Meeting the reduced availability and rising costs of electrical power: Anglo Platinum ventilation and cooling strategies

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Synopsis

The reality of rising electrical power costs and the haunting prospect of decreasing electrical power availability are a threat to the growth of new projects and expansion programmes that could negatively affect the sustainability of mining operations. These threats require the adoption of effective power saving measures aimed at three principal objectives: the elimination of wastage, the reduction of power usage particularly during peak demand periods and, more importantly, improving the efficiency of high power-demand processes. It is reasonable to assume that the greatest impact will be achieved by concentrating on those processes that are large electrical power consumers.

For Anglo Platinum operations, mine ventilation and, currently to a lesser extent, mine cooling are two continuous processes that fall in this category. It is estimated that these may consume fifteen to thirty-five per cent of the power delivered to the shaft head—depending on the shaft's design.

Mine ventilation systems suffer from inherent, historical inefficiencies that lead to excessive power consumption. Air cooling systems are designed to be energy-wise in terms of modulating refrigeration plant operation to meet the underground requirements while maximizing use of 'free' cooling from surface conditions. Currently about ninety-five per cent of the refrigeration capacity used in Anglo Platinum mines is dedicated to surface bulk air coolers. The net thermal efficiency of these systems is compromised as mines expand in depth and on strike. Looking to the future, this practice will be complemented by more energy demanding underground cooling tactics requiring considerably higher electrical power consumption per unit ton produced.

To counter this increase in power consumption, more energy-efficient systems and advantageous transient strategies such as thermal storage and the use of ice—on surface and possibly even underground—are being considered.

This paper describes work currently undertaken and planned by Anglo Platinum operations to reduce power consumption by main fans during off-shift periods, the associated efforts currently introduced to reduce underground air leakage, the possibility of introducing more efficient auxiliary ventilation systems, the feasibility of thermal storage, and a brief look at energy recovery system as a means of countering the anticipated power demand associated with underground cooling.

Keywords

Mine ventilation, mine air cooling, energy efficiency, chilled service water, energy recovery, air wastage, fan selection.

Introduction

Mine ventilation and cooling systems are inherently energy intensive due to the high volumes of air and water as well as the quantity of heat energy transferred as part of the continuous production cycle. Estimates for platinum mining operations are that, depending on the depth and nature of operations, the proportion of electrical power used for ventilation and air cooling can represent fifteen to thirty-five per cent of the total quantity delivered to the shaft head. The cost of ventilating mines per ton produced varies between R9.60 and R21.00 per ton depending on the tonnage produced (the fans operate irrespective of the production levels) and on levies posed by the electricity supplier due to poor power factor or exceptional high demand beyond the contracted limits.

The supply of electrical power to South African users will become significantly more expensive. The 'Megaflex' tariff system currently applied to all Anglo Platinum operations is based on a sliding scale that essentially differentiates between different diurnal demand periods (namely 'peak', 'standard' and 'off-peak') and seasonal demand levels, namely 'high demand' (June to August) and 'low demand' (September to May). In very rough terms, ventilation systems operate continuously while surface bulk air cooling systems are required only when the surface air temperatures exceed the required design parameters—mostly during daytime in the warm season.

Figure 1 indicates graphically the difference in energy cost for 2011 compared to 2008 during the low demand periods. The increase for peak demand times is considerable and, in the case of continuously operating fans and coolers, will result in significant cost escalation per unit ton produced.

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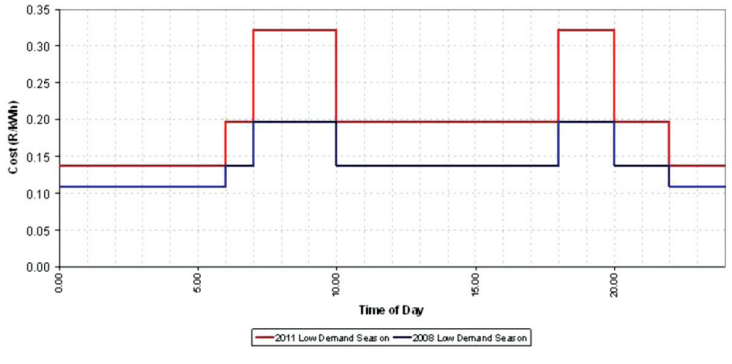


Figure 1—Tariff increase comparison for low demand season (September to May)

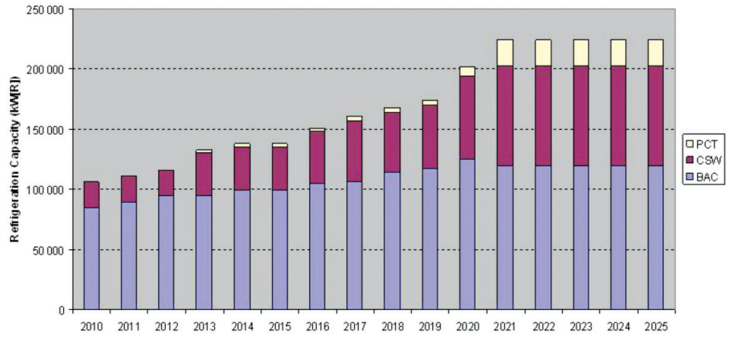


Figure 2—Total refrigeration profile 2010 to 2025

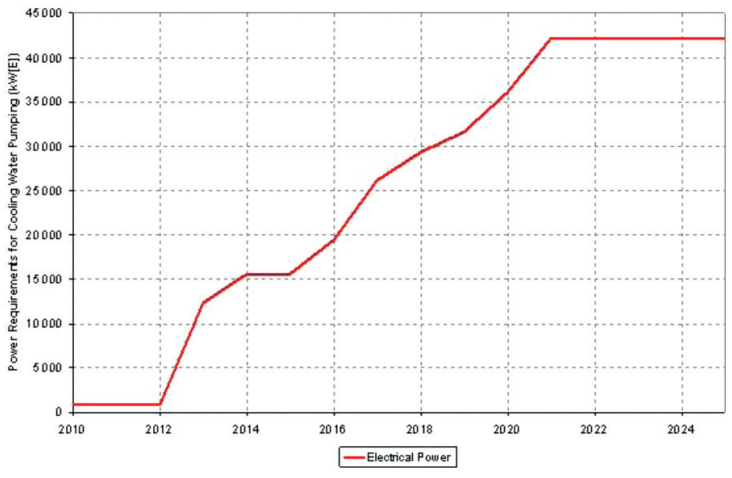


Figure 3—Electrical power demand for chilled service water pumping (2010 to 2025)

The rationale behind the new tariff structure is evident in penalizing consumption during peak demand periods. The figure shows a considerable increase in the cost of energy during these periods. In addition, penalties will be applied it the maximum demand allocation is exceeded at any time but particularly during these periods.

Another challenge facing the expansion of Anglo Platinum's operations at depth is the greater and changed profile of air cooling systems, as shown in Figure 2.

The planned expansion of the cooling and refrigeration indicates an increase in the nominal mechanical refrigeration power required, indicated by the surface bulk air cooling (BAC) and chilled service water (CSW) components as well as the relative proportion among all three components (the third being the water precooling element (PCT) which makes use of the atmosphere's free cooling capacity). The total nominal refrigeration capacity is set to in crease from 97 300 kW(R) in 2010 to 224 400 kW(R) in 2025.

The increase in the CSW component will have the greatest impact on the anticipated power consumption. Figure 3 shows the anticipated electrical power demand for pumping the chilled service water sent underground over the same

period. Unlike surface bulk air cooling, operation of this system will be required continuously—therefore negating any possibility of trimming operations in the off-shift period. At the maximum chilled service water pumping requirement of 42 200 kW(E) occurring from 2021 onwards and applying an average cost of 42.5c/kWh (roughly based on current tariffs) this will equate to an additional cost of R157.1M per annum. This translates to an additional expenditure of R14 per ton mined per month.

It is also estimated that the power required to run the additional refrigeration plants during the same period (say 127 100 kW(R)) will be in the region of 36 300 kW(E) which translates into an additional R12 per ton mined per month.

It is alarming to note that this additional power demand (and that for the additional overall refrigeration requirements) represented here is essentially for 'ore replacement' projects and that therefore no additional revenue will be generated from this increased expenditure. In other words, in 2025 to mine the same ton of ore will require an additional 700 kW of electrical power.

Strategy

Any worthwhile strategy must take into account the current situation within Anglo Platinum. Underground operations vary from very young and shallow mines developed from decline clusters to mature, deep operations off vertical shaft and sub-cluster systems where extraction of Merensky Reef at depths is complemented by UG2 stoping on the upper levels and mostly from the old Merensky infrastructure. In all cases energy demand is on the increase and, for air cooling in particular, such increases will be steep and will manifest themselves in the next five to ten years as exemplified in Figures 2 and 3.

The facts presented above require the implementation of suitable strategies aimed at reducing the costs and ventilating and cooling operations. Although the additional cost per ton mined must be limited by the elimination of wastage, the introduction of energy efficient systems and the recovery of some of the energy required for pumping, there is a risk that the scarce availability of electrical power may hamper the introduction of these systems, therefore affecting the safety of mining operations. This risk may also result in production delays and would therefore have an extensive impact on the profitability of operations. This shortcoming may be mitigated by providing alternative sources of power that are not reliant on Eskom's supply.

Air wastage

Typically in all Anglo Platinum's underground mines, air is circulated continuously by means of exhaust systems where the flow of fresh air is induced through the main intake airways, through the workings and back to surface along return airways and shafts by the action of the main surface fans. A system of doors, seals and brattices is positioned to convey the air streams in the most direct manner to the intended points of use. As sections of mines are worked out and abandoned, the ventilation system needs to be upgraded to prevent leakage through these worked-out areas and dedicate the air to the new working places. A limited amount of leakage through seals and doors is tolerated as part of the system's performance but any air quantity over and above this accepted level is deemed to be air wastage.

In addition, air wastage leads to poor environmental conditions. Equally importantly, the main fans will handle basically the quantity of air equivalent to the system resistance leading to an effective power loss. Typically, the air wastage in deep narrow reef mines that extend for kilometres on strike can be as high as 50% of the total air quantity handled. Although this was 'tolerated' in the past, the cost of energy and scarcity of electrical power demand a review of such practices.

It is estimated that, the average cost of wasting 1 kg/s of fresh air is R17 000 annually for Anglo Platinum operations. In the case where air is bulk cooled, this cost escalates to R43 200 per annum. This is possibly an underestimate of the true figure since bulk air cooling is performed at the deeper mines where the static pressure of the main fans is higher than the average figure used above.

One of the most effective and immediately applicable strategies is the reduction of air wastage in the primary and secondary air circuits is the construction of airtight seals and effective airlocks. These air controls are not completely airtight and system designs make allowance for adequate and acceptable leakage levels—particularly for extensive systems extending over a multitude of working levels where it is not uncommon to design for an overall leakage allowance of 35 to 40% of the total.

Anglo Platinum has undertaken a programme for the reduction of primary and secondary leakage since January 2009. The results obtained so far are shown in Figure 4 where the air power supplied per unit mass of air in

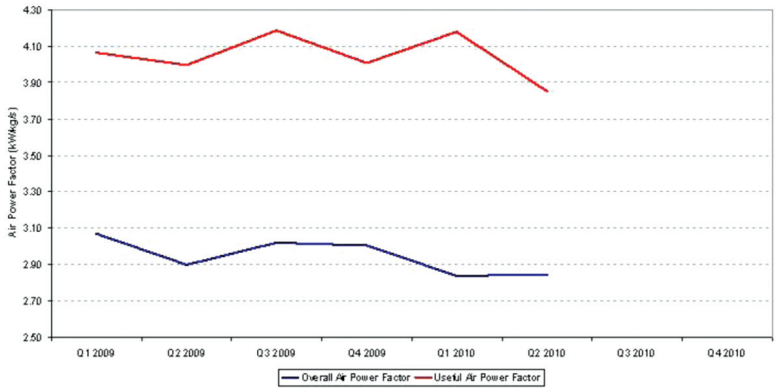


Figure 4—Air wastage monitoring at Anglo Platinum

circulation is represented. The red line represents the 'useful' component or the energy per unit mass of air circulated. The effect of air leakage is indicated by the blue line which indicates the energy per unit mass handled by the main fans.

Main fan design, selection, and operation

A further consideration for optimizing efficiency and reducing the energy consumption of air circuits is improving the selection of main surface fans. Historically main fan selection has been based on the maximum duty close to the end of the life of the project. This implies that the fans so selected would be operating inefficiently for most of their operational life and that the system would be inherently energy 'inflexible' to accommodate changes to the original design. The options at one's disposal to mitigate this are:

- The use of variable speed drives
- The use of twin speed motors
- The replacement of fan impellers
- The use of variable pitch impellers (axial flow fans)
- Active use of guide vanes.

Currently the total nameplate installed power of surface fans is over 46 MW energy consumed by main fans contributes about 25% of the annual expenditure for power. In all cases the main fan selection was based on maximum efficiency at the maximum duty point. All of these fans have single speed motors while the vast majority has centrifugal impeller configuration.

In South Africa variable speed drives are expensive and usually difficult to apply to motors greater than 1 MW. Here, the technology is not mature and not as widespread. Given the nature of air system resistance variations over the life of the mine, such a solution may not be advantageous in terms of total ownership costs.

Twin speed fan motors are tried and tested for deep level mining applications and have been proven to be effective in this respect despite the higher capital cost. This alternative is a feasible compromise to the selection of variable speed drives.

As absurd as it might seem, the replacement of main fan impellers in existing units may be feasible considering the extended life of some of the older shafts. This could well be combined with the refurbishment of other fan major components that would usually deteriorate with time, e.g. fan metal scrolls and evasee`s. The key is being able to ascertain the duty required for the rest of the life of the project and being able to match this requirement to peak efficiency of the new impeller.

Axial flow fans with variable pitch impellers can operate at peak efficiencies over a range of operating conditions but they have limited application for deep operations (low static pressure capabilities) and are better suited for shallow operations

The active use of guide vanes' settings may also assist in reducing the energy required to operate a system below its full capacity. Figure 5 shows how the application of this strategy can best be employed to operate at the duty point (75 m^3/s at 4700 Pa for a shaft power input of 400 kW, η = 88.1%). However, it assumes an imaginary reduced system resistance as might be the case during the early years of the life of the system, as represented by operating point 'A'. For the same vane setting, a lot more air than required is circulated (103 m^3/s) at a very high shaft power requirement (operating point 'B', 390 kW) and low efficiency, (η = 56.8%). For the same air quantity, the main fan guide vane may be set at -40° for a shaft power requirement of 230 kW and efficiency of 29.3%. This means that although the efficiency remains very low, the power consumption is limited and air wastage is reduced.

Since the beginning of 2009, the strategy at Anglo Platinum has been to introduce the monitoring of air wastage together with a continuous air leak reduction programme aimed at reducing significantly energy usage levels. The installation of electronic guide vanes controls is currently being completed foe reducing power consumption during the evening peak periods. These will assist in due time in the reduction of power consumption following the air wastage reduction programme that will result in reduced air quantities. The guide vane system will be used to trim the total air quantity handled thereby reducing overall energy consumption.

Auxiliary fans

Auxiliary fans are axial flow units that vary in motor size from 0.75 kW and 75 kW. In Anglo Platinum mines over two thousand auxiliary fans are operational, mostly around the clock, to ventilate development ends, dead-ends or to ensure minimum ventilation rates in underground workshops, sub-stations and battery charging bays. The total nameplate capacity in use exceeds 22 MW and it is estimated that the

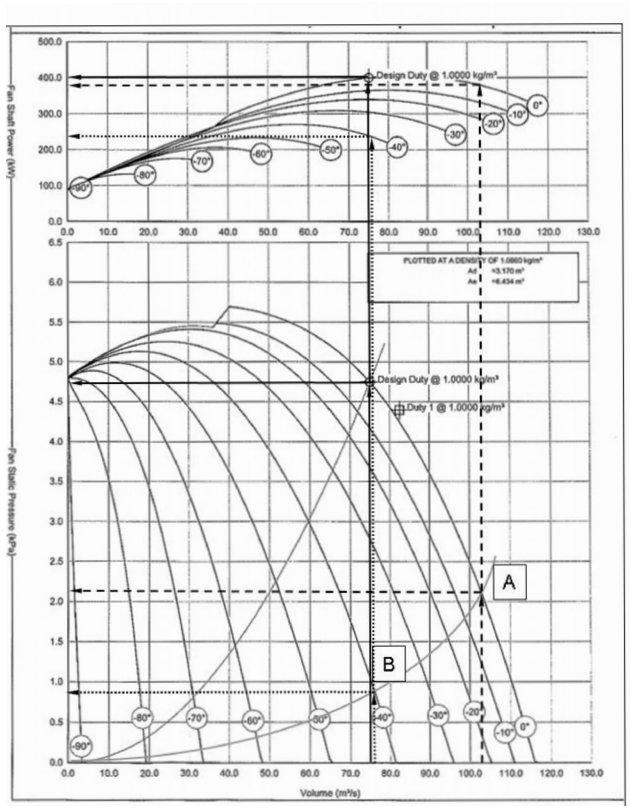


Figure 5—Typical main fan curve showing differing operational point characteristics

annual energy consumption exceeds 190 GWh. It is anticipated that a saving 10% of such a demand can be achieved and that would translate to a saving of over R8 M annually across the Group.

Anglo Platinum is investigating the feasibility of using aerodynamically improved fan impeller design to achieve the desired reduced shaft power requirements. This is being done in conjunction with a reassessment of the air duct geometry that would be used for different development requirements while improving on the levels of interference between the ducting and mining operations (duct design optimization).

Air cooling

As discussed in the introduction and as shown in Figure 2 above, air cooling demand will increase to meet increasing production at depth. More importantly, due to the nature of deeper projects, the emphasis on underground air cooling will increase. At this stage Anglo Platinum's air cooling strategy favours the circulation of chilled service and cooling water generated on surface to strategic positions underground to ensure that the design environmental conditions are achieved. This implies that the water flow down shafts and declines and pumping associated with this will increase by orders of magnitude as shown in Figure 3. This increase in energy demand will have to be managed to contain costs and to keep in line with the availability of electrical power. The impact on the overall cost must be cushioned by the introduction of energy-mindful strategies, equipment and systems.

Typically air cooling systems may be subdivided into:

- Primary or bulk air cooling systems that are located on surface and handle large proportions of the air conveyed to the underground workings. Chilled water for primary air cooler is generated in surface refrigeration plants. These are introduced as the mining depth exceeds 600 m.
- Secondary air cooling systems that are located at large air distribution nodes underground and are used to condition air destined typically for defined ventilation districts or parts of them. Chilled water for these systems is generated in surface or underground refrigeration plants or a combination of both. Typically these are required below 900 m.
- Tertiary air coolers are located close to advancing faces and are used to reduce air temperatures and to maximize air cooling plant positional efficiency. Chilled water for these systems is generated in surface or underground refrigeration plants or a combination of both. These will be introduced below 1 200 m or as required by the formation of 'hot-spots'.
- The use of chilled service water may be beneficial in reducing air temperatures whenever this is sprayed in the environment—such as is the case during drilling operations.

Thermal storage

Primary cooling together with precooling of service water being returned from underground are subject to surface weather conditions. This aspect allows maximum efficiency of plant operation since, when cooler atmospheric conditions prevail, plant operation is curtailed and even stopped. This condition is also favours the introduction of thermal storage where cold water (or ice) is produced during the cooler hours of the night for use during the day shift. The advantage of thermal storage is twofold as this is primarily a load-clipping and load-shifting strategy that can be used to reduce costs. In addition, the intense use of refrigeration plants at night results in a higher coefficient of performance, therefore requiring less input power to generate the same cooling effect than if this were to be done during the warmer diurnal periods.

Thermal storage is a cost-saving tactic that might require plant oversizing, depending on the application and use cycles, and the extensive use of storage dams for either chilled water or ice. Currently, Anglo Platinum is completing the first bulk air cooler with ice thermal storage for the Khuseleka ore replacement project. This 6.5 MW nominal plant will produce ice stored at night that will be melted in a 150 GJ dam during the day for a net chilled water flow of 350 kg/s.

The bulk air cooler plant being constructed for Thembelani No. 2 Shaft is being considered for the inclusion of an ice thermal plant that will enhance the overall power consumption.

As the majority of existing bulk air cooling installations in Anglo Platinum has been operational for some years, the retrofitting of such systems is complex and costly. However, Anglo Platinum is considering the use of flexible membranes in existing water storage dams in order to extend the advantages of thermal storage to these operations as well.

Energy recovery

The biggest opportunity for reducing the power requirements of large water distribution circuits is the recovery of the energy necessary to pump the used service and discard chilled water back to surface. In its simplest form, this could entail the use of closed-loop high pressure systems. Although the only energy input is that required to overcome the piping frictional resistance to flow, such systems require large pipe wall thickness, well-designed supports and anchoring systems (inclusive of thermal expansion compensators), high technology safety devices, and very clean water.

Where open-loop systems are used, energy recovery devices such as Pelton turbines and hydro-transformers are considered. These have been used successfully in deep level gold mines and will provide limited pumping energy recovery as will be demonstrated below. The energy recovery is limited, however, and a power penalty will be incurred.

Energy recovery may also be attained by the use of hydro-transformers and three chamber pipe feeder systems (3CPFS). These are inherently more efficient than turbines and, whereas the introduction of hydro-transformers in gold mines has not been too successful, the use of 3CPFSs has been effective particularly where water quality in terms of suspended solids is an issue. This type of pumping method requires good maintenance and possibly a conventional back-up system with significant underground water storage—as the principle is the displacement of water underground with water sent from surface.

Ice plants

Ice plants have also been used successfully to reduce pumping loads in deep level gold mining operations. The advantage is the reduction of pumping energy from taking advantage of the latent heat of fusion of the ice's solid fraction. The high pumping heads in gold mines amortize the high capital and operational costs of such systems. Given the shallower depths of platinum mines, it is doubtful if a similar advantage will be derived. However, the use of ice as a cooling medium will be considered for future projects where mining depths exceed 2 000 m.

Discussion

Table I compares the power consumption of a cooling system for a model platinum mine producing 250 ktpm, extending to a depth of 2 000 m below surface and requiring 55 300 kW of surface bulk air cooling and 47 800 kW of underground cooling. The table summarizes the power requirements for the underground cooling (i.e. the surface bulk air cooling power requirements are excluded). The base case shows the service water pumping (SW) and cooling water pumping (CW) requirements. The base case is compared to three alternatives, namely one using energy recovery devices (a Pelton wheel turbine and a second using a 3 pipe chamber feeder system), while the third system will provide an equivalent air cooling power by generating ice.

The decision on which solution is most suitable is dependent on a number of factors and varies for different circumstances. In all cases, optimization must be tailor-made for the specific shaft configuration and must consider real costs in terms of capital, operational and maintenance components compared on an equitable basis.

In the above analysis an aspect that was not considered is that of using refrigeration plants located underground. Currently this alternative is not being considered at Anglo Platinum, but in terms of future projects or deepening of existing operations such an option may not be ignored. Important aspects of such solution include, of course, cost and completion timing associated with large underground excavations, the availability of sufficient return air for heat rejection, and a favourable return airway and exhaust shaft configuration and location. In addition, underground refrigeration limits the use of other ventilation strategies such as controlled recirculation of air. In summary, one must take good cognizance of all these alternatives and permutations to arrive at an optimized and balanced solution.

Table I

Comparison in nominal power consumption (kW/ktpm) for different energy and cooling configurations

	Base case	Turbine	3PCFS	Ice plant
Compressors	63.7	63.7	63.7	76.5
Ancilliaries	10.7	10.7	10.7	10.7
SW pumping	9.0	9.0	9.0	9.0
CW Pumping	30.2	30.2	30.2	12.6
Energy recovery		-23.5	-29.4	
Total	113.7	90.1	84.3	108.3

Environmental considerations

The protection of the environment and reduction in the 'energy footprint' in the future are synergistic in nature. The reduction of the overall carbon footprint is seen as part of good corporate policy and in line with undertakings by the South African Government in Montreal and at the 2009 Conference of the Parties to the Kyoto protocol in Copenhagen. This is of course best harnessed by the adoption of clean development mechanisms that provide incentives for the use of renewable resources

Whereas this reality is accepted in terms of the alignment with the Global energy market, another, more insidious consideration could affect the future of expansion projects in the next five to ten years. Anglo Platinum has carried out a desk-top assessment of several renewable energy sources for use in ventilation and cooling systems. The primary focus was the availability of energy for the primary refrigeration cycle. However, some opportunities for the generation of power on a wider scale became apparent during these investigations and have been listed below.

New generation refrigerants

The use of refrigerants to replace chlorofluorocarbons (CFCs such as R11 and R12) and hydrochlorfluorocarbons (HCFCs) is a requirement for compliance with the Montreal Protocol for the reduction and elimination of the production and use of chemicals with high ozone depletion potential (ODP). This brought about the introduction of new hydrofluorocarbon (or HFC) refrigerants (namely R134a), which were used to replace the other refrigerants, not without technical challenges and cost. The adoption of the Kyoto Protocol now requires that article 5 countries, which includes South Africa, stop the consumption of HFCs by 2032 due to the high global warming potential (GWP) of these substances.

A new (fourth) refrigerant generation is now being developed to replace mainly R134a and R123, which are the most popular CFC and HCFC replacements. However, in terms of reducing the carbon footprint, refrigerant users are faced with a dilemma that has to be addressed:

- The reduction on HFC use is looming in the next twenty years
- HFCs have a proven (high) GWP
- Refrigeration systems operate on hermetically sealed closed cycles and the release of these substances to the atmosphere is minimal and mostly as the result of (infrequent) accidents
- So far, new generation refrigerants are less efficient (and more complex to use and substitute as these are blends of chemicals) and therefore require a greater energy input. In the case of fossil fuel electricity generation, as is the case in South Africa, this results in the generation of considerably greater volumes of carbon dioxide into the atmosphere than would have been the case if the full refrigerant charge were to be released.

Therefore the use of new generation refrigerants in South Africa as a means of lowering the overall GWP is open to discussion.

This conundrum affects the selection of possible alternatives for the immediate future of Anglo Platinum's refrigeration capacity expansion programme. Strangely, this situation further justifies the use of ammonia as a surface plant refrigerant. The use of this 'dangerous' refrigerant is the subject of numerous risk assessments and increases the overall cost of plants due to the protective measures that have to be adopted. This situation makes this choice obvious from a technical perspective in that ammonia has a relatively high coefficient of performance (lowering power requirements) and has an ODP of zero and an acceptably low GWP.

New generation refrigerants would be considered for underground applications. Given the issues described above, the adoption of such a strategy is disadvantaged when compared to a total surface refrigeration strategy—with all of its higher energy requirements.

Dry cooling

Considering the looming shortage of water in the North West and Limpopo provinces, the alternative of using dry cooling towers was investigated. The refrigeration plant being constructed for the Khuseleka Ore Replacement Project was used as the base of this desktop study and the possibility of using dry cooling towers as opposed to the evaporative units of the current design was analysed.

The plant, assumed to operate in its conventional R134a water chilling configuration (i.e. ignoring the ice making cycle), would absorb nominally 1 180 kW of compressor and 75 kW of fan power to the cooling tower. At the design atmospheric condition the annual evaporation rate would be 1 135 Mℓ. In comparison, a dry cooling tower configuration would require 1 625 kW of compressor power and 250 kW of fan power for a much lower consumption of water: 255 Mℓ annually.

The figures are comparatively aligned—if not absolutely correct. However, the comparison indicates that despite a considerable saving in water released to the atmosphere, an additional power cost of approximately R790 000 annually would be incurred (2008 tariff levels). More importantly for the environment, the higher power consumption translates to an additional 2 000 t of CO_2 emitted into the atmosphere every year. In addressing this problem, the use of waste water form the Rustenburg Municipality is inevitable.

Geothermal and waste heat sources

Geothermal heat has been used successfully in the northern hemisphere for a number of decades. The technology is mature and works well where large quantities of hot water are present. Typically water at 900ℓ/s arriving on surface at a temperature of 150°C and a pressure of at least 400 kPa gauge could be used to generate some 80 MW of electrical power and to drive a thermal load of 150 MW. To induce the flow of hot water, pumping of water from the surface storage facility is required in a geologically favourable environment using oil drilling technology to access this area.

Refrigerant absorption cycles are well suited for using low-grade heat sources and could conceivably utilize waste heat from other processes or geothermal sources. In addition, low grade waste steam may be used in nozzles to generate ice efficiently.

The only source of waste heat that would be considered is at the refineries in Rustenburg. Given the position of these plants in relation to the various (deeper) shafts in the area, the investigation indicated that these waste heat sources would be best utilized for power generation at the respective sites or at a centralized position.

Having considered the geological structures on Anglo Platinum properties and the budgeted cost of drilling to large depths (due to the 'low' rock temperature gradient), this option was not deemed to be feasible.

Solar power

The use of solar power in operating refrigeration plants was also considered in a conceptual study conducted in 2009. The location of Anglo Platinum mines in the North West and Limpopo provinces is highly advantageous since the incoming solar radiation (or 'insolation') levels are the highest in sub-Saharan Africa. In the Rustenburg and Thabazimbi areas, the 'worst case' solar power values for optimum solar collector tilt are in excess of 6.5 kWh/m²/day.

Based on this and with the assistance of consultants, Anglo Platinum carried out an analysis for the application of solar power for a 43 MW(R) refrigeration plant planned near Thabazimbi. As a first opportunity the analysis considered a direct comparison between the total life cost of a solar-powered refrigeration plant and the conventional base-case. As this first comparison was completed, it became apparent that there was an opportunity to extend the project and size of the solar power plant to generate electrical power that could supplement the Eskom supply for the new shaft, particularly in winter when the refrigeration plant, dedicated to a surface bulk air cooler, would be off line. Once more all cost savings were grouped in terms of carbon credits that would be received for both solar powered alternatives and of the power savings based on the 2009 tariff base escalated and compounded over the life of the project.

The results are shown graphically in Figure 6. The most significant feature of the analysis is the beneficial overall returns. These are, however, realized at a high initial capital outlays that must be funded externally possibly by Eskom and clean development mechanisms from European Union countries.

For the first alternative, the cost of the solar-power plant that would be dedicated to the refrigeration plant is 10% higher than the base case. However, the return over the life of the project would result in a net 19% saving. For the second alternative, where the power generation portion is increased to supplement the Eskom supply, the capital and operational costs are 69% higher than the base case but the returns in terms of carbon credits and savings in power costs reduce the total ownership cost of the project to 31% of the base case.

Another advantage in adopting the latter option is that, on completion of the solar power plant, the project may start irrespective of power availability from Eskom—therefore avoiding any delays in the project that might arise from a deferred starting date,

Currently the project has been deferred in terms of an executive intervention introduced in 2009. However, this evaluation will be considered as a possible opportunity when the project planning is resumed in earnest.

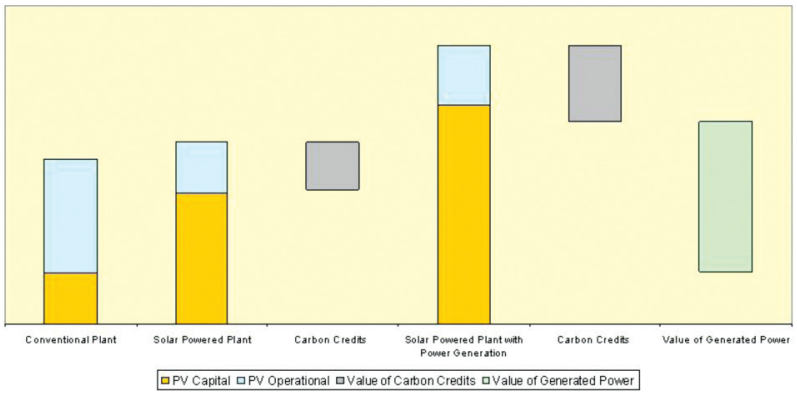


Figure 6—Waterfall graph showing the relative values of the solar plant options considered

System operation on demand

A more challenging strategy is that of operating ventilation and cooling systems on demand. The continuous operation of fans and cooling systems also where mining operations are temporarily suspended has been a customarily accepted practice. In view of the current situation, this strategy should be challenged. Ideally one would like to operate these systems much the same way as one turns on and off the light when entering or leaving a room.

This strategy has been used as a power-saving tactic in commercial and domestic building applications for a number of years—where infrared and motion sensors have been used to deactivate lights and air conditioning systems in unoccupied areas. FutureMine applied research projects completed in 2004 concluded that cooling on demand for mines would be feasible.

The obvious risk and possibly a drawback are the accumulation of dangerous gases and elevation of air temperatures in unventilated excavations. In principle these hazards are not insurmountable and with an adequate infrastructure and adequately risk-assessed procedure, these can be mitigated successfully or eliminated altogether.

The challenge remains to design a robust and effective system that will operate effectively. For example, in terms of thermal transient conditions, the cooling provided on re-entry after a blast or after a long stagnant period of time must have enough 'boosting' capacity to flush and cool the excavation within an acceptably defined period. This might require an 'over-design' of certain components to allow for this boost. It is also accepted that 'traditional' ventilation system strategies will have to be redesigned to accommodate this. In summary, this tactic could be advantageous and should be considered in 'greenfield' mining ventures.

Conclusions

Anglo Platinum is faced with increasing power costs arising not only from tariff escalation but also from an increase in energy requirements due to expansion at depth. A considerable growth in cooling power requirements is anticipated within ten to fifteen years hence. In addition, availability of electrical power supply from Eskom during the next five to ten years is not assured.

The strategy proposed for Anglo Platinum ventilation and cooling systems is based on:

- Defining and addressing patent wastage of air in circulation through various air leakage reduction programmes.
- Reducing main fan power consumption by active use of guide-vanes controls.
- Examining main fan efficiencies and the required duties to the end of life of the mine they serve. This will require careful and critical consideration of the possibility of replacing old, existing main fan impellers with more efficient ones.
- Completing the auxiliary fan and air duct re-assessment exercise and decide on the feasibility of using new generation systems.
- Examining the possibility of extending thermal storage to existing operations and reconsider using this tactic in new projects.
- The use of energy recovery or, alternatively high pressure closed loop systems, is essential in reducing energy consumption wherever chilled service water is required.
- The introduction of underground refrigeration plants is not likely for a number of reasons—not in the least as the result of uncertainties arising from the use of new generation refrigerants. However, this option should not be ignored totally for certain applications.
- The use of solar power for refrigeration plants but, more significantly, as a generic alternative energy source should be considered seriously.
- The advantages postulated by the studies of system operation on demand should be investigated further for possible application to new ventures and evaluated carefully both in terms of any residual risks and of the net benefits that can be realized by adopting this approach.

References

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