Modernization of the BCL smelter

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Synopsis

BCL Limited operates a nickel-copper flash smelting operation at Selebi-Phikwe, situated in north-eastern Botswana. The original furnace was commissioned in 1973 and produces a high grade sulphide matte, from its own concentrates plus additional custom feeds, which is shipped to refineries in Zimbabwe and Norway for further processing.

In 2004 the company embarked on a study to modernize the flash smelting complex, with an emphasis on extending campaign life, improving the furnace integrity and enhancing throughput and process efficiency. First phase initiatives from this exercise, including the fundamental switch to a single concentrate burner operation of the flash smelting furnace, were implemented in July 2007.

This paper summarizes experiences prior to implementation, details the specific improvements made to the flash smelting furnace and associated operations, highlights the improved plant performance after modernization, and outlines second phase expansion plans that are currently under consideration.

Smelter plant description

Figure 1 depicts the schematic diagram of the overall plant.

Feed preparation consists of a pair of Niro spray dryers, each rated at 50 tph, and a Kvaerner multi-coil steam dryer, also rated at 50 tph, supplying dried concentrate to the flash smelting furnace charge bin via three 1 000 tonne capacity storage silos. The concentrate analysis is typically 5% nickel, 3% copper, 30% sulphur, 45% iron and 8% silica. A pair of loss-in-weight feeders supply 120 tph of concentrate feed to a single concentrate burner, with flux, secondary fuel in the form of milled coal and recycled boiler dust being added ahead of the single burner via an arrangement of bins, feeders and drag link conveyors. This gives a total charge to the furnace in excess of 180 tph. Process air is enriched to 30–35% oxygen and steam preheated to 260°C and supplies of the order of 60 tph of oxygen to the process.

Matte produced from the furnace, at a grade of 30–35% combined metal, is upgraded in one of three 30’x13’ Pierce-Smith converters to produce a high grade matte to two customer specifications before being granulated and shipped out of the country for refining. The large volume of slag produced is tapped on a continuous basis from the flash smelting furnace and, along with the converter slag, cascades through a pair of slag cleaning furnaces (both rated at 9 Mva) before being granulated and discarded.

Flash smelting furnace off-gas is cooled through a Foster-Wheeler waste heat boiler, operating at a steaming rate of 80 tph at 67 bar pressure. The cooled gas is cleaned through a pair of Lurgi electrostatic precipitators before being discharged via a 154 m stack to atmosphere.

Historical performance

The historical performance of the BCL smelting operation has been detailed in a previous paper (11th International Flash Smelting Congress, Bulgaria/Spain 2005), which chronicles the continuous improvements in concentrate throughput, metal output and flash smelting furnace campaign life over its 30-year history. By the end of the sixth campaign in 2004, flash smelting furnace campaign lives of around 8 years were consistently achievable and with high furnace utilization (averaging 92%), concentrate throughput and matte output had increased to around 7 000 000 tonnes and 500 000 tonnes per campaign respectively. The production data in Table I clearly indicate the progress made.

Despite a doubling of throughput and production rates, achieved essentially by increasing oxygen-enrichment levels in process air and a move towards custom feed

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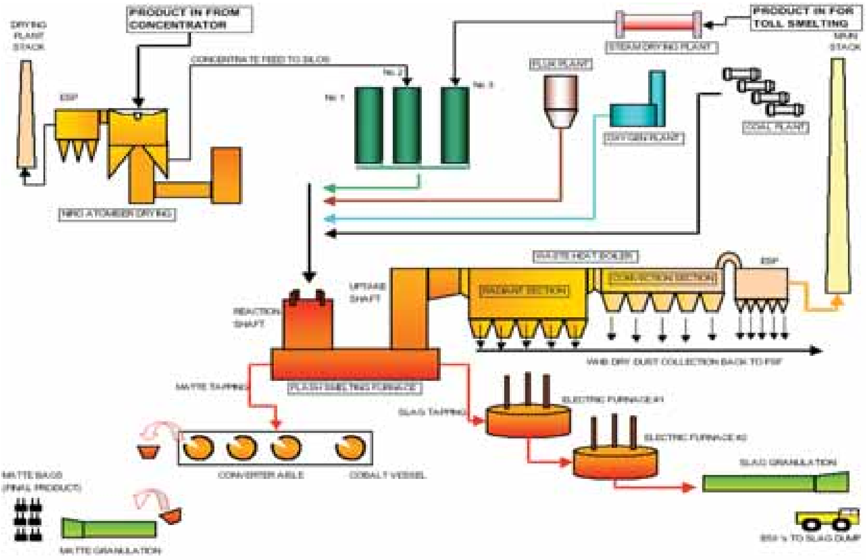

Figure 1—Schematic of BCL smelter

Table I

Production data comparison, first and latest campaign

	1st Campaign	6th Campaign
Duration (months)	15	106
Total concentrates treated (tonnes)	482 000	6 986 000
Custom concentrates treated (tonnes)	-	1 600 000
Nominal furnace feedrate (tph)	70	120
Process air oxygen content (%)	21	35
Total metal produced (tonnes)	5 135	416 532

smelting, very few design or development improvements had been made to improve the integrity of the furnace, particularly furnace cooling and concentrate burner development. Campaigns were characterized by a smooth and reliable first half period, with high furnace availability and utilization (99.2% and 97.6% respectively in the last campaign), followed by a rapid deterioration in furnace integrity over the latter half, making production targets increasingly more difficult to achieve and the operation more hazardous to maintain. Ultimately, the campaign life has been dictated by the inability to maintain acceptable furnace integrity and availability. Figure 2 shows this deterioration in furnace availability over the 8-year campaign life.

The areas of concern which affected most significantly the integrity of the furnace have typically been:

- The reaction shaft roof, which had a life span of only two years once process air oxygen-enrichment levels were elevated to 35%. The roof construction was of the original domed-arch design, without cooling, and would exhibit signs of buckling, overheating and spalling within the first two months of operation and required constant patching and repair after the first year of operation (see Figure 3). This phenomenon was observed to accelerate with each successive increase in process air oxygen-enrichment level, indicating that the

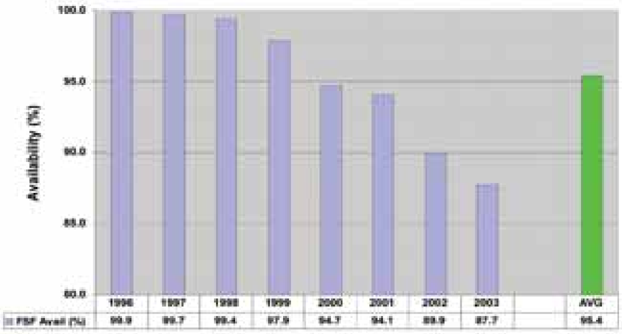

Figure 2—Flash smelting furnace availability for No. 6 campaign

Figure 3—Reaction shaft roof damage

cause was probably due to excessive heat and uneven heat distribution at roof level from the outdated four-burner arrangement.

- The reaction shaft shell, the entire length of which was film-cooled, would begin to crack, corrode and leak from midway through the campaign. The remainder of the campaign would then be an escalating defensive repair strategy of online welding and patching of the shell, interspersed periodically with outages to effect panel replacement of the more seriously damaged portions. The final year of the campaign would require a permanent team of welders carrying out online shell patching in an effort to minimize cooling water leakage into the furnace. Inadequate cooling of the shell was the primary cause, exacerbated by severe and uneven heating of the shell from the four-burner arrangement. Figure 4 shows a heavily patched section of reaction shaft shell taken mid-campaign during an outage to perform a more permanent repair.
- The transition junction between the reaction shaft and settler roof suffered similar, and more pronounced, damage due to the same combination of high heat flux and inadequate cooling. Failure of the ‘L’-type junction cooling elements would typically occur during the third year of service, following which regular routine furnace outages would be required to reinstate the junction, shell and lower cooling water tundish to an adequate working condition

Modernization—Phase 1

In 2004, as part of a five-year business improvement initiative, a study was initiated to modernize the flash smelting complex, the first phase of which would target improvements in integrity that would lead to increased furnace availability and potentially extended campaign life. An initial benchmarking exercise, including visits to a number of European flash smelting operations and discussions with Outotec, clearly indicated that recent significant advancements in flash smelting technology, particularly in the fields of concentrate burner development and furnace cooling design, would be beneficial to the BCL smelter. Following more in depth studies, including the computational fluid dynamics (CFD) modelling of burner combustion characteristics and gas and heat flow patterns, additional benchmarking visits, a detailed first phase modernization package was developed for execution in mid-2007. The CFD modelling exercise was particularly beneficial in that it indicated that cooling improvement efforts should be focused on the lower portion of the reaction shaft shell only and that the reaction shaft roof would remain relatively cool and would not require any water cooling. Additionally, it revealed that shortening of the reaction shaft (an original proposal) would be detrimental, as it would result in reduced reaction time to effect complete combustion of secondary fuel (pulverized coal) and would also modify the burner combustion flame pattern to the extent that the reaction shaft roof could overheat. A 59-day furnace outage was required to complete the upgrade and the key modifications are listed in the Table II.

Figure 4—Typical patch ongoing repairs after six months of operation to reaction shaft shell

Modernization benefits

After one year of steady operation since implementation, the benefits of the modernization programme are readily apparent.

Improvements in furnace integrity

The longer-term project benefits of prolonged campaign life and increased furnace availability will be realized only in years to come, though even at this early stage there are positive indications that significant improvements will be achieved. The reaction shaft roof remains in as-built condition and with a gentle and even temperature profile (below 300°C) there is no indication of overheating or uneven heat distribution. The reaction shaft curtain cooling water flow has been reduced from 500 m^3/hr to 300 m^3/hr and the discharge water temperature has decreased from 60°C to 30°C, a clear indication that the improved single burner combustion profile is keeping heat away from the reaction shaft sidewalls. Similarly, the heat flux in the element-cooled lower third of the reaction shaft and junction are much reduced, cooling water temperatures are much lower and external shell temperature surveys indicate low (below 200°C) and even temperatures. Routine furnace inspections reveal a well distributed, even lining in the reaction shaft. All the above provide a high level of confidence that improved furnace availability will be realized during the later stages of the furnace campaign.

These benefits have been offset to some extent by concerns of increased integrity risk in the settler sidewalls and the uptake shaft resulting from the improved combustion performance and efficiency of the single burner, which has caused an increased heat load to the bath and settler sidewalls of the furnace and a reduction in heat to the uptake shaft and waste heat boiler. The bath is much more fluid than before and the protective lining on the exposed sidewall cooling elements is much less, increasing significantly the risk of sidewall failure. Conversely, the build-up of accretion

Table II

Major scope items of Phase 1 modernization

Plant modification	Detail	Benefits
Concentrate burner	Replace existing four concentrate burners with single Outotec burner, complete with process air speed control and airslide for concentrate feed. (See Figures 5 and 6)	Improved concentrate combustion leading to: 1. Improved integrity and life of reaction shaft roof, shell and junction 2. Reduced radiant dust re-circulation 3. Reduced secondary fuel consumption 4. Improved process control and efficiency
Process air fans	Replace existing pair of fans with a bigger pair with specification matched to new single burner characteristics	1. Allows for operation with a single duty fan and a dedicated standby unit 2. Fan output matched to increased back-pressure of single burner 3. Improved integrity
Process air duct	Replace existing four ducts with a single duct	1. Improved process control 2. Homogenous air/oxygen mix and distribution. 3. Simplified Instrumentation and operational control 4. Improved integrity
Feed system conveyors	Shortened by 3 m	Allow headroom for single burner access
Reaction shaft roof	Replace existing domed roof with a roof of flat, suspended construction	1. Ease of construction 2. Ease of repair
Reaction shaft shell	Replace lower third of curtain cooled section with Outotec cooling element	Improved cooling protection of lower third of shell
Reaction shaft junction	Replace existing ‘L’-element arrangement with Outotec ‘E’-elements (See Figure 7)	Improved cooling protection
Settler roof	Install BIC elements at reaction shaft junction and rebuild first half of settler roof to include cooling beams	1. Restore settler roof integrity 2. Improved cooling protection
New internal cooling water circuit	Install additional 500 m^3/h cooling water circuit, with pump station and cooling towers	Requirement for additional installed cooling capacity in reaction shaft and burner
Radiant section—waste heat boiler	Install two radiation baffles	Improve efficiency of radiant section
Convection section – waste heat boiler	Replace the first 4 (of 8) static pendants with mechanically rapped type	1. Remove requirement for manual ‘lancing’ 2. Increased throughput, by eliminating requirement to reduce feed during lancing

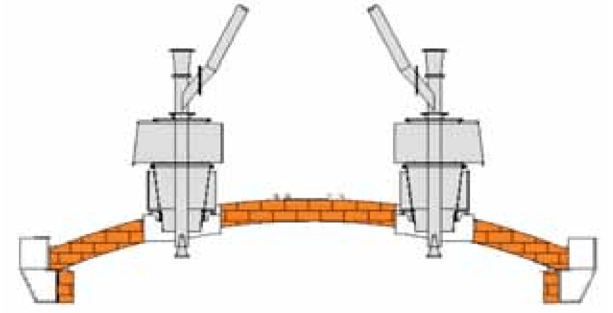

Figure 5—Four burner arrangement

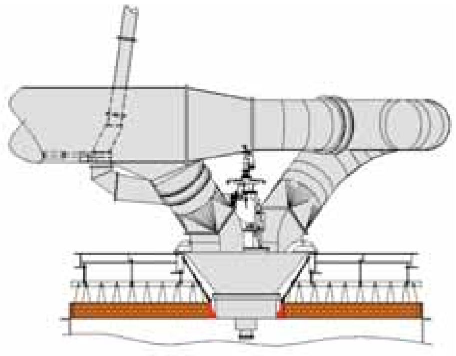

Figure 6—Single burner arrangement

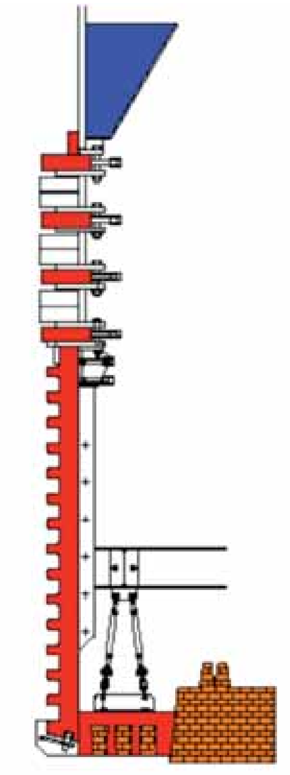

Figure 7—Reaction shaft junction

in the uptake shaft and throat of the waste heat boiler has increased markedly as a result of cooler and lower off gas volumes. Frequent outages are now required to clear the throat entrance to the waste heat boiler. Figure 8 indicates the increase in thickness of the accretion layer in the uptake shaft since commissioning of the single burner and has become a major cause for concern

Efforts to reverse this trend and reduce build-up thickness to a more acceptable level have focused on a dual mechanism of increasing the heat load into the uptake shaft and creating a reducing environment by injecting carbon fuels (oil and pulverized coal) into the base of the uptake shaft.

Improvements in burner efficiency

Table III gives a summary of the changes in key furnace operational parameters resulting from the improvement in burner combustion efficiency, with the highlights being a reduction in radiant dust recycle, a reduction in secondary fuel consumption and a reduction in process air requirement, which in turn leads to increased throughput potential or increased oxygen enrichment levels (both highly desirable at BCL).

Improvements in process efficiency

A step change in process efficiencies and metal recoveries was recorded and the improved efficiency performance since the single burner installation is shown in Figure 9. Improved slag fluidity, matte grade stability and overall process stability has resulted in a significant decrease in metal losses to discard slag. This has enhanced the efficiency improvements achieved by utilizing a higher quality ‘anthracite’-grade coal as reductant in the slag cleaning furnaces from the beginning of 2007, which reduced nickel in discard slag levels from an average of 0.25% Ni to .22% Ni.

Improvements in operational flexibility, arising from the simplification and integration of the feed system to feed the single burner, a reduction in gas volume through the off-gas train and a reduction in the number of feed interruptions to carry out concentrate burner inspections and waste heat boiler lancing, have resulted in a far more stable operation and an increased ability to maintain the operation at maximum concentrate feed rates. This stability improvement is an additional contributing factor to the process efficiency improvement.

Operational performance since modernization

Table IV shows the annualized plant performance data since the modernization of the flash smelting furnace

Phase 2: Modernization plans

The company is currently considering a Phase 2 modernization strategy that will incorporate further integrity improvements as well as a capacity expansion of around 20% to a concentrate throughput level of 1.1 million tonnes per annum. The BCL smelter is geographically well positioned in an expanding nickel-rich region of southern Africa and sees opportunity to benefit from the potential growth opportunities from custom feed smelting in coming years. Key development areas would include the following:

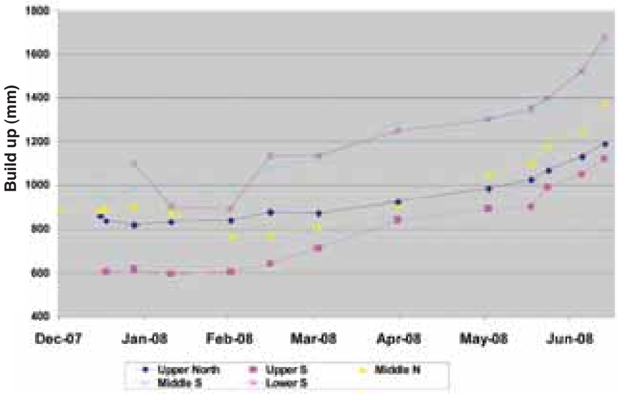

Figure 8—Uptake shaft accretion thickness monitoring

Table III

Comparison of key operational parameters

Parameter	Four burners	Single burner
Maximum concentrate feedrate (tph)	120	130
Process air flow (Nm3/h)	160 000	120 000
Burner air velocity (m/s)	40	120
Oxygen enrichment (%)	30–34	34–38
PF feedrate (kg/t conc.)	61	40
Dust recycle (%)	16-18	7-8
Steam generation (t/t conc.)	0.98	0.67

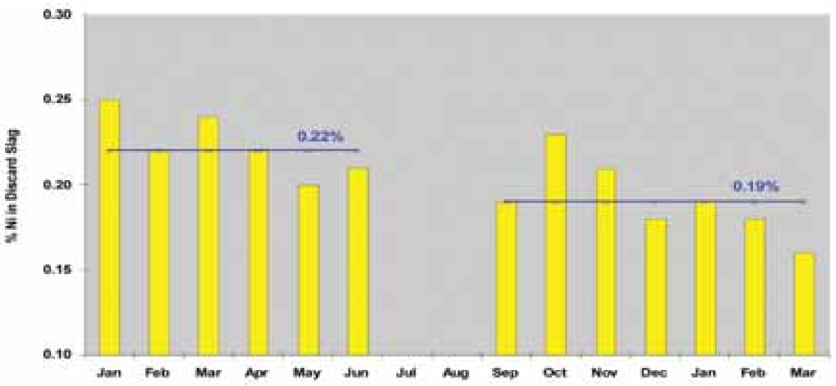

Figure 9—Improvement in discard Nickel slag losses

Table IV

Annualized plant performance data since modernization

Parameter	Annualized performance
Flash furnace availability (%)	97.7
Flash furnace utilization (%)	95.7
Total material charged (tonnes)	1 128 152
Total concentrate smelted (tonnes)	858,462
Feed grade (Ni & Cu %)	8.85
Matte grade (Ni & Cu %)	31.7
Dust recycle (%)	8.7
Total metal production (Ni & Cu tonnes)	61 548
Overall Ni recovery (%)	92.3
Ni in discard slag (%)	0.201
Slag produced (tonnes)	974 662

Custom feed offloading and concentrate drying capacity upgrade

The existing offloading and drying facilities would be inadequate for the processing of any significant increases to current custom feed commitments. The installed drying arrangement, of two 50 tph slurry-feed Niro spray dryers and a single 50 tph cake-feed Kvaerner steam dryer, is restrictive and inflexible, currently requiring a large proportion of the custom feed inputs to be repulped and processed via the Niro slurry dryers, due to limited steam drying capacity. Planned improvements would include an upgraded rail offloading facility and the installation of adequate additional steam drying capacity, utilizing rotating steam dryer technology, as shown in Figure 10. This would allow adequate offloading, handling and steam drying capacity for all custom feed inputs

Figure 10—Rotating steam drum dryer

Flash smelting furnace capacity upgrade

Both the existing concentrate feeders in the feed system and the overall process oxygen supply are running at their maximum output capability to sustain current concentrate throughput levels and would require upgrading. It is envisaged that the pair of existing Schenk 60 tph LIW concentrate feeders would be replaced with a pair of Outotec 80 tph units, complete with all associated ancillary equipment and control technology. A feed arrangement to the concentrate burner similar to the proposal in Figure 11 is envisaged.

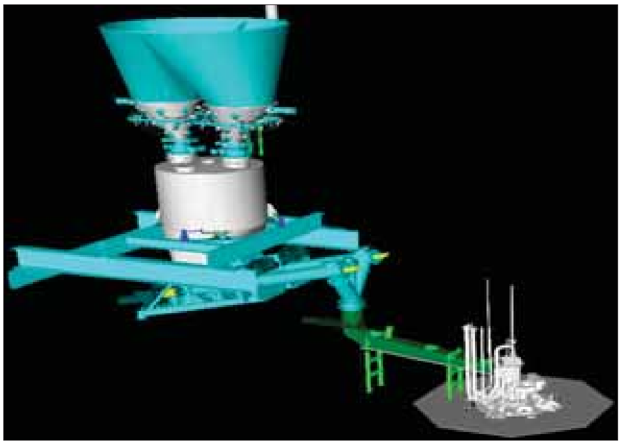

Figure 11—Proposed feed arrangement

The proposal of an additional 385 tpd technical oxygen plant is currently under review and would provide the increased process oxygen requirement. Operational benefits will be an increase in process air oxygen enrichment levels from the current 35% to 45%, which will remove the restriction to concentrate burner capacity and allow the velocity control device to continue to control within its designed operating range.

Flash smelting furnace integrity upgrade

The focus of the proposed integrity upgrade will centre on improvements to the furnace cooling systems, with particular emphasis on the settler sidewall cooling element design and detailing a much more robust construction. The existing sidewall cooling arrangement is as per the original furnace design, dating back to the early 1970s, and provides inadequate and inefficient sidewall cooling, generates minimal protective sidewall lining and hence the furnace is at an increased risk of sidewall failure. In addition to the negative impact on furnace availability, this also constrains the furnace to a lower than desired operating temperature. A redesign will include the latest Outotec sidewall cooling element design technology, an improved breastplate and tap hole arrangement and the raised elevation of some of the slag tap holes. It is envisaged that the redesigned settler sidewalls will provide an effective, integrated wall of efficiently cooled copper elements, that will ensure the desired improvement in furnace integrity and allow the furnace to be operated at a higher temperature and at higher bath levels. This combination of higher operating temperature, increased slag residence time and improved matte retention in the Flash Smelting Furnace is predicted to result in an improvement in overall smelter metal recoveries.

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