VENTILATION ON DEMAND AT GWALIA GOLD MINE

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ABSTRACT

Gwalia gold mine is undergoing rapid expansion and development in the aim of accessing gold bearing ore at depths of over 1100 metres below surface. The expansion of the mine has caused a need for the improvement of the quality of its ventilation. The planned ventilation network is to run twin 1.3 MW primary fans alongside an 8 MW refrigeration plant. This system will be very energy intensive and will be one of the largest electricity consumers of the mine. One suggestion to reduce these ventilation costs is to integrate ventilation on demand system, bringing the mine away from the industry standard of ventilating the whole mine all the time. Ventilation on demand system will accurately distribute only the required amount of air to the working levels, thus reducing primary airflow requirements and in turn electricity operating costs. An investigation into the application of ventilation on demand system at Gwalia Gold mine was conducted to better understand the mechanics of the system, and help identify what style of system operation would best suit the mine**.** To be practical it is found that the full features of the system should be used during the times of full production, and partial usage be used during periods of lower production such as night shifts.

KEYWORDS: *ventilation on demand; automated ventilation control; real time monitoring; fan speed control; mine communication*

1.0 INTRODUCTION

St. Barbara Minerals acquired the Gwalia gold mine in Western Australia in 2004 with the intention of accessing gold bearing ore at depths of over 1100 metres below surface (mbs). Due to the shear depth of the mine, ventilation and refrigeration costs are set to be a major expense throughout the mine life. One suggestion to reduce costs is to install a ventilation on demand (VOD) system, potentially saving hundreds of thousands of dollars in power costs every year. This paper explores the benefits of installing a VOD system at the Gwalia gold mine to reduce power and operating costs of the proposed ventilation and refrigeration system. The integration of a VOD system would bring the mine away from the industry standard of ventilating the whole mine all the time, and ventilate only those areas that need be ventilated with their respective quantity of air required. The major elements of a VOD system should include:

- Real time integrated monitoring of environmental conditions in underground work areas,
- Communication system to relay information from monitors and sensors to control rooms and devices, and
- Automated ventilation control devices including regulators, vent doors and fan speed controllers.

An essential feature of a VOD system is the automation and remote control of mine ventilation control devices such as regulators and fans. The concept is not a new one to mining, but one which has been tried and tested to different levels of success or failure around the world. Maximizing operational efficiency has led to the development of real time ventilation monitoring and automated control systems to reduce ventilation downtime and hence production losses (Hartmann *et al*, 1997). The benefits that can arise from real time ventilation monitoring and remote control capabilities may be observed from a technical, economic and safety perspective (Wu and Gillies, 2004).

Wu and Gillies (2004) details the study of Cannington mine in New South Wales trials with an automated control system. The system utilizes roller door type regulators remotely operated from the surface. As the differential pressure, and quantity flow across the regulators can be calculated both empirically as well as using the ventilation software, operators are able to set regulators to deliver a recommended flow at every level of the mine. Such a system enables adequate air to be delivered only to the headings and areas requiring air, eliminating the inefficient ventilation of stagnant areas. Automation allows such devices to be controlled from surface, and adjusted to a setting that will provide adequate ventilation. The system can then be monitored using the real time monitoring system. Remote control and automated regulators also decrease maintenance costs throughout the ventilation network. With the ability to open all regulators at blasting times, damage to the devices through air blasts and shocks is significantly reduced. Such a process can reduce maintenance and upkeep costs for the devices. Re-entry times can also be reduced through automatic ventilation control by exhausting blast fumes more efficiently after blasts by redirecting the air to the exhaust at an earlier stage.

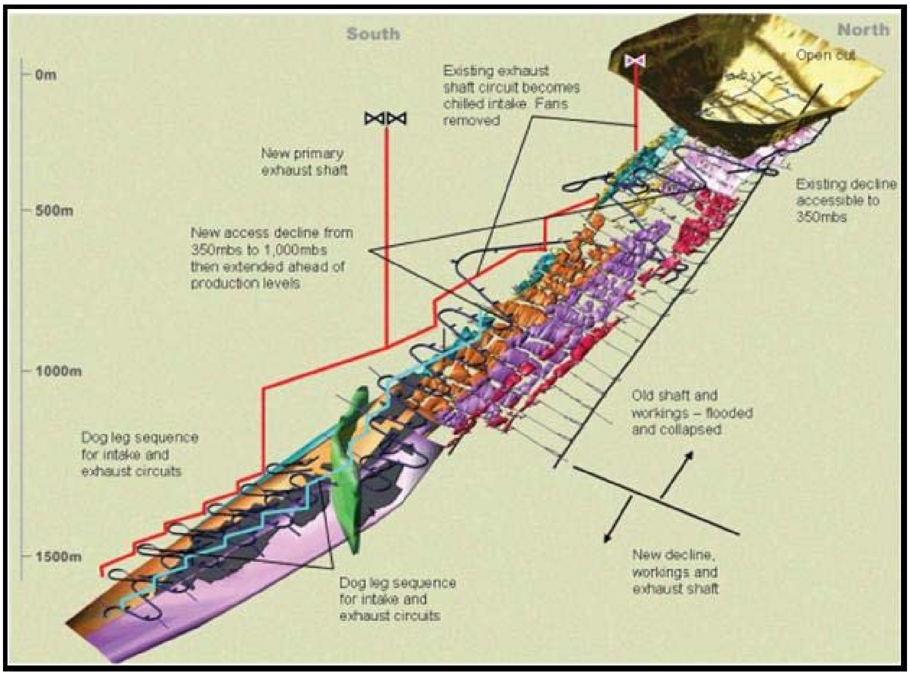

Figure 1: Ventilation network of Gwalia mine

2. VENTILATION NETWORK

Mining at Gwalia has been conducted since as early as 1897 with the original underground workings being mined to a depth of over 1000 mbs. Open pit operations commenced in the late eighties, mining to a depth of 250 mbs before underground operations were recommenced via decline access to a depth of 1200 mbs. St. Barbara took over the operation in 2004 with the development continuing from the bottom of this decline. Depths of over 1200 mbs have recently been reached, with the first production stope fired in September 2008. The proposed ventilation infrastructure is illustrated in Figure 1. The ventilation network at Gwalia is currently in the transitional phase from the development network to the full production network. The development network utilizes the existing exhaust shaft extended via a series of dog legs to the current working levels of 1200 mbs and beyond. The designed production ventilation system comprises of the following.

2.1 Intake System

The mine will utilize the decline as the main intake system. The 6.0 m x 5.8 m decline will provide the majority of fresh air throughout the mine life. The Southern Ventilation Raise (SVR) and by pass raise/emergency egress ladder way will act as a secondary intake. Surface coolers will be fitted to one of these intake airways delivering cool air to the lower workings leaving the decline unchilled.

2.2 Exhaust System

The main exhaust shaft, commissioned in July 2008, is a 5.5 m diameter 830 m deep raise bore from surface. The primary fans will be located on top of this shaft. The exhaust network will be extended via a series of 4.5 m parallel raise bores and 5 m x 6 m horizontal developments connecting to this main exhaust level.

2.3 Primary Fans

Primary fans to be installed are twin Howden Type WB Model B Size 3300 single inlet 1250 kW centrifugal fans. These will also be fitted with variable frequency drives so speed control would be available, an important feature in a VOD system.

2.4 Refrigeration Plant

A refrigeration plant with nominal cooling capacity of 6-8 MW will be installed and commissioned in early 2009. The refrigeration plant will deliver cool air down the SVR where it will be forced to deeper workings via a series of raise bores and horizontal development. The cooling plant will also include variable speed drives on the main fans so the volumetric flow can be altered according to mine conditions.

3. VENTILATION REQUIREMENTS

Of primary concern to a VOD system is to supply just enough ventilation requirements at any time through the mining process. These ventilation requirements determined using an appropriate modeling procedure will be used as the primary tool for analyzing and designing the VOD system.

3.1 Diesel Fleet Requirements

Ventilation requirements for diesel units are based on the fleet profiles proposed for the mine. These diesel requirements define:

- An indicated minimum ventilation rate of 201 m^3/s for the load haul dump fleet and 308 m^3/s for the entire fleet. Note that a ventilation rate of 0.05 m^3/s per kW rated diesel power is specified in the Western Australian regulations and was used for design purposes. Furthermore, in hot conditions (>25°C wet bulb) the air velocity in working places should be at least 0.5 m/s to assist air cooling power with a recommended design of 0.75 m/s.

- When a truck and loader are on a level at the same time the local requirements will be 46 m^3/s reducing to 18 m^3/s for a single 354 kW loader.
- If all five trucks (or similar) were to be in the decline system at the same time, the decline ventilation rate would have to be 142 m^3/s.

3.2 Deep Zone Ventilation Requirements

Based on design guidelines used elsewhere, it would be normal to allocate 250 to 300 m^3/s per million tons per year (Mtpy) for the mining method plus 50 to 70 m^3/s to account for decline haulage. For the proposed production rate of 0.6 to 0.8 Mtpy of ore plus waste, the range of volumetric requirements would therefore be 220 m^3/s to 250 m^3/s at depth of mining. These values are also broadly consistent with the overall ventilation requirements of 201-208 m^3/s for diesel equipment. Actual ventilation requirements at depth of mining are based on a number of rationale and assumptions concerning the number of production and development levels, and the activities taking place in each of these locations. In the worst case scenario, where all the activities are performed simultaneously the total ventilation requirement was determined as 450 m^3/s at surface conditions.

3.3 Argument for Ventilation on Demand

This worst case ventilation scenario will require a rather large volumetric requirement of air. The ventilation system designed for Gwalia is capable of handling this ventilation rate, but it must be argued whether this volumetric capacity is required 100% of the time. At shallower mining depths and lower production rates, this volumetric capacity can be significantly reduced highlighting the advantage of a VOD system. Over the eight year mine life the maximum volumetric flow is only required in the last quarter of the mine life with a steady ramp up of air required from 360 to 450 m^3/s.

4. VENTILATION ON DEMAND SYSTEM INTEGRATION AT GWALIA

The best solution for Gwalia mine would be a semi-automated system adjusted on a shift by shift basis. The push to stay away from a fully automated system is due to the novel nature of the technology, the heavy reliance on computers to control ventilation networks and the continually changing nature of an underground mine. The production pattern changed a great deal in the night and day shifts in this operation. Owing to this fact it was found that the system that best suited to Gwalia was one adjusted on a shift-by-shift basis. Work plans are devised in pre shift meetings and ventilation requirements calculated for all working levels, and the mine as a whole. Adjustments to ventilation controls are made using the Citect mine control and monitoring system and these changes monitored using the real time monitoring software. Once work begins, all working headings are adequately ventilated with correct distribution of air lending to increased power savings.

Table 1: Shift plan sheet

Level	Activity profile	Nominal quantity (m3/s)	Comment
Production	Maximum of 3 production areas (Two loading)		
980L Stope	Loading	46	Loader and trucks - full shift
980R Stope	Loading	46	Loading to stockpiles only
1030 Stope	Drilling	20	Drilling and charging full shift
Development	Maximum of 7 Development areas (Two loading)		
Hoover	Loading	46	Loader plus truck on level
Barden	Bolt/drill/charge	20	Full shift
800 Vent drive	Bolt/drill/charge	20	Full shift
1050 Vent access	Bolt/drill/charge	30	Priority two
Miscellaneous	Exploration, service crew, geology and survey		
770	Diamond drillers exploration	15	1 to 15 m3/s
650	Service crew - pump move	15	
Level subtotal		258	
Other infrastructure			
Fuel bay		20	Vent to return
Magazine		15	Vent to return
Workshop		0	Air re used
Upper level leakage		20	Approx
Infrastructure subtotal		55	
Mine total (U/G)		313	
Fan total (Multiply by 1.15)		360	

4.1 How the system works

During pre-shift meetings, a shift plan will be devised, and working areas defined. From these plans, ventilation requirements can be calculated for every working area.

A suitable plan sheet is shown in Table 1. A list of nominal air quantities will be on hand so no confusion is made to how much air is required for each activity. This sheet will be updated on a regular basis, or whenever new machinery is purchased. An example of such a sheet is shown in Table 2. Once the shift plan is finalized, adjustments to the ventilation network can be made via the control centre on surface. A suitable software system identified was Citect based software, similar to that used at Cannington mine in Queensland, Australia (Gillies *et al*, 2004).

Table 2: Activity based requirements

Activity	Nominal quantity required (m3/s)
Loading (with or without trucks)	46
Drill/charge/bolt	20
Shotcrete	30
Service crew	15
Diamond drillers	15
Re-entry (<30mins)	25
If not on list, multiply machinery engine kilowatts by 0.05	

All quantity controls come through the adjustment of primary and secondary fan speeds along with the settings of primary network regulators. These controls are adjusted remotely via the leaky feeder system already installed at the mine. The system is quick and easy to adjust and allows for full adjustment of all ventilation controls. The fact that the system must be set at the beginning of every shift by management provides a factor of safety in which ventilation conditions are set to safe levels for all working areas.

Once all changes have been made, the atmospheric conditions are monitored through a Ventsim based real-time monitoring system, and when ideal conditions achieved underground, the green light given to commence the shift work. The Ventsim ventilation simulation program allows for real time monitoring input, and has proven extremely effective in such situations (Ventsim, 2008). When a number of sensors are installed throughout the mines ventilation network, real time data can be sent back to the program and inputted into the live ventilation model. If these sensors are installed in independent branches of the ventilation network the whole model can be updated by using a small number of live sensors. Where automated control of devices such as fans and regulators is required, Ventsim does not have the capabilities to date, so more sophisticated software is required. The most common in Australia is the Citect software. The software can incorporate the real time monitoring inputs from Ventsim, and a simple graphical interface is available for manual control.

4.2 System Components Required

The system will require infrastructure including:

- Citect software integrated into ventilation network
- Roller door type regulators installed in primary branches. These regulators are controlled via a programmable logic controller (PLC) and communicate with the main control centre via the leaky feeder system. The regulators are easily adjusted to control airflow across the working levels, and can be set on a shift-by-shift or continual basis. The regulators are also fully opened during firing to minimize the risk of damage, and ensure fast re-entry times.
- Variable speed drive control for primary and secondary fans. Two types of controllers are available for speed control of secondary fans in the Australian market.
- Leaky feeder communication system integrated into all controls
- Manual over-ride system at all ventilation controls
- Real time sensors built into ventilation network including velocity and gas sensors

5. COMPARISON WITH A CONVENTIONAL VENTILATION SYSTEM

To prove the viability of a VOD system at Gwalia a comparison of ventilation power savings is made with a conventional ventilation system.

5.1 Primary Fan

The majority of power savings are made through the primary fan speed reductions. Life of mine ventilation requirements have been calculated and summarized in Table 3 along with fan speeds required to achieve these requirements.

Table 3: Life of mine ventilation requirements

Mining period (years)	Ventilation requirement (m3/s)	Fan speed (rpm)
0-2	360	460
2-4	390	490
4-6	430	540
6-8	450	572
8+	450	572

By running a Ventsim model of the proposed network the required fan speeds to achieve these ventilation rates have been calculated, and the typical power savings determined as summarized in Table 4. Annual power cost reduction of almost 50% are achievable through the earlier years of the mine life if the fan is to be run at a reduced speed and deliver only the required volume of air.

Table 4: Life of mine primary fan savings

Situation	Life of mine power cost (A$)
No control	28,048,489
With control	20,861,992
Cost reduction	7,186,498

5.2 Secondary Fan

Similar to the way savings were calculated for the primary fan, power savings achievable through the secondary fans were also calculated. All electrical power input to the secondary fans is converted to heat energy and reducing the speed conserves electrical energy and lowers the generation of heat. It was assumed that these secondary fans can run at a 40:60 speed ratio. This means 40% of the time the fans will be delivering the higher quantity of 41 m^3/s to support loading activities, whilst the remaining 60% of the time the fans will only deliver 25 m^3/s to support auxiliary activities. These results are summarized in Table 5.

Table 5: Secondary fan annual power savings

Speed	Quantity (m^3/s)	Electrical Power (kW)	Annual Cost (A$)
1485	41	185	346,896
1000	25	99	157,680
Power saving			233,366

5.3 Regulators

The use of regulator control will also add to power savings over the life of the mine. Where working headings are in the primary ventilation network, the regulator control will assist in reducing the primary fan ventilation requirements by supplying only the required volume of air to the heading.

6. CONCLUSIONS

The findings of this project conclude that the implementation of a ventilation on demand system at Gwalia mine is extremely beneficial, and one that should be incorporated into the development of the mine. The system recommended in this study involving a shift-by-shift basis of ventilation control has the ability to save operating costs due to significant power reductions to the primary and secondary fans, and correct control of regulators. These savings are further increased when maintenance issues are reduced due to the lower operating hours and fan speeds.

VOD systems also have some inherent disadvantages. Once controls have been adjusted there is a time delay between adjusting fan speeds and regulators, and the ventilation network reaching a state of equilibrium. For a large mine like Gwalia, this delay can be up to 10 minutes, so careful observation of the atmospheric conditions must be made over this time period. Another setback of such a system is the time consuming nature of adjusting each level's ventilation controls, and the fact that adjusting one level's regulators will affect all other levels in primary ventilation flow. This is another reason why a good real time monitoring system is also required with such a system.

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