VENTILATION DESIGN FOR A NEW ORE BODY AT DEPTH

J. Watkinson
Battle Mountain Canada Ltd.
Golden Giant Mine
Marathon, Ontario, Canada

E. De Souza
Department of Mining Engineering
Queen's University
Kingston, Ontario, Canada

ABSTRACT

The Golden Giant Mine is a gold mine operation with a target production rate of 3,000 tonnes per day. To maintain this rate, planning for the mining of a new orebody at depth, called Block 5, is being developed. Block 5 is a narrow orebody situated below the existing mining infrastructure, including production shaft, ventilation raises and access ramp. The offset location of Block 5, in particular in relation to the existing exhaust infrastructure, required that extensive design work be developed to attain the most practical ventilation layout for the economic exploitation of the orebody. This paper presents the designed ventilation layout for Block 5 and discusses the air quantity and quality requirements during the development and production stages of mining. Auxiliary ventilation designs for the development phase are addressed and modelling of the ventilation network for the production phase is presented, including the sizing of raises and associated booster fan requirements.

KEYWORDS

development ventilation, production ventilation, design, modelling

INTRODUCTION

The Golden Giant Mine, located in the province of Ontario, Canada,, began production in 1985 and holds reserves approximating 6.5 million tonnes with an average grade of 9.5 grams/tonne. Mineralization occurs in quartz-feldspar porphyry intrusives. The orebody dips at 65° and its width varies from 3 to 40 m. The hanging wall and footwall are composed of fairly competent metasediments. The mine uses the blasthole stoping method of production with delayed paste backfill. The mine is accessed by a production shaft and an internal ramp provides access to stoping blocks and production levels.

Commissioning of a new orebody at depth, called Block 5, has initiated. The Block 5 orebody is a narrow tabular vein of 3 to 4 metres average thickness. Its strike length is approximately 300 metres and it dips at approximately 65°. Reserves approximate 686,000 tonnes at 10.8 grams per tonne. Block 5 is located on the eastern side of the main orebody (Figure 1), and is situated below the original mining infrastructure, including production shaft, ventilation raises and access ramp. The shaft has been extended to a depth of 1422 m to permit hoisting of production ore from Block 5, and sublevels, internal ventilation raises and ore passes are being developed.

The size and position of the Block 5 orebody, in particular in relation to the existing exhaust infrastructure, poses a significant engineering challenge to the establishment of a suitable ventilation system which would support appropriate airflow and air quality requirements during development and during mining. Extensive design work was developed to attain the most practical and economical ventilation layout for the exploitation of Block 5. This paper presents the planned ventilation layout for Block 5 which will evolve from the development stage to the production phases of mining.

THE MINE MAIN VENTILATION SYSTEM

In order to define the ventilation requirements for Block 5, a brief description of the mine main ventilation system is presented. The primary ventilation system is a complex network of raises capable of handling 481 m^3/s (1,020,000 cfm), schematized in Figure 1. Each component of the mine ventilation system is briefly described below (Krog, 2000).

The fresh air system, located on the eastern side of the mine and near the production shaft, comprises two raises, the Fresh Air Raise #1 (FA#1) and the Fresh Air Raise #2 (FA#2), which supply approximately 458 m^3/s (970,000 cfm) of fresh air to the production areas. A main ramp is used to distribute the fresh air to required mining blocks of the mine. In general, fresh air is added to the ramp on primary levels and exhausted on sublevels. FA#1 primarily supplies air to the upper sections of the mine and FA#2 supplies fresh air to the lower production sections of the mine. The fresh air system only uses surface fans; such fans being capable of supplying all the pressure required to transport the fresh air through the raises to the bottom of the mine. FA#1 uses two centrifugal fans operating in parallel to supply 231 m^3/s (490,000 cfm) underground. The fans are belt driven by four 186 kW (250 HP) motors. Each fan operates at a break power of 268.5 kW (360 HP), 1.71 kPa (7" w.g.) static pressure and 74% efficiency. FA#2 uses two centrifugal fans operating in parallel to supply 227 m^3/s (480,000 cfm) underground. The fans are direct driven by two 522 kW (700 HP) variable frequency motors. Each fan operates at a break power of 309.5 kW (415 HP), 2.19 kPa (9" w.g.) static pressure and 80% efficiency.

The exhaust air system consists of raises located at both extremities of the ore body. The western and the eastern exhaust systems handle approximately 60% and 35% of the total exhaust air volume, respectively. The reminder of the exhaust air volume is expended via the

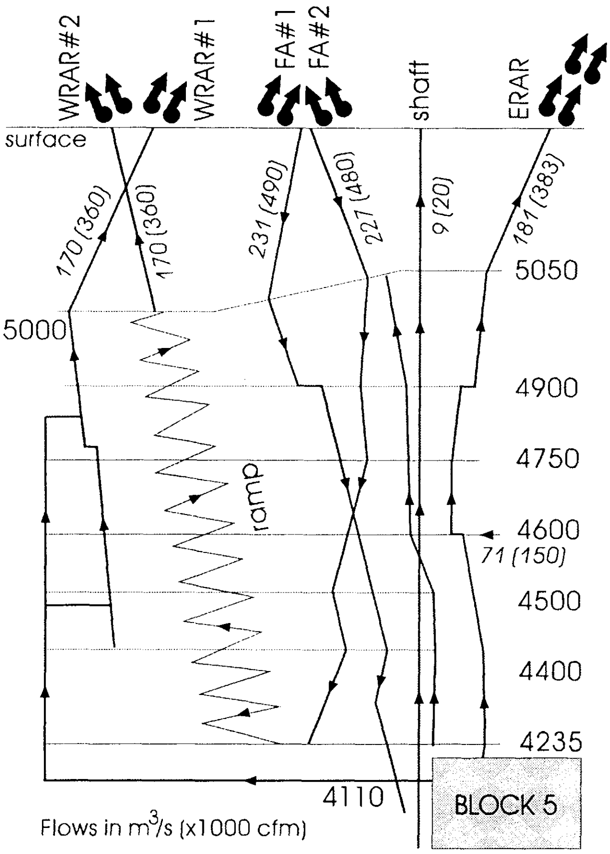

Figure 1. The mine main ventilation system and Block 5 location

production shaft.

The East Return Air Raise System (ERAR) system uses surface fans to generate all the pressure required to exhaust the air volume from the bottom of the mine. Regulators are used to control individual level exhaust flows. ERAR uses four 1.98 m (78") diameter axial flow fans operating in series-parallel, in two stacks, to exhaust 181 m^3/s (383,000 cfm). The fans are driven by four 186 kW (250 HP) motors. Each stack operates at a break power of 257.5 kW (345 HP), 2 kPa (8.2" w.g.) total pressure and 75% total efficiency. ERAR serves as the primary exhaust air system for Block 5.

The West Return Air Raise System (WRAR) uses surface fans and underground booster fans, installed on each level connected to the exhaust system, to exhaust the airflow from the mine. Two surface raises are used to exhaust mine air via the WRAR. The primary exhaust raise, WRAR#1 uses two 1.98 m (78") diameter axial flow fans operating in parallel, in two stacks, to exhaust 170 m^3/s (360,000 cfm). The fans are driven by two 186 kW (250 HP) motors. The fans operate at a break power of 298 kW (400 HP), 1.39 kPa (5.7" w.g.) total pressure and 78% total efficiency. WRAR#2 uses two 2.13 m (84") diameter axial flow fans operating in parallel, in two stacks. The fans are driven by two 261 kW (350 HP) variable frequency motors. The fans exhaust 170 m^3/s (360,000 cfm) at a total pressure of 1.24 kPa (5.1" w.g.), break power of 269 kW (360 HP), and at a total efficiency of 78%. The WRAR system will receive some of the Block 5 exhaust air via a haulage drift at the 4110 level (Figure 1).

Extensive modelling work has been performed to assess the capacity of the main mine ventilation system to serve Block 5 (De Souza and Gotz, 1999) and both ERAR and WRAR exhaust systems have been extensively upgraded to accommodate for increased requirements in exhaust capacity (Gotz and De Souza, 1999; De Souza *et al.*, 2001).

BLOCK 5 LAYOUT

Development and production layouts for Block 5 has been produced by the engineering group at the Golden Giant Mine. The planning of a new orebody is a very dynamic process and involves collaboration of all engineering departments, including production, planning and ventilation. The layout presented in this paper is the result of a multitude of revised proposals and will continue evolve as production commences and more information is gathered underground.

A simplified schematic, in longitudinal section, of the proposed Block 5 development layout and ventilation system is shown in Figure 2. Four main level access drifts connect the shaft to the orebody, at the 4110, 4035, 3960 and 3945 levels. From the access drifts, footwall production drifts are driven along strike. Crosscut drifts are used to provide drawpoint to the stopes. Two orepasses are used for muck flow. Sub-levels, spaced at 15 metres (49 feet) and accessed via the service raises, are used to develop stopes for production.

The flow distribution is based on estimated air volume requirements for Block 5 of 56.6 m^3/s (120,000 cfm). The ventilation scheme is to supply fresh air to the production levels using two service raises, A and B, located at the extremities of the orebody; return air is exhausted via a raise, D, located at the western side of Block 5.

Fresh air is supplied to Block 5 via the ramp, 70.8 m^3/s (150,000 cfm), and fresh air raise, 14.2 m^3/s (30,000 cfm). The ramp air at the 4110 level, 51.9 m^3/s (110,000 cfm), is supplied to the east and west service raises, which transfer air to the production levels and sublevels. Fresh air from the shaft, 4.7 m^3/s (10,000 cfm), is used to ventilate the shaft stations at the 4035 and 3960 levels. Return air, 56.6 m^3/s (120,000 cfm), from Block 5 is exhausted via the west exhaust raise, D, to the 4110 level. The return air in the 4110 level is then exhausted via a return raise, E, to ERAR, 56.6 m^3/s (120,000 cfm) and via the drift to Block 4B and WRAR, 28.3 m^3/s (60,000 cfm).

DEVELOPMENT VENTILATION

The development of Block 5 involves the establishment of a infrastructure of drifts, ramps and raises for muck and ventilation, in preparation for full production using sub-level stoping (Figure 3). Development is planned in four stages. When sizing the ventilation infrastructure for the development phase, an attempt was made to use fan/duct systems of same size.

Development Phase 1

The first stage aims at establishing a return air system for Block 5 and at developing access to the main levels. In this stage the shaft is deepened to the 3899 level and connections to the 4110, 4035, 3945 levels established. From the shaft stations, access drifts and ramps to the orebody on levels 4035, 3945 and 3960 are developed.

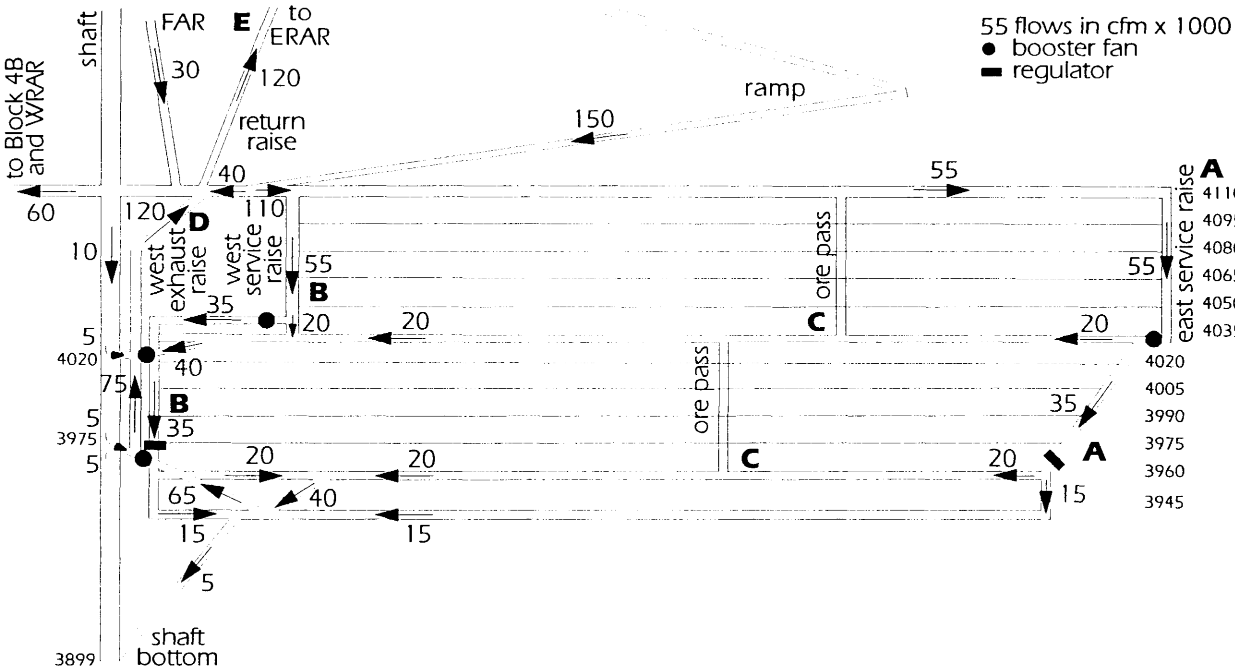

Figure 2. Schematic of Block 5 ventilation system

The west exhaust raise is also driven from 3975 to 4110. During this development stage fresh air is supplied via the shaft and ducted to the headings.

Development of the 338 m (1110 feet) long '3975 shaft station to 3945 level access drift' (1-2, Figure 3), will require the use of a 1.07 m (42¼") axial flow fan fitted with a 106.7 cm (42") diameter canvas ducting, to supply a flow of 14.2 m^3/s (30,000 cfm) to the face at a total head of 1.97 kPa (7.9" w.g.). The fan design flow is 18.9 m^3/s (40,000 cfm), assuming 25% leakage. This system will then be extended to drive the '3945 level to shaft bottom ramp' (2-3, Figure 3). The ramp is 338 m (1110 ft). Two 1.07 m (42¼") axial flow fans, installed in series, will be required, to operate at a total head of 4.1 kPa (16.3" w.g.).

Development of the 107 m (350 ft) long 'ramp access from the 3945 level to the 3960 level' (4-5, Figure 3) will utilize the duct system from the 3975 level shaft station to the ramp (1-2, Figure 3). The overall duct system will be approximately 357 m (1170 feet) long. A 1.07 m (42¼") axial flow fan fitted with a 106.7 cm (42") diameter canvas ducting, to supply a flow of 14.2 m^3/s (30,000 cfm) to the face at a total head approximating 2.2 kPa (8.8" w.g.) will be required.

Development in the 3960 level will then proceed to the western extreme (5-6, Figure 3) to permit development of the 4035-3960 west service raise. The 5-6 level drift is 80 m (263 ft) long. Thus, the requirements of a 437 m (1433 ft) long duct system running from the 3975 level shaft station to the 4035-3960 west service raise (1-4-5-6, Figure 3) are 2.67 kPa (10.7" w.g.) total head at 18.9 m^3/s (40,000 cfm) at the fan. Two 1.07 m (42¼") axial flow fans, installed in series, will be used. The west exhaust raise will be driven from the 3960 to the 4035 level, using an Alimak, in phase 2.

In the 4035 level, access to the level via the '4020 level shaft station to 4035 level access drift' (7-8, Figure 3) is first developed. This will permit driving of the 4110-4035 west service raise. The drift is approximately 255 m (837 feet) long. The requirements of a 106.7 cm (42") duct system are 1.62 kPa (6.5" w.g.) total head at 18.9 m^3/s (40,000 cfm) at the fan; one 1.07 m (42¼") axial flow fan will be used. The west exhaust raise will be extended from the 4035 to the 4110 level, in phase 2, using an Alimak.

Development Phase 2

The second stage aims at establishing airflow through the western side of Block 5 through the development of the west service raises from 4035 to 4110 level (9-10, Figure 3), and from 3945 to 4035 level (11-12, Figure 3). Both raises will be driven using an Alimak.

Development Phase 3

The third stage aims at establishing airflow through the eastern side of Block 5. In this stage, development in levels 4035, 3960 and 3945 are completed and the east service raise is fully established. The ore passes are developed and the first sublevels are started.

Development of the 3945 level production drift would follow to the eastern extreme (2-13, Figure 3) to permit development of the 3960-3945 east service raise. The 2-13 level drift is 294 m (965 ft) long. Thus, the requirements of a 106.7 cm (42") duct system running from the 3975 level shaft station to the 3960-3945 east service raise (1-2-13, Figure 3) are 3.8 kPa (15.3" w.g.) total head. Two 1.07 m (42¼") axial flow fans, installed in series, will be used.

Development of the 3960 level production drift would proceed (5-14, Figure 3) to permit development of the 4035-3960 east service raise. Having a new source of fresh air at the 4035-3960 west service raise, the duct system would run from 6 to 5 and to 14, the overall length being 376 m (1233 feet). The requirements of a 42" duct system are 2.2 kPa (8.8" w.g.) total head; one 1.07 m (42¼") axial flow fan will be used.

Development of the 4035 level would proceed to the east (9-15, Figure 3) to permit development of the 4110-

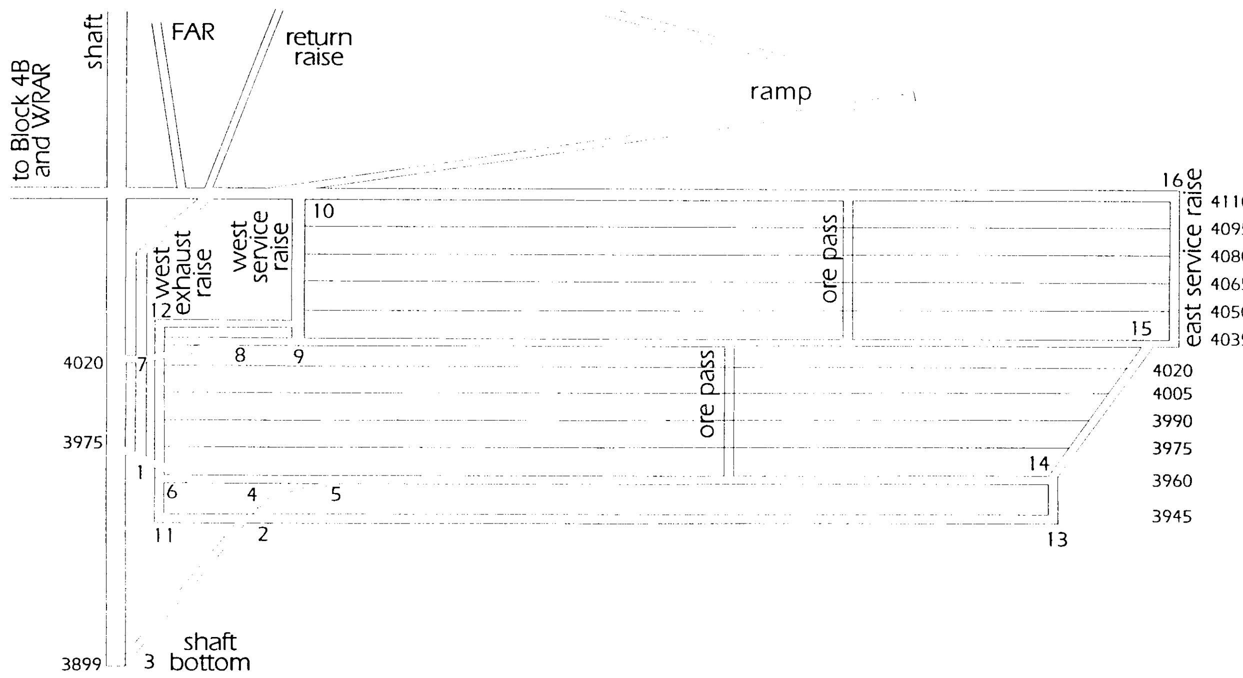

Figure 3. Schematic of development stages for Block 5

4035 east service raise. The duct system, starting at the west service raise, will have an overall length of approximately 400 m (1312 feet). One 1.07 m (42¼") axial flow fan will be used to supply a total head of 2.45 kPa (9.84" w.g.) at 18.9 m^3/s (40,000 cfm).

The east service raise will be driven from 3945 to 3960 level (13-14, Figure 3), from 3960 to 4035 level (14-15, Figure 3), and from 4035 to 4110 level (15-16, Figure 3), using an Alimak. The orepasses from 3960 to 4035 level and from 4035 to 4110 level will also be Alimak driven.

Development Phase 4

The forth stage aims at completing all development in Block 5 for full production. In this stage, development of all sublevels is completed. All required booster fans and regulators will be established to provide the required airflow distribution, shown in Figure 2, in each production level.

PRODUCTION VENTILATION

The mining method and sequence have been established to maximize productivity. Sub-level stoping will start at the centre of the orebody and retreat toward the east and west service raises. The ventilation design for full production was extensively studied with a combination of practical experience and model simulations. The ventilation design strategy is to supply fresh air to the production levels using two raises located at the extremities of the orebody and to exhaust return air via a raise located on the western side of Block 5, as illustrated in Figure 2. Airflow distribution requirements, booster fan and regulator positions, during full production, are also shown in Figure 2. The estimated air volume requirement for Block 5, based on installed production equipment, is 56.6 m^3/s (120,000 cfm). The general airflow management and distribution system, including details for each level, is presented below.

Airflow Management in the 4110 Level and Ventilation Raises

Level 4110 serves as a transfer of fresh air from the ramp to the production levels. The 4110-4035 west service raise supplies 26 m^3/s (55,000 cfm) of fresh air to the western section of Block 5. A booster fan is used at the 4035 level to draw air to the lower extension of the service raise, 4035-3945 level. Air is distributed to the production levels at 9.4 m^3/s (20,000 cfm) in the 4035 level, 9.4 m^3/s (20,000 cfm) in the 3960 level, and 7.1 m^3/s(15,000 cfm) in the 3945 level. A regulator is used at the 3960 level to control the split of supply air to the 3960 and 3945 levels.

The fresh air distribution at the eastern side of Block 5 follows a similar approach. The 4110-4035 east service raise supplies 26 m^3/s (55,000 cfm) of fresh air to the eastern section of Block 5 and a booster fan is used at the 4035 level to draw air to the 4035-3945 east service raise, level. Air is distributed to the production levels at 9.4 m^3/s (20,000 cfm) in the 4035 level, 9.4 m^3/s (20,000 cfm) in the 3960 level, and 7.1 m^3/s(15,000 cfm) in the 3945 level. A regulator is also used at the 3960 level to control the split of supply air to the 3960 and 3945 levels.

Return air from Block 5, 56.6 m^3/s (120,000 cfm), is primarily exhausted via the west exhaust raise to the 4110 level and to ERAR via a return raise. Two exhaust fans are connected to the west exhaust raise, one at the 4020 shaft station and one at the 3975 shaft station.

Airflow Management in the 4035 Level

The main supply of fresh air to the 4035 level are the 4110-4035 and the 4110-4035 west service raises. Auxiliary fans, mounted on bulkheads at each service raise, are used to supply 9.4 m^3/s (20,000 cfm) of air each to the production faces. It is noted that the 26 m^3/s (55,000 cfm) from the 4110-4035 east service raise is split at the 4035 level; 16.5 m^3/s (35,000 cfm) continues down to the

3960 and 3945 levels with the assistance of a booster fan and 9.4 m^3/s (20,000 cfm) is supplied to the 4035 level. Similarly, 26 m^3/s (55,000 cfm) from the 4110-4035 west service raise is split at the 4035 level; 16.5 m^3/s (35,000 cfm) continues down to the 3960 and 3945 levels with the assistance of a booster fan and 9.4 m^3/s (20,000 cfm) is supplied to the 4035 level.

The 4035 level exhaust air, 18.9 m^3/s (40,000 cfm), is directed to the west exhaust raise via the shaft access drift ('4020 shaft station to 4035 level access drift'). A booster fan, located in the 4020 shaft station, is used at the 4020-4110 west exhaust raise, to provide exhaust pressure to ERAR.

Airflow Management in the 3960 Level

The main supply of fresh air to the 3960 level are the 4035-3960 east and west service raises. Auxiliary fans, mounted on bulkheads at each service raise, are used to supply 9.4 m^3/s (20,000 cfm) of air each to the production faces. The 16.5 m^3/s (35,000 cfm) of fresh air from the 4035-3960 east service raise is split at the 3960 level; 9.4 m^3/s (20,000 cfm) is supplied to the 3960 level and 7.1 m^3/s (15,000 cfm) continues down to the 3945 level. This split is controlled by a regulator installed in the 3960 level. Similarly, 16.5 m^3/s (30,000 cfm) from the 4035-4360 west service raise is split, using a regulator, at the 3960 level; with 9.4 m^3/s (15,000 cfm) continuing down to the 3945 level and 9.4 m^3/s (20,000 cfm) being supplied to the 3960 level.

The 3960 level exhaust air, 18.9 m^3/s (40,000 cfm), is directed to the west exhaust raise via the '3945-3960 access ramp'.

Airflow Management in the 3945 Level

The main supply of fresh air to the 3945 level are the 3960-3945 east and west service raises. Auxiliary fans, mounted on bulkheads at each service raise, are used to supply 7.1 m^3/s (15,000 cfm) of air each to the production faces. The 3945 level exhaust air, 14.2 m^3/s (30,000 cfm), is directed to the west exhaust raise via the '3975 shaft station to 3945 level access drift'. A booster fan, located in the 3975 shaft station, is used to provide exhaust pressure to the 3975-4020 west exhaust raise.

MODEL SIMULATIONS

As previously mentioned, a number of booster and auxiliary fans and regulators will be required to control the air distribution in Block 5 during full production. A ventilation model was developed and a series of simulations were performed to size the fans and regulators and to evaluate different mining and ventilation scenarios, to arrive at the most practical and economic alternatives.

A ventilation model comprising the entire mine was first run to find flows and pressures at the raises and drifts supplying air to and exhausting air from Block 5. An independent model for Block 5 was then developed using the boundary flow and pressure conditions established by the model run for the entire mine. In the model the raises were 3 m by 3 m (10' by 10') and the level drifts were 4 m by 3.5 m (13.1' by 11.5') and the ramps 5.5 m by 5 m (18' by 16.4') in size.

Figure 4 shows the ventilation circuit for Block 5 with design flows; it corresponds with all the ventilation airways previously described and presented in Figure 2. The model comprises a total of 54 nodes and 77 branches. Four booster fans and eight auxiliary fans are used to maintain flow.

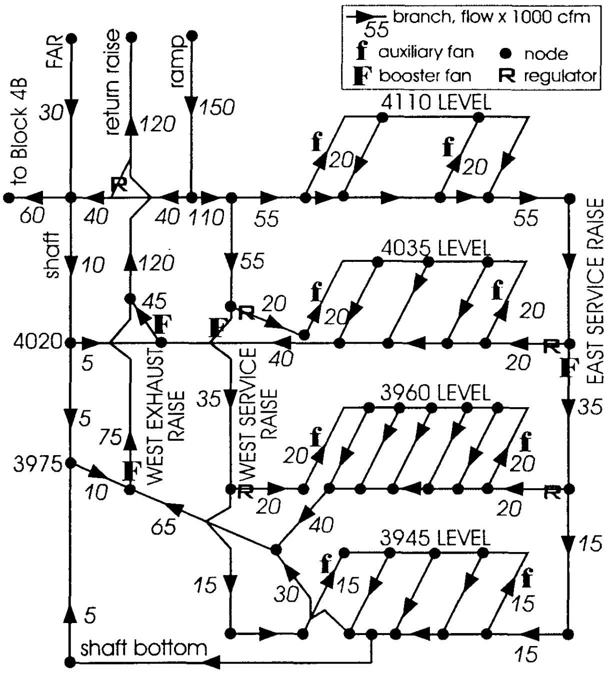

Figure 4. Ventilation circuit for Block 5

Simulations have indicated that Block 5 has low resistance characteristics, requiring relatively low pressures to generate the flow distribution.

The booster fans required flows ranged from 21.2 m^3/s (45,000 cfm) at the 4035 level west exhaust raise, to 26 m^3/s (55,000 cfm) at the service raises, and to 35.4 m^3/s (75,000 cfm) at the 3960 level west exhaust raise. Required pressures approximated 0.5 to 0.75 kPa (2 to 3" w.g.) and 1.22 m (48") diameter fans were selected.

The duct systems ranged in length between 64.6 m (212') and 163 m (536'). Required flows were 9.4 m^3/s (20,000 cfm) at the 4110, 4035 and 3960 levels, and 7.1 m^3/s (15,000 cfm) at the 3945 level. Auxiliary fans of 0.61 m (24") diameter were sized, for pressures ranging between 2 kPa (8" w.g.) and 3 kPa (12" w.g.).

CONCLUSIONS

The complexity of designing the ventilation system for a new orebody at depth has been described, showing how the integration of the development and production phases of mining were implemented to attain the most practical ventilation layout for the economic exploitation of Block 5. It demonstrated how practical experience - through the direct involvement of production, planning and ventilation departments - and modelling can be combined to achieve success.

REFERENCES

De Souza, E., Gotz, L., Krog, R. and Watkinson, J., 2001, "Conversion of a backfill raise to a ventilation exhaust

raise, a success story," Proceedings, 15th Mine Operators' Conference. CIM, Sudbury, Ontario, pp. 8.
De Souza, E., 2000, "Examination of preliminary ventilation design for Block 5," Internal report, Battle Mountain Canada Ltd., Golden Giant Mine. pp. 17.
De Souza, E. and Gotz, L., 1999, "Simulation of airflow expansion requirements for an exhaust raise common to two mines," Proceedings, Eighth U.S. Mine Ventilation Symposium, UMR, Rolla, pp. 559-563.
Gotz, L. and De Souza, E., 1999, "Optimization of main exhaust system at Battle Mountain Gold Ltd. Golden Giant Mine," Proceedings, Eighth U.S. Mine Ventilation Symposium, UMR, Rolla, pp. 605-609.
Krog, R.B., 2000, "Assessment and recommendation for the ventilation system at the Golden Giant Mine," M.Sc. Thesis, Department of Mining Engineering, Queen's University, pp. 182.
Williamson, S., 2000, "The ventilation design of Block 5 at Golden Giant Mine," B.Sc. Thesis, Department of Mining Engineering, Queen's University, pp. 58.