Ventilation Considerations for the New Level Mine Project Access Tunnels

E Acuña[1], R Alvarez[2], K Wallace[3] and B Prosser[4]

ABSTRACT

This paper describes the ventilation analyses performed for the access tunnels at the New Level Mine project (NLMP) at Codelco's El Teniente operation outside of Rancagua, Chile. This new mine is anticipated to reach a final production of between 137 and 180 kt/d. Production from the NLMP is scheduled to start in the year 2017. The main access tunnels (MAT) are approximately 9 km in length, with one for personnel and supply access and the second one for ore extraction through a conveyor system. These two tunnels are a critical component of the initial stage 1 development and will be constructed independently of the existing mine workings. The tunnels were originally designed to be constructed with two tunnel boring machines. However, later analyses changed the construction approach to a conventional drill and blast technique. Because the design included two mid-tunnel ramp-to-surface connections, conventional mining methods would allow for development of the tunnels with multiple working faces to achieve a more rapid schedule. This paper presents the initial baseline considered for the ventilation design and the optimisation methodology applied by Codelco to minimise the airflow and pressure requirements of the ventilation system. Modifications to the design resulted in the addition of strategic airways and raises that could provide a saving of approximately 1 MW, when compared to the original design.

INTRODUCTION

CODELCO currently operates one of the largest block cave mines in the world at its El Teniente mine. A major expansion project is currently underway to develop a new mining horizon below the existing block cave. This project is called the New Level Mine Project (NLMP). Anticipated production from the NLMP is expected to be between 137 and 180 kt/d. Access to the NLMP is critical to the success of the project. This access is via two 9 km tunnels. One tunnel is for material and personnel access, while a parallel tunnel is used to convey the ore from the mine.

The ventilation design for the tunnels initially was designed to account for providing airflow in sufficient quantity to dilute diesel emissions, while maintaining safety in the tunnel in the event of a fire. The conceptual design of the access and conveyor belt tunnels was developed by Mine Ventilation Services, Inc (MVS) and considered two mid-tunnel ramps to act as intake and exhaust. The concept was to provide different splits of air to the tunnels thus minimising the airflow required from the mine to ventilate these airways and to provide fresh air in three splits in the tunnel. This design assumed construction of the tunnels by tunnel boring machines (TBMs) and had a bypass tunnel connecting to the primary access tunnel near the portal. Since this design, the project has elected to construct the tunnel by conventional drill and blast methods and eliminated the bypass tunnel from the design. With these design changes, the mid-ramp accesses become necessary to allow for more rapid tunnel development, with multiple faces being mined from each ramp access connection to the tunnels.

As more detailed engineering and construction sequences were developed, the project was able to refine the ventilation design both through equipment review selection and drift cross-section formalisation. In addition, criteria were established for ventilation of equipment entering the tunnel. These criteria resulted in modifying the ventilation design to allow for more uniform ventilation demands in each tunnel segment, which, in turn, resulted in adding a ventilation raise, surface connection and ventilation cross-over to the design. This additional infrastructure increased the tunnel capital cost, but significantly reduced the tunnel fan operating cost.

INITIAL CONCEPT AND VENTILATION DESIGN

The initial concept and design developed by MVS is presented in Figure 1 and considered two ramps (A and B) each one equipped with a ventilation system connecting to the two tunnels. The access tunnel connects to the production level at the mine, while the conveyor tunnel connects below the crusher structure. Ramp A was defined as intake and ramp B as exhaust. The main reason for this arrangement was to have airflow flowing from the mine to the tunnels and to split the air in three, roughly equal lengths. This design minimised the risk of fumes from a tunnel fire entering the mine and would contain a fire to only one-third of the tunnel length. Cross-cuts

1. Ventilation Engineer, CODELCO, Proyecto Nuevo Nivel Mina, Monseñor Sotero Sanz 161 piso 5, Providencia Santiago, Chile. Email: EAcun005@codelco.cl

2. Ventilation Analyst, SKM, Monseñor Sotero Sanz 161 piso 5, Providencia Santiago, Chile. Email: RAlva026@contratistas.codelco.cl

3. President, Mine Ventilation Services, Inc 1625 Shaw Avenue, Suite 103, Clovis Ca 93611, USA. Email: keith@mvsengineering.com

4. Principal Engineer, Mine Ventilation Services, Inc 1625 Shaw Avenue, Suite 103, Clovis, Ca 93611 USA. Email: brian@mvsengineering.com

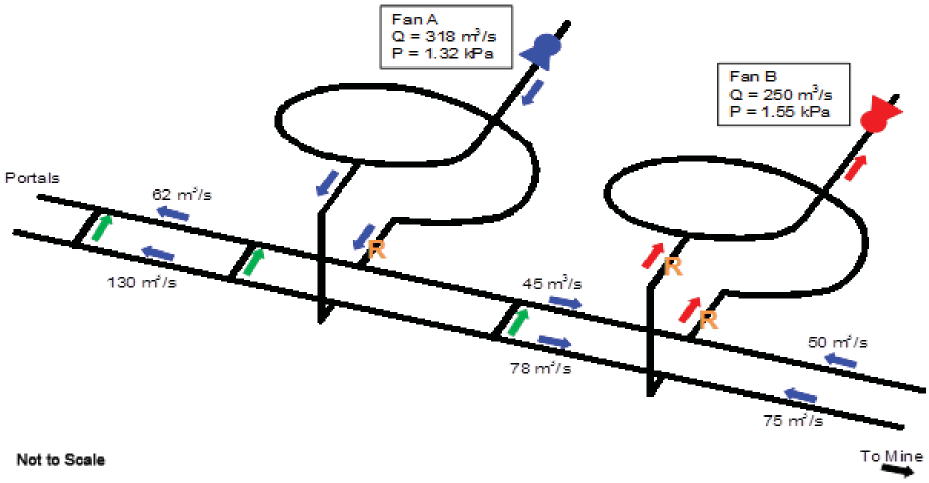

FIG 1 - Initial concept and ventilation design.

were to be developed every 300 m between the two tunnels, with escape doors to evacuate people from one tunnel to the other in case of an emergency.

The airflow requirements were estimated at 50 m³/s for the conveyor tunnel and 75 m³/s for the access tunnel. The airflow considered for the conveyor tunnel is the result of maintaining the conveyor air speed in the range of 1.5 m/s. The airflow estimated for the access tunnel was derived from an initial estimation of diesel equipment operating in the tunnel. At the time of the study no equipment fleet was available to estimate the airflow requirements for the access tunnel.

The fan systems were determined as presented in Figure 1, with an intake fan in ramp A moving 318 m³/s at 1.32 k/a and an exhaust fan in ramp B moving 250 m³/s at 1.55 k/a. The power requirement was estimated at 559 kW and 516 kW for fan A and fan B, respectively. The capital estimation was developed accordingly to this initial input.

UPDATED INITIAL VENTILATION DESIGN

During basic engineering, the construction of the tunnels was modified from a TBM to a drill and blast methodology. This resulted in changes to the tunnel geometry. In addition, a segment of tunnel connecting to the access tunnel was removed from the design and the ramp connections were modified to reflect actual surface connections. The ramp connections were also refined with a known dimension, length and orientation. These changes resulted in the need to remodel the tunnel ventilation system, which was initially defined by Mine Ventilation Services, 2010c and Mine Ventilation Services, 2010d. Figure 2 shows the tunnel cross-section areas, with Figure 3 illustrating the tunnel layout. This updated layout was proposed by the contractor company assigned to develop the tunnels and was developed only considering the construction criteria and not with long-term ventilation needs. However, the final result was not completely different from the initial concept.

From Figure 3 it is noted that the two access ramps are identified by their respective locations along the tunnel length and are labelled P500 and P4600, respectively. The P500 access is a 6 m × 6 m arched ramp that connects to the tunnels at a distance of 3100 m from the portals. The P4600 access ramp has the same cross-sectional area as the P500 and connects with the access tunnel at 7250 m from the portals. The tunnel segments in this design are not equal distant as the middle segment is over 4 km in length.

The airflow requirements of the conveyor tunnel remained at 50 m³/s (Mine Ventilation Services, 2010b), but the airflow requirement of the access tunnel was recalculated based on an anticipated equipment fleet moving in the tunnel (Mine Ventilation Services, 2010a). To operate a large block cave mine at a production rate of 180 000 t/d takes significant manpower. To this end, it was estimated that during

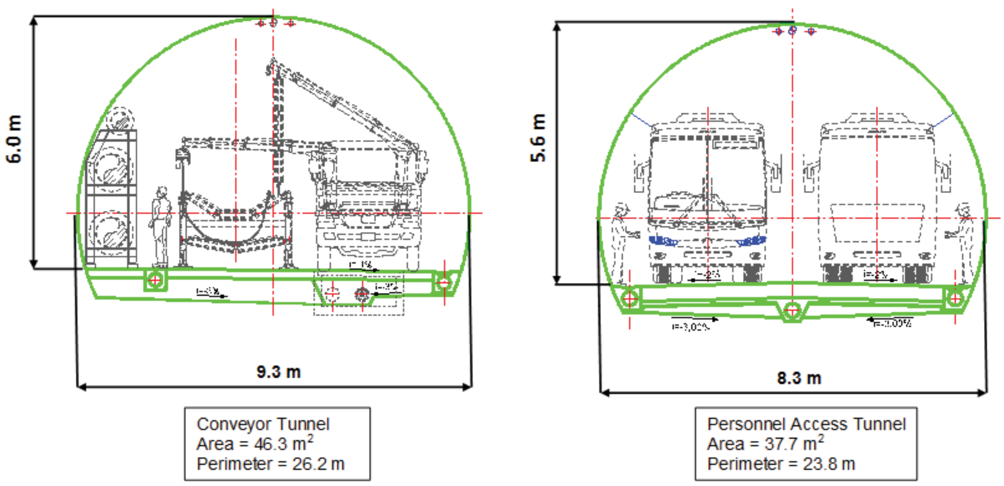

FIG 2 - Cross-sectional areas of conveyor tunnel and personnel access tunnel.

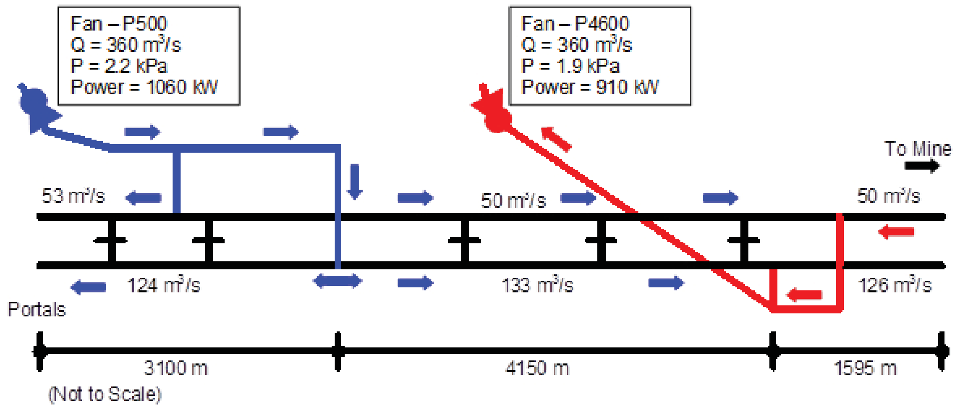

FIG 3 - Diagram of the updated geometry for the access and conveyor tunnels.

shift change upwards of 56 full-size diesel buses will be required to transport personnel into and out of the mine. An administrative control will be in place during personnel travel to limit traffic to one direction only (eg no two-way traffic). The second criterion considered was that all buses will travel in the tunnel over an approximate 40 minute window, with a complete turnaround of buses over a two-hour period (personnel taken in and dropped off and the buses reloaded with the shift-ending personnel). The mine is anticipating two shifts per day resulting in four hours of bus travel time each day. The remaining time will be available for the movement of supplies, explosives, etc. During the remaining time the traffic will be two-way. The actual equipment fleet during non-personnel transport is not defined for full production; however, assuming a certain equipment fleet resulted in an airflow required at 95 m^3/s per segment.

For the bus fleet, a series of calculations were performed based on various bus speeds, airflow required for each diesel engine and spacing between buses. These calculations showed that the airflow requirement would vary per tunnel length since each segment would have a different number of buses and result in significant airflow required in the longer centre segment. This consideration led to modifying the design to create equal tunnel lengths.

Ventilation analyses results, using the VnetPC Pro+ simulation package, gave the results presented in Figure 3. The P500 intake fan(s) are estimated at 360 m^3/s at 2.2 kPa, while the P4600 exhaust fan(s) would require 360 m^3/s at 1.9 kPa. The power requirement was estimated at 1100 kW and 900 kW for the P500 and the P4600 fans, respectively. These results are considerably larger in both capital and operating costs than those predicted during the basic engineering study.

Based on this updated design, NLMP engineers proposed infrastructure changes that could be offset by the savings in energy. This helped minimise the impact of this design when compared to the basic engineering study.

OPTIMISED DESIGN

From the updated base design, NLMP engineers investigated several alternatives to reduce tunnel fan requirements and to create equal tunnel segments. The two primary changes investigated were:

1. Develop a connection drift and 5 m diameter raise connecting the P4600 ramp to the access tunnel resulting in an even segment length.
2. Develop a second adit in the P500 ramp to reduce the resistance of this surface connection.

The P4600 new drift and 5 m diameter raise modification is shown in Figure 4. As noted in this figure, the distances along the access tunnel are 3100 m, 3000 m and 2745 m, respectively. This configuration allows for even ventilation in each tunnel segment and reduced the P4600 fan requirement. Figure 5 shows the location of adding an adit to the P500 location. This adit would be approximately 500 m in length.

Adding the P4600 drift and raise allowed for a reduction in airflow to the middle segment. This reduction, combined with a lower resistance to move air to the tunnels, resulted in lowering the P4600 fan requirements from 360 m^3/s at 1.9 kPa (motor of 910 kW) to 340 m^3/s at 1.2 kPa (545 kW); a decrease of 365 kW. Adding in the P500 parallel surface connection reduced the fan duty at this location from 360 m^3/s at 2.2 kPa (motor of 1060 kW) to 340 m^3/s at 0.9 kPa (410 kW); a decrease of 650 kW. These two modifications result in a decrease in

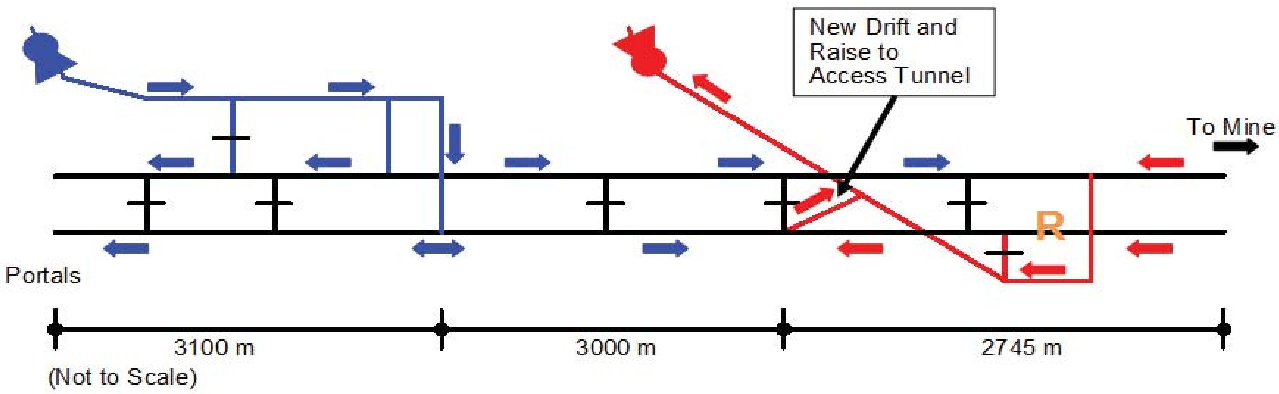

FIG 4 - Diagram of the updated geometry for the access and conveyor tunnels showing the P4600 connection drift and raise location.

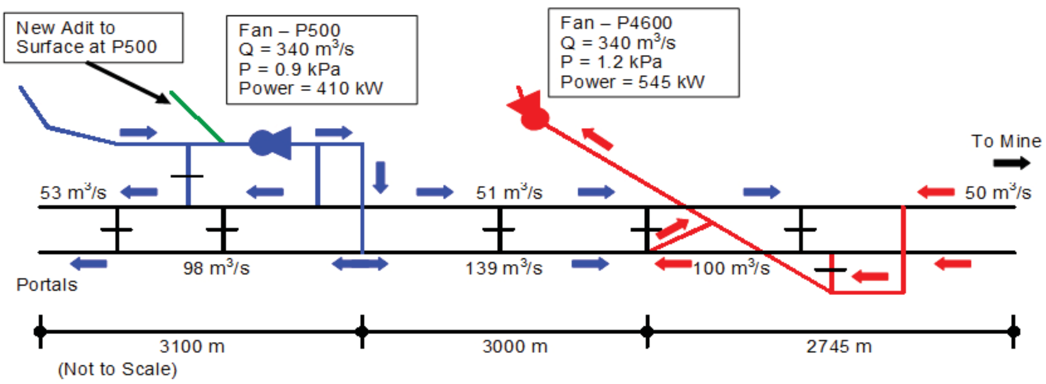

FIG 5 - Diagram of the updated geometry for the access and conveyor tunnels including the P4600 raise and P500 drift, with predicted fan requirements.

the total fan power of approximately 1 MW. A costing study was performed to evaluate the economics of incorporating the new infrastructure, conceptually similar to the economical cross section (Hartman *et al*, 1997 and McPherson, 2009), where a balance between the capital cost and the discounted operational cost is developed to determine overall economical solution. This study showed that because of the relatively high electrical power costs for the project, the payback for the second adit (P500 ramp) is approximately seven years, while the payback for the new adit and raise (P4600 ramp area) is in the order of ten years. Given the extremely long life of the mine (estimated at 40 years), the cost of these modifications were considered to be justified. The NLMP engineering department is currently performing detailed engineering on these modifications.

CONCLUSION

A comprehensive ventilation study was performed on the new conveyor and access tunnels being developed for the New Level Project at Codelco's El Teniente mine. This study investigated the airflow required during normal operations and the distribution of this air. Improvements were developed from the basic designs, which included adding additional surface connections on the P500 ramp and adding an access drift and 5 m diameter ventilation raise on the P4600 ramp. These changes resulted in a better distribution of air through the tunnels at a reduced fan operating requirement, with a decrease in fan power by approximately 1 MW.

Further studies being conducted for ventilating the tunnels include continued verification of the airflow required for the equipment fleet accessing the mine and conducting fire studies to validate the design for personnel escape and containment of fire combustion products.

REFERENCES

Hartman, H L, Ramani, R B, Mutmansky, J M and Wang, Y J, 1997. *Mine Ventilation and Air Conditioning*, third edition, 730 p (John Wiley and Sons, Inc).

McPherson, M J, 2009. *Subsurface Ventilation Engineering*, second edition, 824 p (Fresno, CA: Mine Ventilation Services, Inc).

Mine Ventilation Services, Inc, 2010a. Design criteria document, T09E205-01-MVS-24110-CRTM104-2500-001', prepared for Codelco, May.

Mine Ventilation Services, Inc, 2010b. Control of dust, T09E205-01-MVS-24110-CRTM104-2500-002, prepared for Codelco, August.

Mine Ventilation Services, Inc, 2010c. Ventilation Model 137 KTPD, T09E205-01-MVS-24110-CRTM104-2500-003, prepared for Codelco, September.

Mine Ventilation Services, Inc, 2010d. Ventilation Model 180 KTPD, T09E205-01-MVS-24110-CRTM104-2500-004, prepared for Codelco, September.