS preparation circuit. Four large DMS processing modules have been installed to treat the tonnage, with high expected rejection levels.

Finally a review of the DMS process capability on an ostensibly disseminated micro-gabbro nickel ore is given, which shows the remarkable impact that preconcentration can have on an operation, both in terms of profitability and a successful process 'expansion'. The performance of the DMS plant has significantly extended the life of mine, allowing the mine to significantly reduce mine cut-off grades and curb its previously selective mining practice.

Mine status—early 2005

By early 2005 the Tati Nickel Phoenix mine had been operating for about two years; however, it did not achieve design throughput for any sustained period. DRA Mineral Projects, based in Johannesburg, were invited to review the potential for improving the plant capacity to 4 Mtpa, and to determine any limitations in the process at the same time. In order to extend the life of mine and increase the nickel units produced, the mine was assessing and redefining the mining plan. The selected plan chosen was to increase the Phoenix mine reserves by lowering the cut-off grade from about 0.25%Ni, to 0.2%Ni, and even possibly 0.15%Ni which in turn resulted in the concentrator having to treat additional tonnage at lower head grades.

Due to the hard and abrasive nature of the disseminated nickel-copper sulphide micro-gabbro, the Metso C160 jaw crusher closed-side setting was relaxed from a design 130 mm, up to 190–200 mm to alleviate chokes and stalling problems (associated with slabby ore 'tombstones'). The knock-on effect was that this significantly coarsened the expected feed to the secondary and tertiary crushing and screening circuit. Following a review of the production statistics it became apparent that the concentrator redesign should focus mainly on improving the performance of the crushing and milling circuits, rather than on the downstream process.

The milling-flotation circuit had been operating at a nominal 470 tph, with limited incursions beyond this apparent threshold value. Unfortunately, no tenable grind-recovery relationships could be derived from the plant metallurgical results due to unsteady operations.

However, it was possible to determine the ore comminution variability (which generally follows grade variation), and it was found that preferential grinding was taking place. The mill circuits were simulated using population balance modelling, using 'in-house' model parameter derivations, and Excel-VBA computer models.

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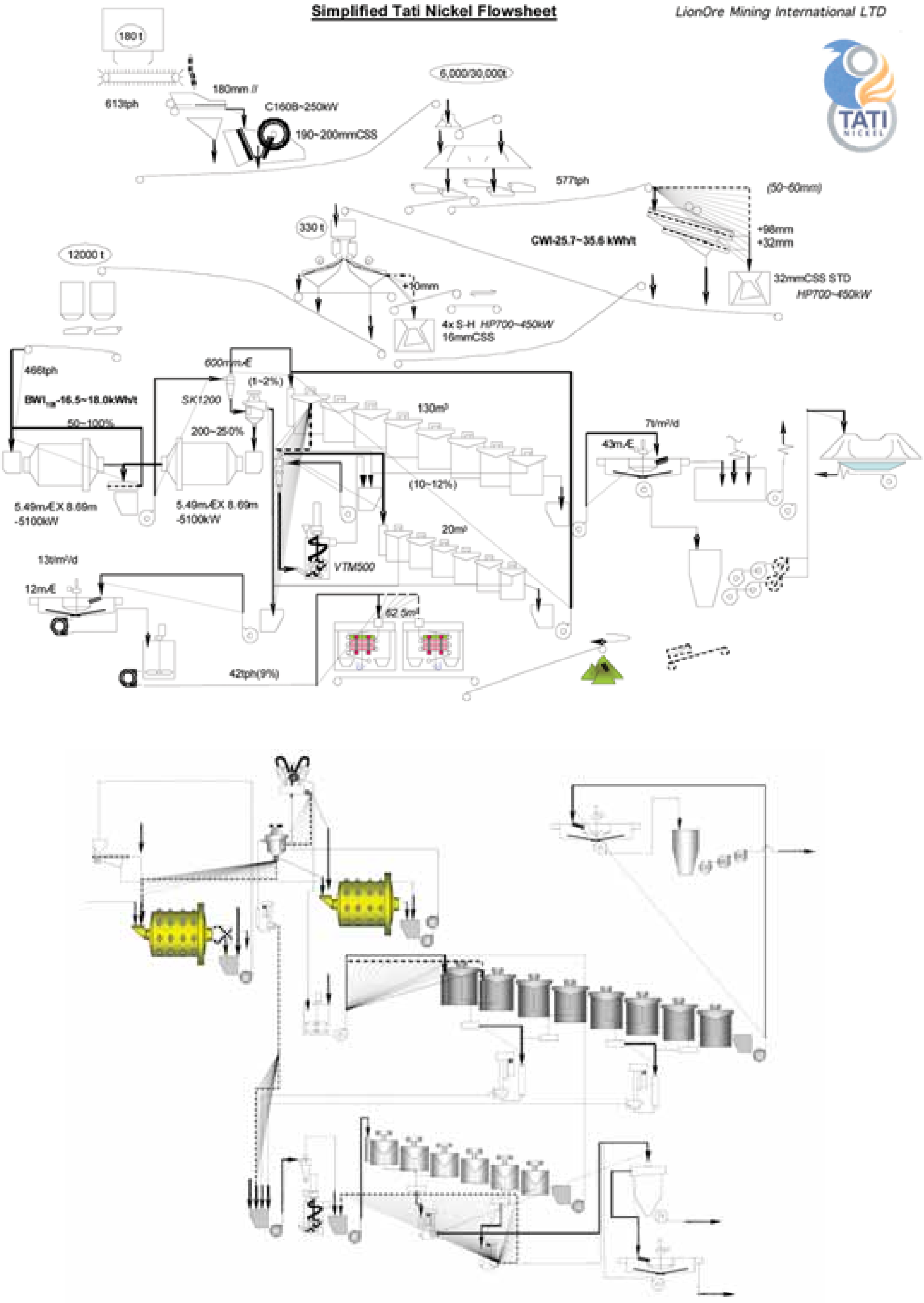

Figure 1—Original plant simplified flowsheets

Concentrator 'stress testing'

Although the crushing circuit had already been identified as a throughput constraining step to the current process, a 'stress test' of the milling circuit was organized to determine the limitations of the milling circuit, and to try if possible to obtain a grind-recovery relationship. A concerted effort was put into filling the mill silos ahead of the test campaign, so that the true capacity of the milling circuit (post-crushed minus 12 mm) could be ascertained without running out of similar feedstock. Care was taken to prepare this bulk sample in terms of what ore is to be treated in the future. The two-stage ball milling circuit was sampled at known feed rates to assess the grinding performance, and to develop discrete-size population balance simulation models that could reliably describe the milling process for typical low-grade Phoenix pit ore.

The mill feed rate was increased in increments from 525 tph up to 600 tph, and sampled about the milling circuit after change following 4 hours of stabilization.

The ore specific breakage rates for the each of the rate tests were determined and the ore breakage characteristics were not found to be radically different from the historical mine performance data. The graphs (Figure 2 and 3) show that the primary and secondary milling 'stress test' modelled breakage rates provided reasonably consistent results. A single milling classification screen was used for the first ramp-up tests, two screens for the 600 tph and repeat 575 tph tests. A combination of 6 mm and 4.5 mm aperture screens were used in order to 'broaden' the recycle size distribution to the primary mill, improve progressive grinding, and reduce the effect of 'pip' surges. As primary milling circuit had only a 4.5 minute cycle residence time. The performance of the primary mill was quite difficult to simulate satisfactorily because of the 'oversize' effect influencing the flow through the mill. Modelling the upper sizes, especially their mill discharge distribution, responded better to a plug-flow model compared to a fully mixed single-reactor model. The secondary mill behaviour was found to be satisfactorily modelled by three fully-mixed reactors in series, which is regarded as normal.

It was therefore determined from the field test work that the plant could achieve a nominal 625 tph on a steady state basis. It was also noticed that the primary screen oversize was of a lower grade than feed. It was inferred to be due to preferential grinding, and that premature rejection of this fraction may also increase fresh mill throughput even further. Modelling of the current milling circuit configuration (i.e. mills in series) also indicated that it was relatively self-compensating, and contributes a further 2% by mass of minus 75 μm to the mesh of grind when compared to a parallel mill circuit.

Project 5Mm

The design requirements of the concentrator upgrade could now be cost-effectively assessed, given the limitation of throughput capability of the milling circuit. (Figure 4.)

The necessary improvements to the crushing circuit in order to sustain an annual throughput of 5 Mtpa were assessed. A trade-off study using various crusher simulation models revealed that a second jaw crusher station and a common open-circuit secondary crusher (H8800-600kW) ahead of the ROM stockpile would improve the crushing plant delivery rate and the performance of the tertiary crushing circuit.

A decision was also made to upgrade the flotation circuit on a prorata basis, in order to treat the higher process flows. The cleaner circuit was bolstered by two large high mass-pull/high lip length cell units (OK50TC) at the head of the bank in order to reduce the flows into the existing cells (that were known to be currently flow restricted). A later addition to the project scope was the reconfiguration of the cleaner circuit to produce two separate concentrates, and to increase the filtration capacity to 700 ktpa. This was prompted by the announcement of the Activox Project, and sourcing alternative smelter contracts given the threatened future closure of BCL.

The proposed method of increasing the primary mill power draw was converting it to a semi-grate discharge from an overflow discharge condition; however, it did not go to plan. The liner change did not go smoothly and after several disastrous overloads, and liner damage incidents, it was decided to abandon this method and revert to the overflow discharge.

The secondary mill, as a consequence of limited power on the primary mill, operated 'teetering' into the overload condition, most of the time. However, the expected grind-recovery relationship was maintained at 5 Mtpa throughput.

Dense media separation possibilities

As the mine cut-off grade was reduced, it became necessary to investigate the possibilities of a preconcentration stage ahead of the 'uprated' concentrator.

Following the observation that preferential grinding was taking place, it was speculated that the ore may respond well to DMS. Heavy liquids tests on various grade ore types from Phoenix Mine were conducted at Mintek. The samples tested, were split into -20 mm+10 mm and -10 mm+1 mm size fractions prior to DMS and a densiometric analysis derived between 2.7 and 3.2 t/m^3. (Figures 5–7.)

A bulk sample was also pilot tested and gave promising results. For the low grade ore, it was found that up to 59% weight of ROM could be rejected, with a rejects grade similar to the concentrator flotation tailing.

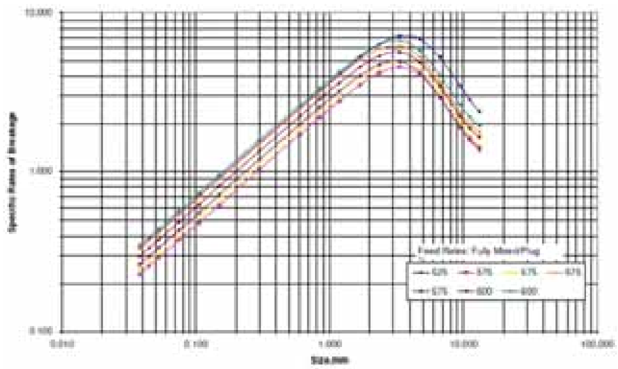

Figure 2—Stress test primary mill-specific rates of breakage

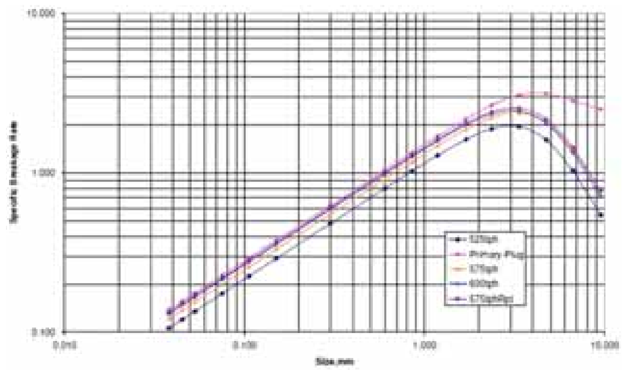

Figure 3—Project 5M primary/secondary crushing upgrade

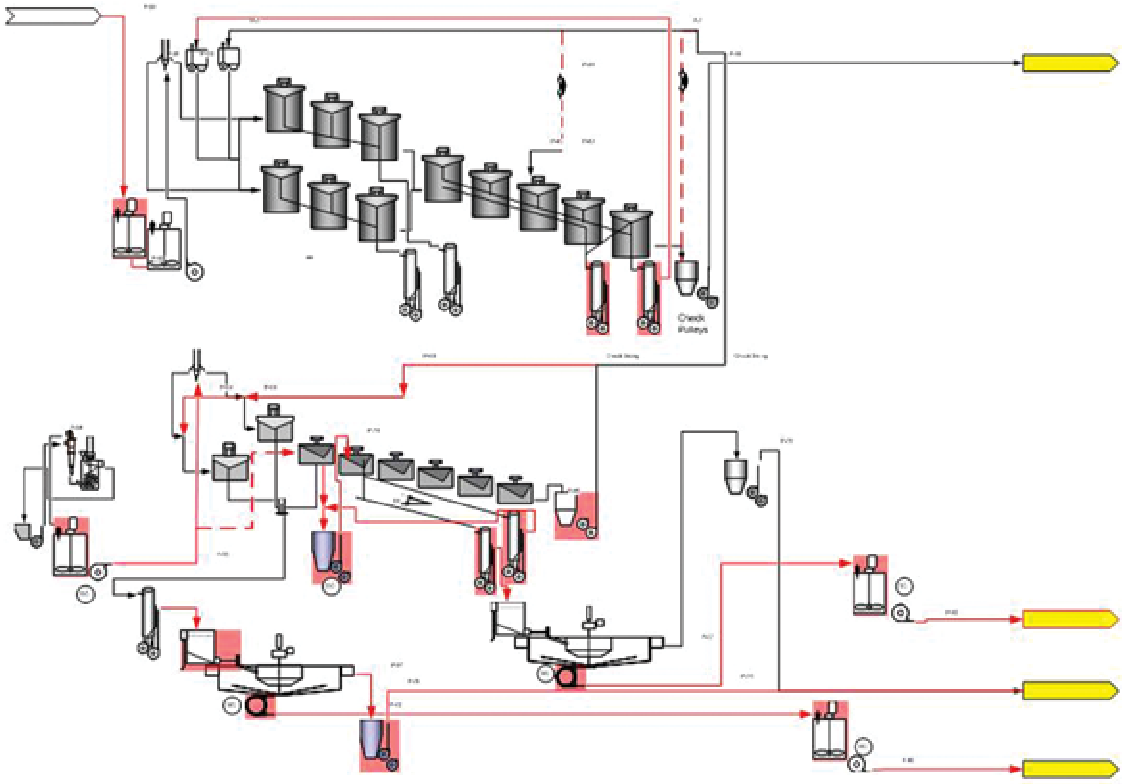

Figure 4—Project 5M and flotation section high-low grade split cleaner upgrade

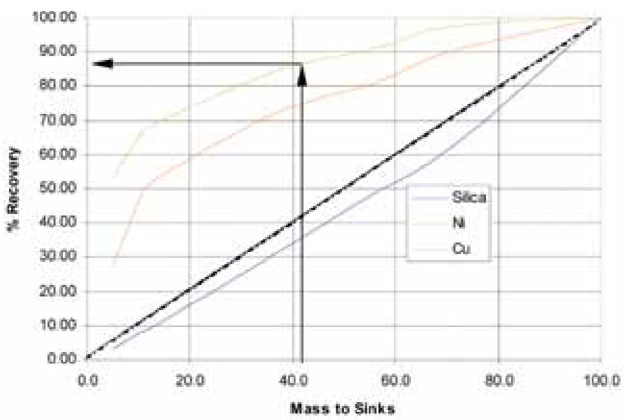

Figure 5—Mass recovery relationship -20 mm + 10 mm

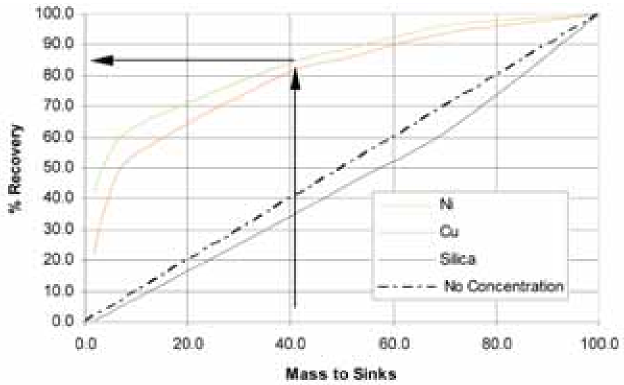

Figure 6—Mass recovery relationship -10 mm+ 1mm

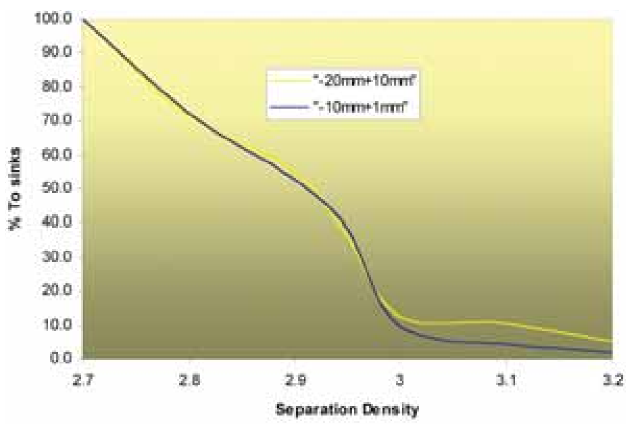

Figure 7—Density mass profile

A decision was therefore made to build a 'demonstration' 200 tph DMS plant (DMS 1A) treating minus 20 mm plus 1 mm at Tati, using some of the old equipment from the Selkirk magnetic separation plant to prove the system on an industrial scale.

Ep-values of 0.065–.07 @ 2.95–3.0 t/m^3 cut-point for separation were experienced at times (due to anticipated pyrrhotite built-up in the FeSi), but these were expected to improve to 0.026–0.032 in practice. A pyrrhotite bleed and flotation unit was incorporated into the circuit. (Figure 8.)

The 'industrial unit' operated satisfactorily, despite an

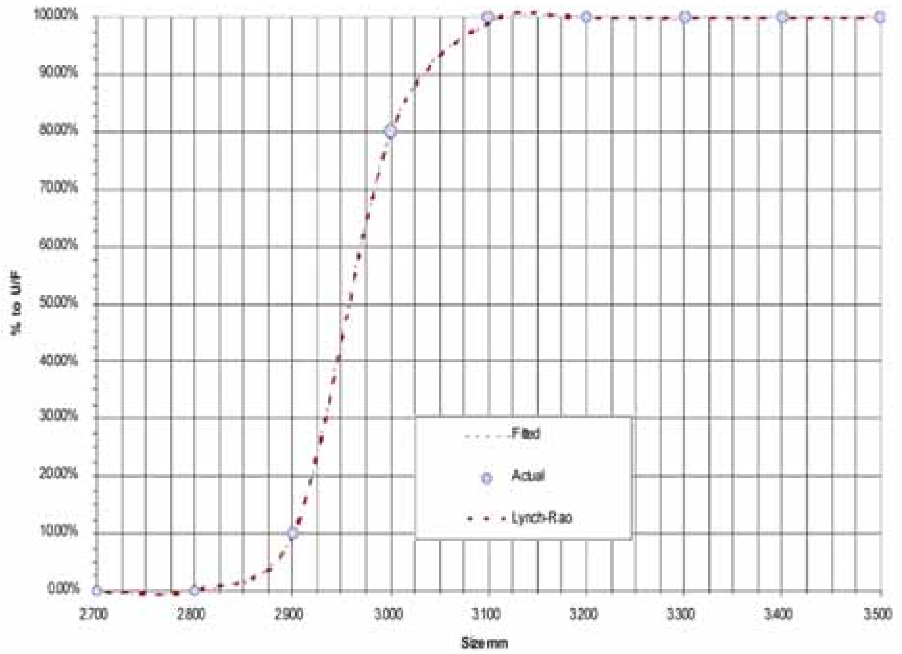

Figure 8—*In situ* tracer test Tromp Curve

Figure 9—Testing at ECTL Japan, the sample (in shot) required 47 mt force to break, much to the delight of the Japanese 84–100 MPa typical requirement for fracture

interesting development: due to batch processing the pyrrhotite build-up in the ferrosilicon medium began to corrode with the medium, giving off hydrogen gas. This caused a minor explosion during a plant shutdown, following which measures were put into place to control the medium pH and pyrrhotite bleed in order to avoid further occurrences.

TATI DMS—expansion project

Having proved the viability of DMS on an industrial scale, Tati Nickel set out on an ambitious plan to expand the crushing and preconcentration circuit to treat up to 12 Mtpa, in order to feed the 5 Mtpa concentrator. Phase I of the project was to treat 8 Mtpa ROM while a future expansion would further increase the life of mine and lower the cut-off grade.

A trade-off study clearly showed that a gyratory crusher was the best solution to receive ROM from the pit, as it could treat at the required nominal rate of 2 600 tph. Open circuit secondary crushing (in a similar fashion to the Project 5 M preparation circuit) ahead of closed-circuit tertiary crushing, could then produce minus 25 mm DMS feedstock. Four large single-stage gravity fed DMS modules were designed to treat up to 400 tph each (total 1600 tph). Slimes and fines

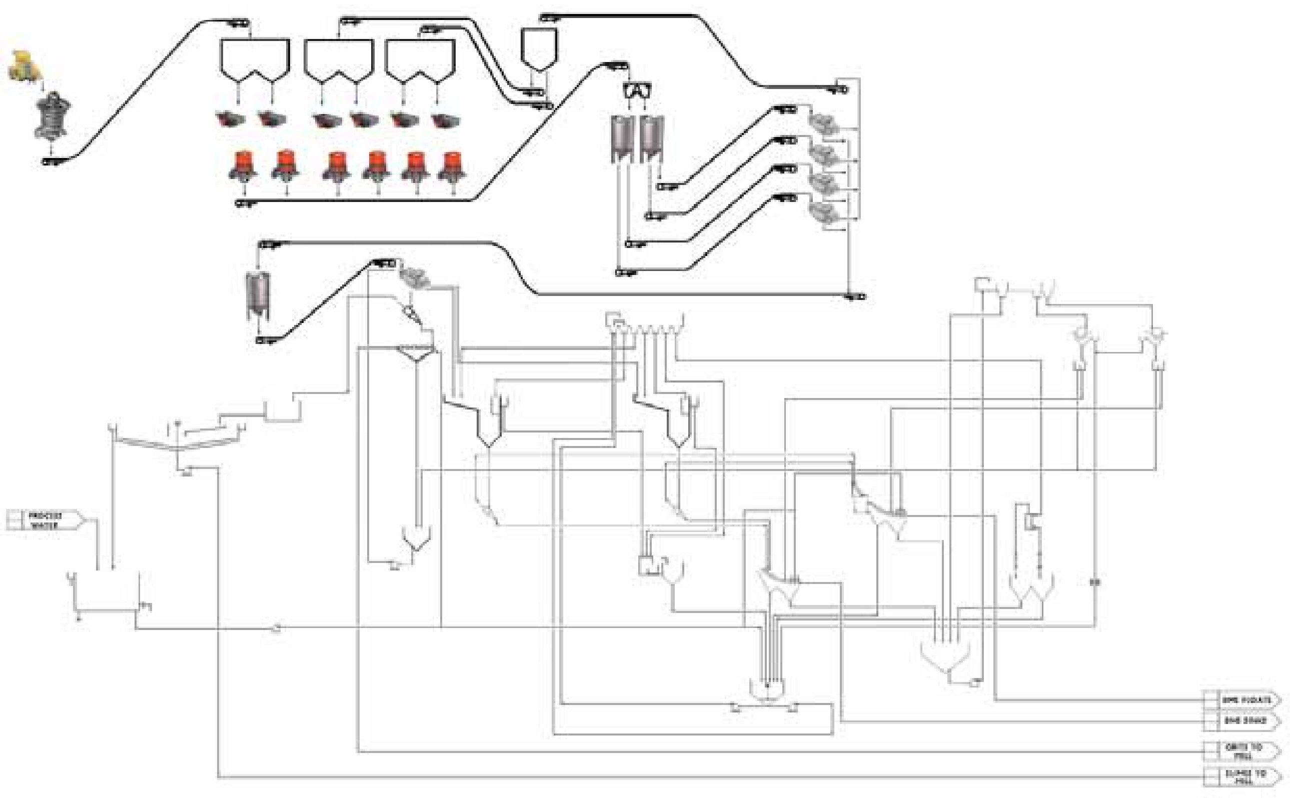

Figure 10—Simplified expansion crusher—DMS x4 flowsheet

fractions would be collectively introduced to the primary milling circuit. Temporary stockpiling of grits and slimes in a thickener, served as intermediate storage for whenever the main concentrator was down. The DMS sinks product was reintroduced to the existing (now) 'quaternary' closed-circuit crushing circuit for producing the majority of mill feed to minus 10/12 mm, which goes for storage in the existing mill silos. The 'side-lined' jaw crushing circuits could then be used for preparing high-grade ore arisings in the existing (parallel) conventional crushing circuit, for stockpiling ahead of the 'quaternary' crushing circuit.

Gyratory crusher design

Kawasaki was awarded the contract to custom-design a gyratory crusher for the notoriously hard Tati ore. The JK Tech Drop weight test ranked Tati ore in the top ten hardest ores ever tested in their database.

The 60"Ø gyratory crusher was designed by Kawasaki (KG15026 EHD-S) after stringent testing at their Earth Technica facility in Japan. Three of the major rock types were sent for specific rock mechanic and crushing tests. Gabbro, dolerite and granite were each tested to ascertain scaled-up breakage characteristics for 1 m^3 equivalent lumps, the power requirements and the optimum chamber nip angle. As a result it was decided to install a 1 MW motor, despite the fact that the estimated average consumption would be about 690–730 kW, to ensure that the crusher would not stall. It is interesting to note that this was only the third 60"Ø x 1 MW gyratory crusher in the world, and all installed by DRA Mineral Projects. The other two were built by the other two main gyratory crusher protagonists, FL Smidth and Metso, for Anglo American's PPRust North (Mogalakwena) project and Kumba's BKM project, respectively.

Commissioning of the crusher was successful, achieving the design requirements and even justifying the need for a 1 MW motor.

Upside potential

Following the successful commissioning of the gyratory crusher and the DMS modules, it may be possible for the crusher section to operate 'off peak' and thus significantly reduce the power operating cost for the plant.

Tati Nickel has come a long way in four years, and it is hoped that in the current economic climate they may continue to prosper and the upgrade will assist them.

The author wishes to extend his gratitude to all at Tati Nickel for their enthusiasm and endeavour, with special thanks to Ian Moore, Corrie Swart, Alan Sammons, and Joe Brooks. ◆