MODELLING OF AN EXHAUST SYSTEM SHARED BY TWO NEIGHBOURING MINES

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ABSTRACT

Golden Giant mine, located near the north shore of Lake Superior in Ontario, is one of the largest gold producers in Canada, operating at 3000 tonnes per day in an underground trackless operation utilizing longhole stoping. The mine primary ventilation system is based on a push-pull configuration, with two fresh air raises supplying 458 m^3/s (970,000 cfm) and three exhaust raises and production shaft exhausting 529 m^3/s (1,120,000 cfm). The balance of the air (71 m^3/s or150,000 cfm) is transferred from a neighbouring mine, the David Bell Mine. The Golden Giant mine is planning the mining program for its crown pillar which is located under the exhaust system of a second neighbouring mine, the Williams mine. In order to improve its exhaust capacity, Golden Giant is planning to extend its internal ramp to intersect one of Williams primary exhaust raises, in order to transfer 57 m^3/s (120,000 cfm) of exhaust air to the Williams mine exhaust system. This paper presents a complex design and modelling study developed to assess the technical feasibility of integrating the exhaust systems from the two neighbouring mines.

KEYWORDS

modelling, simulation, design, exhaust ventilation

INTRODUCTION

The Hemlo gold deposit is a high grade orebody shared among three mining companies, Battle Mountain Gold (BMG), Williams Operating Corporation and Teck Corona Operating Corporation. The deposit is estimated to contain 21.2 million ounces of gold in 84.78 million tonnes of rock. Battle Mountain Golden Giant mine operates at 3000 tonnes per day from 9.15 million tonnes of reserves grading 9.96 g/t, Williams operates at 6600 tonnes per day from 32.15 million tonnes of reserves grading 5 g/t, and Teck Corona David Bell mine operates at 1200 tonnes per day from 5.06 million tonnes of reserves grading 9.98 g/t. The three production mines, although managed and operated independently share a number of components of their ventilation network including access ramps, exhaust raises and escapeways.

The Golden Giant mine is planning the mining program for its crown pillar, located under the Williams mine exhaust system, shown in Figure 1. In order to improve its exhaust capacity, Golden Giant will be extending its internal ramp to intersect one of Williams primary exhaust raises, as indicated in Figure 1. In this manner Golden Giant plans to transfer 57 m^3/s (120,000 cfm) of exhaust air to the Williams ‘A’ zone exhaust system. Utilization of the Williams exhaust system by Golden Giant offers a major technical challenge. The addition of 57 m^3/s (120,000 cfm) to the Williams mine must be managed such that its existing fan configuration is not overloaded and its current air distribution is not greatly affected.

This paper presents a complex design and modelling study developed to provide engineering specifications for integrating the exhaust systems from the two neighbouring mines. A ventilation model incorporating the two mines was developed and calibrated, and a multitude of scenarios were simulated in order to achieve the most practical concept which would permit the utilization of the Williams exhaust system by Golden Giant without violating a number of restraining ventilation and air quality conditions. The most practical ventilation layouts which have been designed and modelled are presented, including the sizing of required booster fans, regulators and internal raises. A comparison of alternatives is presented to demonstrate how the final layout was selected for implementation in the field.

THE WILLIAMS ‘A’ ZONE EXHAUST SYSTEM

The Williams ‘A’ zone exhaust system, illustrated in Figure 1, is represented by a complex network of raises and level drifts as described below. Four booster fans, installed in series-parallel in the 9975 level , are the primary movers of exhaust air. The fans are 149 kW (200 HP) Joy Series 2000 Axivane 78-30-1170, with a blade setting of 2.5. At the installed blade setting, the fans can normally operate at a flow ranging between 113.3 and 169.9 m^3/s (240,000 and 360,000 cfm) with corresponding total pressures of 3.0 and 0.77 kPa (12.21 and 3.1" w.g.). The 'A' zone is made up of relatively large, unrestricted airways, and represents a network of relatively low resistance. The exhaust network has the capacity to accommodate an increased volume of exhaust air without greatly affecting the 9975 booster fans.

At the 9975 level, air from the booster fans follows four different routes. Approximately 14.2 m^3/s (30,000 cfm) exhausts directly to atmosphere via the A-shaft exhaust with small underground booster fans connected to it. At the access drift 'A' to 'B' zone shaft, the direction of flow can be reversed as required by the ventilation department. In Figure 1, approximately 16.5 m^3/s (35,000 cfm) is directed to 'B' zone. The ramp to the 10045 level provides the route of lowest resistance in the network and directs most of the exhaust air volume, 66.1 m^3/s (140,000 cfm), to other airways of the network. The 9975 to 9992 level access drift, exhausting 49.6 m^3/s (105,000 cfm), provides air route to the 9992 level. At the 9992 level air splits at a ratio between 1.5:1 to 1.8:1 to the East exhaust raise and to the West exhaust and West backfill raises. Some restriction to flow exists at the West exhaust and at the West backfill raises; both raises offer limited exhaust flow capacity. The East exhaust raise, on the other hand, offers an excellent parallel exhaust route to the ramp. Restriction to flow at the 10072 level connection exists in the form of a stopping.

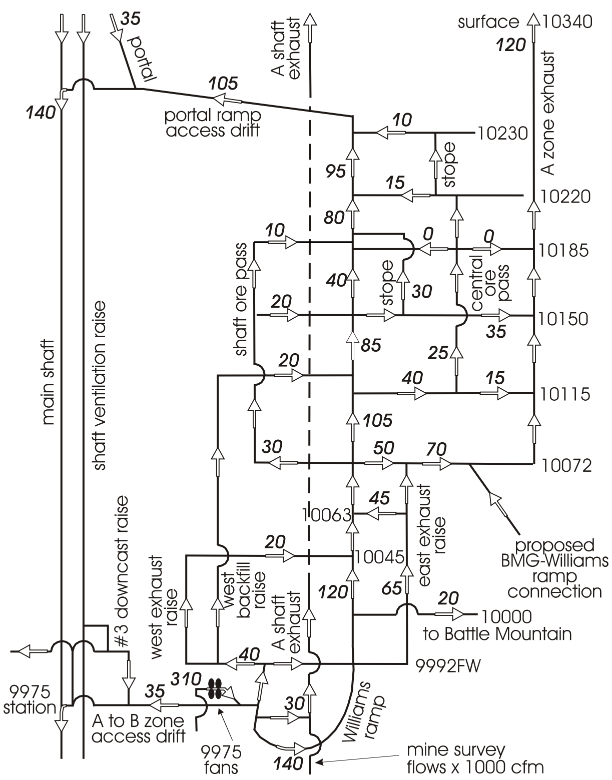

Figure 1. The Williams 'A' zone exhaust system

The 10000 level connects the two mines, with minimum leakage, through an airlock. At the 10045 level, the West exhaust raise connects to the ramp and the 10063 level provides an exhaust air route from the east exhaust raise to the ramp.

At the 10072 level the shaft ore pass exhausts minimum volume of air to the 10150 and 10185 levels. The connection at the 10072 level is via a dump door/finger raise. At the east of the 10072 level, exhaust connection to the 'A' zone exhaust raise is established. As will be later discussed, this airway would serve as the exhaust route from the BMG 5023 ramp to exhaust 56.6 m^3/s (120,000 cfm). A booster fan would be required at this location.

The 10115 level also provides exhaust connection to the 'A' zone exhaust raise. A central ore pass, extending from the 10115 level to the 10220 level, offers an important parallel exhaust air route to the 'A' zone exhaust raise.

The 10150 level also connects to the 'A' zone exhaust raise, with a regulator installed at the connection drift. The connection of the 10150 level to the central ore pass is closed by a gate. A parallel exhaust air route is also provided via an open stope at the 10150 level. The 10185 level provides an air route from the open stope to the Williams ramp. Although access to the 'A' zone exhaust raise is available, minimum flow exhausts via the central ore pass to the raise due to regulation.

VENTILATION MODEL DEVELOPMENT AND CALIBRATION

An equivalent ventilation circuit was developed to simulate the 'A' zone exhaust system, as shown in Figure 2. Each airway was characterized by sectional dimensions and length, k factor and resistance. A combined curve for the 9975 fans was also incorporated into the ventilation model.

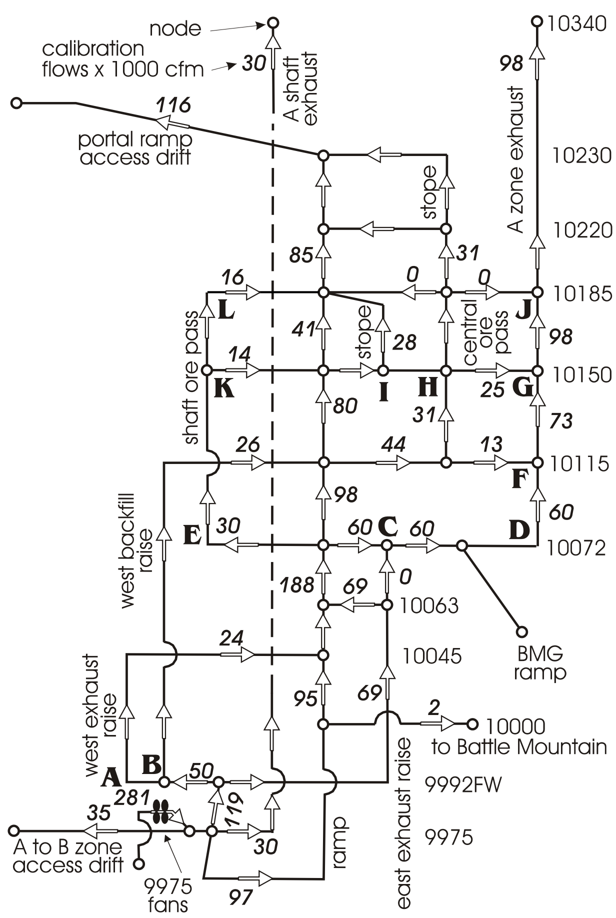

Figure 2. Ventilation circuit for the Williams 'A' zone exhaust system

Extensive model calibration work was performed by matching model flows with actual flow distributions based on underground surveys, and by matching model fan operating points with field readings. The calibration process involved the adjustment in airway resistance, the incorporation of stoppings, regulators and doors correspondent to underground installations, and the simulation of such features as muck piles, stopes, etc. as per actual underground conditions. The calibration flows are shown in Figure 2 and can be readily compared with the mine survey flows listed in Figure 1. Some of the calibration features used to match the underground conditions, described in section 2, are listed below:

- restriction was incorporated at the West exhaust raise, 9992 level, to replicate a muck berm (A, Figure 2);
- restriction was incorporated at the West backfill raise, 9992 level, to replicate an existing culvert (B, Figure 2);
- regulation was incorporated at the East exhaust raise, 10072 level, to replicate a stopping (C, Figure 2);
- restriction was incorporated at the 10072 level connection to the 'A' zone exhaust raise, to replicate an existing door frame (D, Figure 2);
- restriction was incorporated at the 10072 level connection to the shaft ore pass, to replicate a dump door/finger set up (E, Figure 2);
- restrictions were incorporated at the 10115 level east drift to replicate a muck pile and level regulator (F, Figure 2);
- regulation was incorporated at the 10150 level east drift to replicate a level regulator (G, Figure 2);
- regulation was incorporated at the central ore pass connection to the 10150 level, to replicate a closed gate (H, Figure 2);
- regulation was incorporated at the open stope draw point, 10150 level, to replicate a muck berm (I, Figure 2);
- regulation was incorporated at the 10185 level east drift to replicate a level regulator (J, Figure 2);
- restrictions were incorporated at the 10150 and 10185 level connections to the shaft ore pass, to replicate dump door/finger set ups (K, L, Figure 2).

CONDITIONS TO BE MET AND PRELIMINARY MODEL SIMULATIONS

A number of conditions had to be met in order to permit appropriate incorporation of an additional 57 m^3/s (120,000 cfm) into the Williams 'A' zone exhaust raise:

- The flow distribution and pressures at the Williams exhaust circuit should not be greatly affected;
- Any changes to the system should not generate excessive pressures at the 9975 level booster fans. Such fans should run within their operating range, previously described;
- The flow volume exhausting via the portal ramp access drift should not drop below 89.7 m^3/s (190,000 cfm);
- Ideally, the Williams exhaust volume to the 'A' zone exhaust raise should be maintained at or below 66.1 m^3/s (140,000 cfm).

Model Simulations

A sequence of simulations was initially developed to assess the possibility of utilizing the 'A' zone exhaust raise to receive exhaust air from the BMG 5023 ramp. Over 50 models were developed and tested to primarily to verify the sensitivity of design changes on the established conditions. Results of this preliminary work would then be used to refine and re-calibrate the model for further detailed assessment, and to arrive at a practical layout for implementation. Some of the preeminent results of the preliminary simulation work are provided.

An initial simulation was made to evaluate the requirements of a surface fan installation at the A-zone exhaust. A forced flow of 122.7 m^3/s (260,000 cfm) was placed at the raise (A, Figure 3). Results indicated that the surface fans would be run at 0.47 kPa (1.87" w.g.) and that the 9975 fans would experience an increase in pressure to 2.81 kPa (11.28" w.g.). The ramp would exhaust 56.6 m^3/s (120,000 cfm) at a required pressure of 0.38 kPa (1.53" w.g.). Such results, backed by cost analysis, indicated that underground booster fans would provide a better alternative.

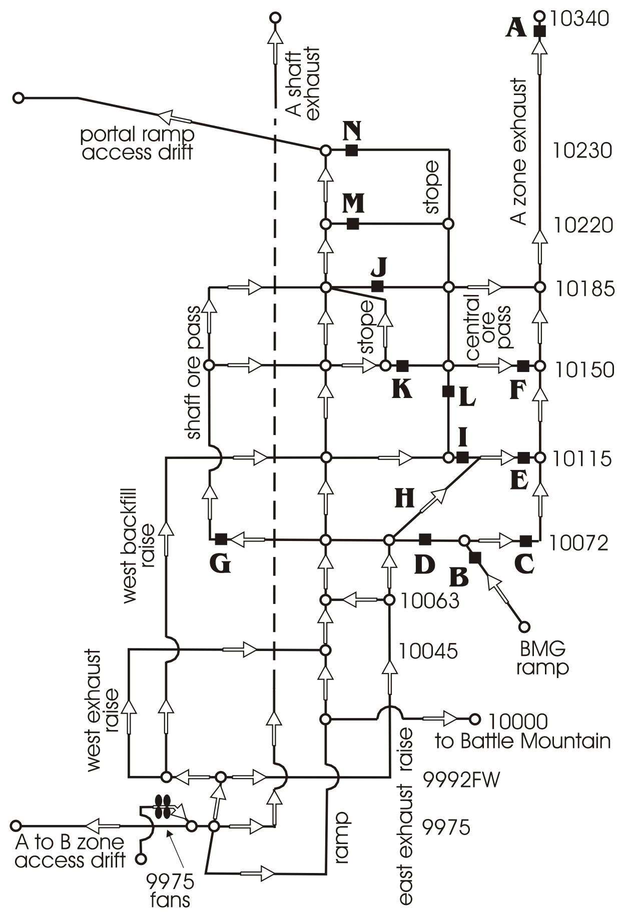

Figure 3. Underground stations modified during preliminary simulations

A simulation was then developed to incorporate a forced flow of 56.6 m^3/s (120,000 cfm) at the BMG ramp to simulate a booster fan at the BMG-Williams intersection (B, Figure 3). This simulation indicated that the required fan pressure at the ramp should approximate 0.38 kPa (2.25" w.g.) to achieve the required flow. As a result, a decrease in exhaust capacity at the 10072 and 10115 levels occurred and the 9975 fans experienced a head of 2.99 kPa (12" w.g.). An increase in flow at the portal ramp access drift was also observed. This showed that fans should not be used at the BMG ramp pressurizing the Williams exhaust system.

Further simulations, now with a booster fan placed at the 10072 east drift (C, Figure 3), to exhaust 56.6 m^3/s (120,000 cfm) from the BMG ramp actually resulted in a reversal of flow at the BMG ramp with a consequent increase in flow at the 10072 west drift, in some cases reaching 112.3 m^3/s (238,000 cfm). Also, when a bulkhead was placed at the 10072 west drift (D, Figure 3), with no flow forced at the BMG ramp and no fan at the 10072 east drift, the flow reversed at the BMG ramp at 61.3 m^3/s (130,000 cfm) and the 9975 fans pressure reduced to 2.68 kPa (10.75" w.g.). These simulations indicated the necessity of incorporating simultaneous control and regulation at the 10072 level to achieve the desired flow conditions.

A more particularized simulation followed by incorporating a bulkhead the 10072 west drift (D, Figure 3) and a booster fan at the 10072 east drift (C, Figure 3) set at 56.6 m^3/s (120,000 cfm), and with no flow forced at the BMG ramp. Pressure requirements for the 10072 booster fan were 0.51 kPa (2.06" w.g.) and the 9975 fans pressure increased to 3.02 kPa (12.13" w.g.), due to the restriction in flow at the 10072 west drift. The pressures in the network were also increased due to the restriction in the 10072 west drift. This showed how regulation can readily create undesirable excess pressures.

Several simulations were designed to alleviate the pressure at the 9975 fans. One simulation incorporated a booster fan at the 10072 east drift (C, Figure 3) and a booster fan at the 10115 level (E, Figure 3), both set at 56.6 m^3/s (120,000 cfm). The 10072 west drift was bulkheaded (D). The 10115 booster fan had little effect on the 9975 fans, such fans experienced a pressure of 3.0 kPa (12.03" w.g.). Further simulations were attempted to verify the effect of such changes in layout as installing regulators of different sizes in the 10072 west drift (D, Figure 3), instead of bulkheads, but no appreciable gains were observed. A simulation attempted to move the booster fan from the 10115 level to the 10150 level (F, Figure 3), set at 56.6 m^3/s (120,000 cfm). In this case, the flow reversed at the 10115 level. Little effect was experienced by the 9975 fans (pressure 2.93 kPa, 11.76" w.g.). Such simulations indicated the ineffectiveness of booster fans installed in at the 10115 or 10150 levels if proper regulation is not provided.

Other simulations attempted to install a booster fan at the shaft ore pass (G, Figure 3), set at 56.6 m^3/s (120,000 cfm), with the 10072 west drift regulated (D, Figure 3), and with a booster fan installed in the 10072 level (C, Figure 3), set at 63.7 m^3/s (135,000 cfm). The pressure at the 9975 fans was 2.94 kPa (11.8"), and the flow at the BMG ramp was 57.1 m^3/s (121,000 cfm). When an additional fan was installed in the 10115 level (E, Figure 3), set at 56.6 m^3/s (120,000 cfm), the pressure at the 9975 fans reduced slightly to 2.91 kPa (11.69" w.g.), and the flow at the BMG ramp remained at 57.1 m^3/s (121,000 cfm). Such simulations indicated the little influence a booster fan at the shaft ore pass would have on the 9975 fans.

Previous simulations have indicated the impact the 10072 west drift has on the 9975 fans. Several simulations were designed to fully utilize the 10072 west drift by placing a booster fan in it (D, Figure 3) set at 42.5 m^3/s (90,000 cfm). A booster fan is also placed at the ramp (B, Figure 3), set at 56.6 m^3/s (120,000 cfm). Under these conditions, the 9975 fans experienced a pressure of 2.96 kPa (11.87" w.g.). The 10072 booster fan operated at 0.13 kPa (0.51" w.g.) and the ramp fan operated at 0.64 kPa (2.56" w.g.). The flow reversed in the 10115 level at 19.8 m^3/s (42,000 cfm). When the 100115 level was bulkheaded to prevent flow reversal, the flow reversed in level 10150 at 6.6 m^3/s (14,000 cfm). When both 100115 and 10150 levels were bulkheaded, the 9975 fans experienced a pressure of 2.91 kPa (11.70" w.g.).

A model was developed to verify the effect of extending the east exhaust raise to the 10115 level (H, Figure 3). Booster fans were placed in the 10072 west drift (D, Figure 3), set at 42.5 m^3/s (90,000 cfm), and at the BMG ramp (B, Figure 3), set at 56.6 m^3/s (120,000 cfm).The 9975 fans experienced a pressure of 2.93 kPa (11.78" w.g.). The flow in the 10115 level was reversed due to the higher pressure at the 'A' zone exhaust raise in relation to the level pressures. Another simulation was attempted to control the flow in the 10115 level by installing a bulkhead in the east drift, between the central ore pass and the east exhaust raise (I, Figure 3). The 9975 fans (pressure of 2.94 kPa, 11.8" w.g.) were relatively unaffected by the change.

A more detailed model incorporated the east exhaust raise extension to the 10115 level (H, Figure 3), a booster fan placed at the 10072 level (C, Figure 3) to exhaust the 5023 ramp air, and a booster fan placed at the 10115 level (E, Figure 3) to pull 56.6 m^3/s (120,000 cfm) up the extended east exhaust raise. The 10072 west drift (D, Figure 3) and the 10150 east level drift (I, Figure 3) were also bulkheaded. Under this layout, the 9975 fans experienced a pressure of 2.83 kPa (11.36" w.g.). The 10072 level booster fan operated at 0.72 kPa (2.9" w.g.) and the 10115 level booster fan operated at 0.47 kPa (1.88" w.g.). This model seemed to satisfy the requirements for exhausting air from the BMG 5023 ramp without affecting the Williams A zone exhaust conditions. It however required the development of 46 m (150') of a 2.1 x 2.1 m (7' x 7') raise connecting the 10072 and 10115 levels, considered an expensive alternative.

A simulation considered the placement of a high-flow booster fan at the 10072 east drift (C, Figure 3), set at 99.1 m^3/s (210,000 cfm) and the regulation of the 10072 west drift (D, Figure 3) to approximately 42.5 m^3/s (90,000 cfm). Under these conditions, the 9975 fans experienced a pressure of 2.95 kPa (11.85" w.g.) and the 10072 booster fan operated at 0.64 kPa (2.55" w.g.). The flow at the BMG ramp approximated 56.2 m^3/s (119,000 cfm). Also, the flow in the 10115 level reversed, at 19.8 m^3/s (42,000 cfm). A subsequent simulation incorporated regulators at the 10115 and 10150 levels (E and F, Figure 3) to eliminate the reversal of flow. Minimum changes to conditions were encountered.

A more evolved model, developed to eliminate the need for extending the east exhaust raise, included booster fans installed at the 10072 east drift (C, Figure 3), at the 10150 east drift (F, Figure 3), and at the shaft ore pass (G, Figure 3), all set at 56.6 m^3/s (120,000 cfm). The 10072 west drift (D, Figure 3) and the 10115 east drift (E, Figure 3) were bulkheaded. Under these conditions, the 9975 fans experienced a pressure of 2.86 kPa (11.47" w.g.). The 10072 booster fan operated at 0.64 kPa (2.57" w.g.), the

10150 fan operated at 0.28 kPa (1.14" w.g.) and the shaft ore pass fan operated at 1.0 kPa (4" w.g.). Although the model layout was satisfactory, three underground booster fans were considered an unecessary expense.

An elaborate model was developed to simulate a more practical layout. In this model the 10185 level was closed off (J, Figure 3), the 10150 level east was closed off (K, F, Figure 3), the central ore pass was closed off (L, Figure 3), the 10220 level was closed off (M, Figure 3), the 10230 level and stope were closed off (N, Figure 3), and the 10072 west drift was bulkheaded (D, Figure 3). The east exhaust raise was also extended to the 10115 level (H, Figure 3). A booster fan at the 10072 east drift (C, Figure 3), and a booster fan at the 10115 level east (E, Figure 3), both set at 56.6 m^3/s (120,000 cfm), were incorporated into the network. Under these conditions, the 9975 fans experienced a pressure of 2.9 kPa (11.63" w.g.). The 10072 booster fan operated at 0.76 kPa (3.06" w.g.) and the 10115 booster fan operated at 0.35 kPa (1.41" w.g.). Such layout, although complex in configuration, seemed to conform to the restrictions established by the mines.

Conclusions from the Preliminary Simulation Work

The model simulations described above have indicated the following conclusions:

- The use of underground booster fans may be more feasible than surface fans;
- The circuit characteristics call for low pressure-high flow underground booster fan(s);
- The 10185, 10150 and 10115 levels are very sensitive to pressures developed in the 'A' zone exhaust raise, and flows can easily reverse in such levels if not properly sealed off or pressurized with an appropriate booster fan;
- The central ore pass and connected airways (10185 and 10220 west drift and 10230-10220 stope) provide an important air route system and could provide pressure relief for the 'A' zone exhaust raise;
- The 10150-10185 stope provides an important exhaust route at the 10150 level.

MODEL REFINEMENT AND RE-CALIBRATION

The preliminary simulation work provided the technical information to permit the incorporation of a number of modifications to the layout of the 'A' zone exhaust system which would enable the introduction of an additional 56.6 m^3/s (120,000 cfm) into the system and at the same time meet the requirements listed in section 4. The primary concept of the modified layout was to establish two parallel exhaust routes within the 'A' zone network: the 'West Exhaust Route' (consisting of the ramp, West exhaust raise, West backfill raise, shaft ore pass and portal access drift) and the 'East Exhaust Route' (consisting of the 'A' zone exhaust raise, East exhaust raise and central ore pass).

The West Exhaust Route would continue to operate at its current configuration, with the primary air pathway being via the ramp. This route would also offer the potential to accommodate further increases in exhaust flow volume by augmenting utilization of the shaft ore pass, West exhaust raise, and West backfill raise.

The East Exhaust Route was modified to accommodate the additional flow from the BMG 5023 ramp, as follows. These changes were also actualized underground.

- the East exhaust raise stopping at the 10072 level (C, Figure 2) is removed;
- the 10115 level West drift is mucked out and the regulator (F) is removed;
- the 10150 level regulator (G) is removed;
- the 10150 level connection to the central ore pass (H) is opened.

Extensive re-calibration of the refined model was then made, until matching of model flows with actual flow distributions based on underground surveys, and matching model fan operating points with field readings were achieved. The re-calibrated model was used for a detailed analysis of alternatives, presented below.

REFINED MODEL SIMULATIONS

A sequence of simulations was developed to design the required modifications to the mine ventilation layout which would permit expansion of the 'A' zone exhaust system, yet satisfying the conditions described in Section 4. Although a multitude of model simulations were performed, only two pertinent models are presented.

Simulation A

Simulation A, shown in Figure 4, aimed at dedicating the 10072 level East drift to the BMG 5023 ramp by discontinuing airflow from the Williams ramp to the 10072 East drift through the installation of a bulkhead (A, Figure 4). A Joy Series 2000 Axivane 60-26-1170 booster fan (B, Figure 4), blade setting 0, was also installed at the 10072 east drift connection to the 'A' zone exhaust raise to provide the operating exhaust pressure for the BMG ramp. Other modifications made to the layout, necessary to satisfy the stated requirements, included: airflow through levels 10230, 10220 and 10185 was curtailed by the installation of bulkheads (C, D, E, Figure 4); and airflow from the Williams ramp to the 10150 West drift was discontinued by the installation of a bulkhead (F, Figure 4).

Under these conditions, the 9975 level fans experienced a static pressure of 2.58 kPa (10.35" w.g.) at 129.3 m^3/s (274,000 cfm), thus indicating that the 10072 airway has a modest effect on the performance of the 9975 fans. Use of the 10072 level East drift to solely exhaust 5023 ramp air thus seemed feasible, even though the Williams exhaust flow at the 'A' zone exhaust raise increased to 77.4 m^3/s (164,000 cfm) from 46.3 m^3/s (98,000 cfm). Also, with the installation of the 10072 bulkhead (A, Figure 4), most of the 28.3 m^3/s (60,000 cfm) previously exhausted via the 10072 east drift, now exhausted via the Williams ramp, resulting in an increase in flow at the portal ramp. The operating point of the 10072 booster fan was 0.62 kPa (2.5" w.g.) static pressure, 66.1 m^3/s (140,000 cfm), 59.7 kW (80 HP) break power, 67% efficiency. Although this fan exceeded the design BMG ramp flow by some 9.4 m^3/s (20,000 cfm), the overall flow distribution fell within the required conditions.

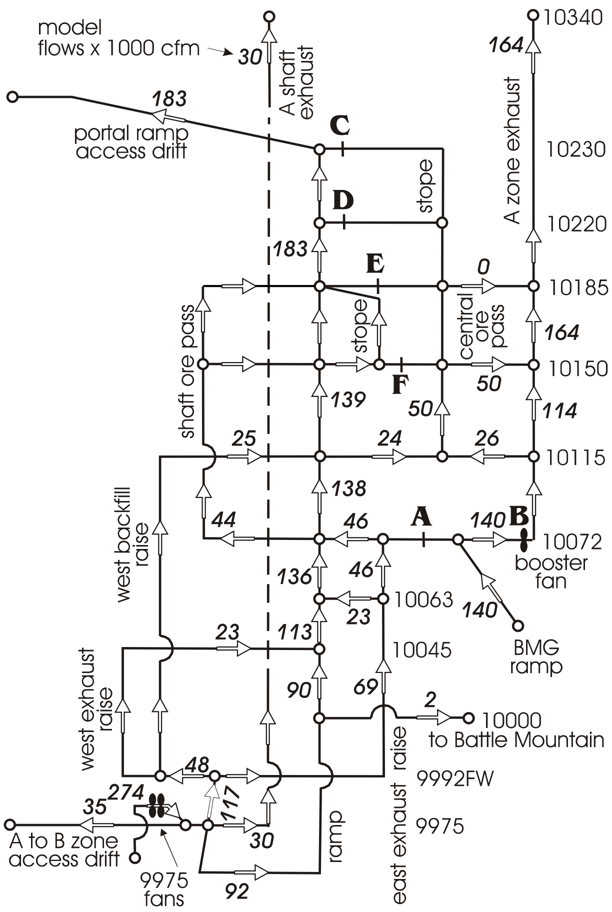

Figure 4. Model results for simulation A

Regulation in the upper levels had a minimum effect on the overall resistance of the 'A' zone network; the Williams exhaust flow was simply redirected to the Williams ramp. It is noted that the Williams exhaust flow contribution to the 'A' zone exhaust raise volume flow was now only 11.3 m^3/s (24,000 cfm). This confirmed the authors presumption that the 'A' zone is made up of relatively large, unrestricted airways, and represents a network of relatively low resistance and that the ramp seems to provide the route of lower resistance in the network, followed by the 'A' zone exhaust raise. Any changes to the access routes to the 'A' zone exhaust raise (10072, 10115 and 10150 level east drift connections) would thus increase the flow at the ramp and portal access drift without compromising the Williams exhaust requirements.

The layout represented in simulation A seemed favourable for further implementation. Although it seemed that reduction of Williams exhaust flow at the 'A' zone exhaust raise did not have any abnormal effect on its operating capacity, a plausible provision was considered by the installation of a booster fan at the 10115 level, as described by simulation B.

Simulation B

Previous models, which let to the perfected model represented by simulation A, have indicated that restriction of Williams exhaust flow at the 10072 level East drift would result in air volume to preferentially exhaust via the ramp and portal drift (path of lowest resistance). If Williams exhaust air flow is to be sustained toward the 'A' zone exhaust, airflow would have to be forced by a booster fan, via 10115 and 10150 levels (path of higher resistance). Simulation B had a similar layout to simulation A, but incorporates a Joy Series 2000 Axivane 60-26-1170 booster fan, blade setting 0, at the 10115 level connection to the Williams ramp, as shown in Figure 5.

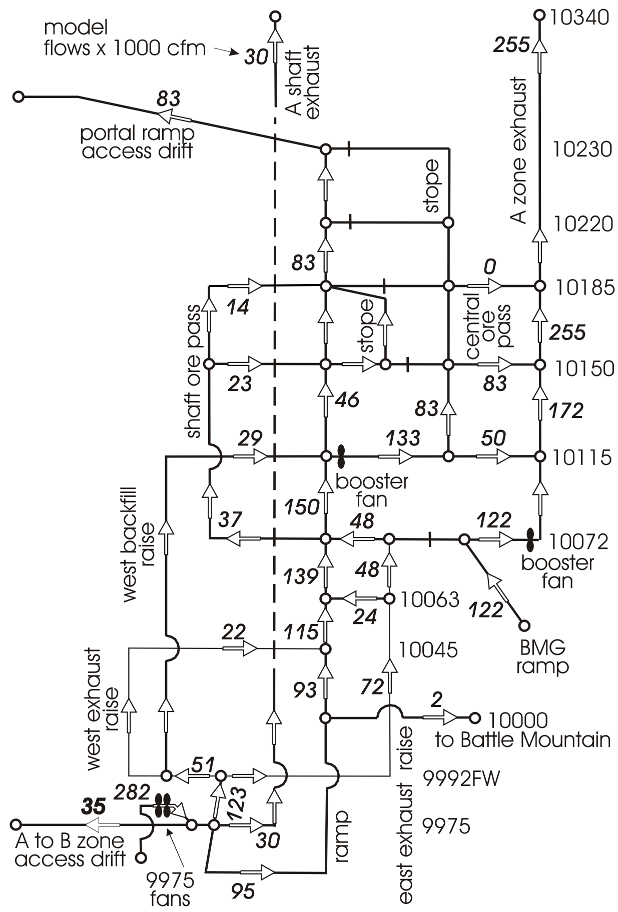

Figure 5. Model results for simulation B

Model results indicated that the 10115 booster fan had an effect of reducing the static pressure at the 9975 level 200 HP fans to 2.44 kPa (9.8" w.g.). The 10072 level booster fan now drew 57.6 m^3/s (122,000 cfm) from the BMG ramp, at a static pressure of 1.06 kPa (4.27" w.g.).

The flow distribution at the 'A' zone network seemed to fall within the required conditions and the Williams exhaust flow at the 'A' zone exhaust raise was 62.8 m^3/s (133,000 cfm). Naturally, the air volume exhausting via the portal drift was reduced to satisfy for the flow balance. It is thus noted that design modifications made to satisfy one condition (Williams exhaust volume to the 'A' zone exhaust raise to be maintained at 66.1 m^3/s, 140,000 cfm), would compromise the other (the flow volume exhausting via the portal ramp access drift not to drop below 89.7 m^3/s, 190,000 cfm).

As previously discussed, it is believed that a reduction of Williams exhaust flow toward the 'A' zone exhaust raise may not have any negative effect on the system overall operating capacity, as the western side of the network has the capacity to accept additional air volume. Installation of a booster fan at the 10115 level was therefore seen as a back up option, for situations at which Williams exhaust air volumes became inadequate.

CONCLUSIONS

This paper presented a complex ventilation network simulation work developed to combine the exhaust of two neighbouring mines. It showed how model calibration and refinement based on underground observations and on survey data plays an important role in developing realistic engineering designs.

Only after a two-phased study represented by multiple simulations and model re-calibrations was successfully accomplished that a favourable layout was developed. The premise was to establish two parallel exhaust routes within the 'A' zone network: the 'West Exhaust Route' and the 'East Exhaust Route'. The 'East Exhaust Route' would accommodate the additional 56.6 m^3/s (120,000 cfm) of BMG exhaust air volume into the network without greatly affecting the Williams exhaust conditions. The layout primarily involved the installation of a bulkhead at the 10072 West drift and the placement of a booster fan at the drift connection to the 'A' zone exhaust raise. Some rehabilitation work and installation of bulkheads were also considered. Also considered was the installation of a booster fan at the 10115 level. The design was approved by both companies and is being currently implemented.

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