New technologies in the concentration of PGM values from UG-2 ores

by M.A.W. Bryson*

It is well documented that a significant amount of the new PGM (Platinum Group Minerals) production that is coming on stream now, and over the next few years, is to come from the UG-2 reef. Clearly the reservations, or perhaps the perceived reservations, attached to the processing of this ore are no longer there. What were the metallurgical issues that delayed the exploitation of the PGM values from this reef?

Traditional furnaces treating Merensky concentrates were not able to accept the concentrate produced from a UG-2 plant due to the relatively high chromite content of this product. The chromite reports to an insoluble spinel phase that accretes in the furnace, resulting in the necessity to shut down and dig the furnace out periodically. This was clearly not an attractive economic option, so producers stayed away from it in the early days. The Merensky ore had all higher base metal credits anyway, and you needed them to get a matte fall, so there was no driving force to look seriously at the UG-2 reef. Platinum demand at this time could be easily met from the Merensky ore, so the motivation to tackle more complex ores was not there. The low price of PGMs meant that these operations were not particularly profitable and there was little effort directed at improving the operations. Concentrators were generally not run very efficiently and the emphasis was on cost reduction through increasing milling rates.

The growth in the PGM market, in the 1980s, driven by the expanded use in the jewellery and autocatalyst fields, required that new sources of PGMs be found and developed. Most Merensky ores that could be accessed were either deep and patchy in grade, or were in areas where the development costs were likely to be high. It was an obvious step, thus, to look more closely at the UG-2 ore that could be accessed from the current infrastructure. At the same time, the proximity of the UG-2 reef to chromite operations meant that the mineral rights were sometimes held by these operations and not by the large producers. Opportunities were therefore created for newcomers to get into the market. First Lonrho entered, followed by Rand Mines, Aquarius, Southern Era, Cluff, and others.

There were in those days some technical challenges to overcome in the concentration process. Would flotation work on an ore where sometimes the association of the PGM values with base metal sulphides was weak? Would flotation work on PGM minerals when sometimes the PGM grain sizes are between 1 and 2 microns? Would it be possible to reject chromite from the final concentrate when this mineral represents at least 60% of the ore?

The answers were soon available. Yes, one could concentrate the bulk of the values by a milling and flotation process, but generally the PGM recoveries to the product were lower than that from a Merensky ore. In addition, the response to the upgrading was variable, with predicted PGM recoveries varying from 70 to 85%. The variability was directly related to the mode of occurrence of the PGM values, with a higher proportion of values being present locked in silicate phases in highly altered poor recovery ores.

The chromite grade of the concentrate was more of a problem to define, and after extensive test work a level of between 2 and 3% Cr_2O_3 was eventually decided upon as attempts to reduce it further resulted in PGM losses. Techniques to smelt this material directly were found but most of the producers chose to adapt current practice and to blend the concentrate with the Merensky concentrate to avoid the necessity of making major changes to their operations.

What have been the technical advances that have made the processing of the UG-2 even more attractive in recent years?

Starting from the front end, there has been, and still is, a major thrust to reduce mining costs, make mining more safe, and to reduce the amount of manual labour required to extract the reef. This has in general meant that mechanized mining is being introduced in the new operations. With this comes wide reef development of sometimes 1.8 m to get the machines in. This results in the mining of a significant amount of barren waste rock. Sometimes, though, one may be able to take other reefs such as the leader reef and chromite stringers that contain value, depending on the proximity of these reefs to the main reef. So the miner's job is perhaps easier and safer by adopting these methods. The problem, though is passed to the concentrator that needs to get the same amount of PGM ounces out but needs to treat up to 40% more ore without enhancing the unit processing costs per ounce of PGM produced. This is not an easy problem but there are methods by which this can be achieved.

The first method that was adopted by Kroondal Platinum mines was to scalp out some of the large tabular pyroxenitic rocks at source and to leave them in the stopes. The rest of the ore is brought to surface, where it is crushed, and the coarse fraction (+2–30 mm) passed through a dense media separation plant designed to separate the dense high value chromititic rocks from the siliceous waste. This process works well in rejecting a significant proportion of the waste but it is limited as material below a certain size (-2 mm) cannot be separated effectively in a single stage process by

* *Mintek, Johannesburg*

this technology. It is, however, a low capital and moderate operating cost option that they have used very effectively to bring the leader and main reefs into the concentrator at a reasonable head grade. This has contributed to making them one of the lowest cost producers.

This type of technology is limited, however, to operations where the PGM content is exclusively associated with the chromitite. This is not always the case as there are operations where significant mineralization is present in the footwall pegmatoid. There are also cases where contamination with Merensky ore occurs through cross tramming of ores. The decision as to the viability of installing a DMS plant in an operation then becomes more complex as one needs to evaluate the potential benefits of wide reef mining against the losses in PGM values.

Another consequence of installing a DMS separation plant that is more subtle is that there is a relationship between the chromite content of the feed to a concentrator and the chromite content of the final product. This is because some operations specifically produce a low-grade product of around 150 g/t 3 PGM+au as a way of improving the PGM recovery, and as a way of meeting the smelter contract specifications. Now that the DMS plant is removing a significant proportion of the siliceous gangue, the concentrate grades will go higher but so will the chromite content. The solution is to make sure that the smelter contract is written in a way that suits your specific operation.

Optical sorting technology was proposed for use by the gold industry 20 years ago but it failed to live up to expectations at the time as the hardware and software available then was not capable of handling high throughputs and rapid variations in ore types. Machines that have been working on relatively simple industrial mineral and refuse sorting applications (glass, metal and plastic) are now being applied to UG-2 reef waste rock sorting with encouraging results. Advances in computer and camera technology has enabled these machines to be designed as high throughput machines that can sort ore from waste on the basis of pre-set rules.

Thus much more complex separations such as the isolation of mixed ore/waste from pure waste can be achieved. In addition, these machines can work on coarse 250 mm rocks, thus allowing for maximum waste rejection before fines creation in a crusher. It is predicted that these types of machines will become the industry standard located at the shaft head or underground to minimize transportation and processing of waste rock. Although capital intensive, the very low operating costs of these types of machines should bring plant operating costs down significantly in the future for those operations that mine significant waste.

It was recognized in the early days that the milling and classification circuits for UG-2 ores would have to be unique. The large chromite content of the ore, the fact that the density of this mineral is significantly higher than the silicate minerals, the observation that the bulk of the PGM values sit at the major mineral grain boundaries, that there was a component of the PGM value finely locked in silicate minerals, and that the PGM minerals were fine at between 2 and 5 microns (as compared to the base metal sulphides with sizes from 20 to 40 microns), all pointed to the design of the concentration circuit being a mill-float-mill-float circuit with screens as classifiers rather than cyclones.

Some of the early plants did not use this approach and tried to do the milling to a fine 80%–75 microns in a single stage but these are now being converted to MF-2 circuits with noticeable benefits. Others attempted to use pre-milling classification on the secondary mill to save on milling energy but in reality they were running chromite milling operations, and the coarse silicates, in which some of the last of the PGM values reside, were bypassing these mills. This is being addressed by using open circuit secondary milling or by using two-stage cyclones to split the mill feed into two secondary mills, with one treating the chromite rich underflow and the other the silicate rich overflow.

Screening as the means of classification within the milling circuits of a UG-2 concentrator would be the ultimate device to use as the separation is done solely on the basis of particle size and not density. Basic screening technology at fine 75 to 106 microns size ranges is still limited though by the excessive screen area required to get efficient separation at the plant feed tonnages. Innovations such as the Pansep screen attempted to address this problem by using rotating screen trays, which were fed from both the top and bottom, to increase the feed rate to the screens without needing fields of screen capacity. Although these screens did generate much excitement in the industry, problems with mechanical reliability indicated that they could not be put in key positions where failure was catastrophic to plant operation. They may find application, though, for use with a three-product cyclone where they would treat the middlings stream and scavenge the coarse silicates out of this relatively low volume stream.

The PGM values in a UG-2 ore can be classified on the basis of flotation rate into fast, slow, and non-floating components. With the knowledge of these ratios, one can design the flotation circuit accordingly to ensure that adequate flotation residence time is built into the key sections of the plant. At the same time, it is documented that if an ore has a high proportion of slow floating PGM value, it is important to ensure that sufficient power is installed in key sections of the plant to recover these values into the flotation concentrates. Some of these principles were not applied to UG-2 ore concentrator design in the early days and rather, based on experience from copper and nickel ores, it was thought best to build up a circulating load in the cleaner circuits as a way of pushing up the product grade. Some of the original plants thus suffered from poor cleaner circuit design, with the result that some of the plants did not achieve the predicted performances. These aspects have largely been addressed in current flotation plant designs that are increasingly run in open circuit mode between the rougher and cleaner, with circulating load build up being between the re-cleaner and cleaner.

A significant effort is being made by the industry through an Amira joint funded P9 project to understand the factors that control the design and scale up of a PGM milling and flotation circuit. Significant progress has been made in developing measuring procedures by which to evaluate these issues, but the system is very complex and progress is slow.

In designing a flotation circuit, it is important to understand the mineralogical features that dictate the potential product grades and PGM recoveries that are achievable from a specific ore. For example there are ores that are high in base metal content, where the highest grade achievable may only be 150 g/t 3 PGM+au, whereas for other ore types this can be increased to over 300 g/t without any detrimental effect on the PGM recovery. Similarly, there are ores where the PGM liberation characteristics dictate that one should not aim for a high grade of concentrate as a significant proportion of the PGMs would be lost to tails under these conditions.

These difficult ores have provided scope, though, for the installation of new technology designed to liberate the very fine PGM values from the siliceous gangue, thus boosting product grade and PGM recoveries. At present a horizontal bead mill, called the Isamill, designed from test work on poorly liberated base metal concentrates, is the furthest down the development curve, and large megawatt mills are going to be installed to treat plant cleaner tails streams and possibly in the future even plant tails steams. Other technologies that are under evaluation are the Stirred Media Detritor and the Pelorex mill.

An area of active technology development is in the field of the reagents/equipment used by the concentrators. Although the separation process is relatively simple, in that it is a bulk sulphide mineral flotation process, scope exists to improve on the PGM recovery in both the coarse and ultrafine particle size range. New high energy flotation cells are available for use in specific positions within flotation circuits, as are new reagents with more specific features. Much research is also being undertaken to find more specific gangue depressants for use in enhancing the concentrate grade without loosing PGM recovery. Thus, a depressant research facility, funded by most of the PGM producers, is working at the University of Cape Town to characterize these polymers and understand how they work so that improvements can be made.

Another area of active interest to some producers is, methods by which to improve the PGM recovery from near surface UG-2 ore. The PGM recoveries from these ores, which come from depths of between 0 and 40 m, usually vary from 30 to 70%. Although not significant in terms of the overall reserve of a deposit, they are important in mine planning as these ores can often be used to build up cash reserves whilst access to the deeper ore is being developed.

Plant instabilities due to variations in feed rates, aeration rates, reagent dosage levels, froth heights, etc. were a major hurdle preventing real progress from being made on improving overall plant performances. Traditionally running a concentrator was considered an art honed by years of practice. Operators were able to make adjustments as they saw fit and often this resulted in, for instance, the night shift getting significantly different results from the day shift. At the same, time when problems occurred on the plant, it could take many hours to get the plant back to steady state as all adjustments were manual.

The installation of plant control strategies, such as the level control platform offered through Floatstar and mill control through Millstar, have gone a long way to improving plant stability, to the extent that metallurgists can now focus on understanding the metallurgical parameters that influence plant performance. This field is an active area with research taking place on many different fronts, such as the use of froth imaging to predict the concentrate removal rate and thus the mass pull, and the use of sophisticated enrichment models linked to plant operating set points to drive plant operation to the optimum point on the grade recovery curve.

All the above process improvements are built around the assumption that the amount of chromite in concentrate that a smelter can tolerate is fixed, and to some extent that is true for the larger producers, who have large investments in fixed infrastructure in smelters, base metal refineries, etc. Process improvements at the smelting stage, though, have already allowed these producers to tolerate higher chromite levels in the smelter feed. This has been done by ensuring that the furnaces can be run at higher temperatures, by creating a reducing environment in the furnace, and by not recycling converter slag.

There are new technologies, undergoing active evaluation at present, that may find niche applications in the future. The Conroast Process does not follow the traditional matte smelting route but rather goes for a two-stage route-: a dead roast with complete sulphur capture and a reduction smelt with an iron alloy collection. The claim for this process is that it is more environmentally friendly and it can tolerate any level of chromite. The disadvantages are that some minor adjustments to the base metal refinery may be required.

Platinum group minerals, particularly those of platinum, are difficult to leach and require very aggressive conditions to leach them directly. Direct leaching of relatively low-grade concentrate has thus not competed with the smelting option. Pre-treatment of some of these concentrates, as has recently been shown, can result in the PGM values being leachable under less severe conditions. This opens up the option to a small producer to process concentrate to a higher value product that will be acceptable directly into a PGM refinery and thus eliminate the large penalties paid to the smelter. The disadvantages are that it is unlikely that the PGM recoveries will be as high as smelting, there may be environmental costs associated with going the hydrometallurgical route, and it is largely undemonstrated technology and thus carries more risk.

In summary, the technology to extract the value out of the UG-2 ore effectively does exist and it does work. There is, however, still room for process improvements to get the PGM recoveries and the concentrate grades higher. Significant effort has been, and is still being invested by all the producers in research and development in this area.

For small producers the option of going the smelting route on their own does not exist at present and they will have to tolerate the penalties placed on the concentrate they produce. As the chromite level and the mass of concentrate produced are key to these penalties, it is important that emphasis is placed on ensuring that the concentrator puts in the technology to ensure that the best performance is achieved. With the high rates of return being achieved with most UG-2 projects using the concept of only doing the mining and concentration, it is unlikely that they will need to consider the higher risk options at this time.

The focus of research and development in PGM processing over the next few years will probably be in:

- Preconcentration, either optical sorting, DMS, or a combination
- Effective screening/classification of -75+106 micron material
- The evaluation of hydrometallurgical routes. ◆