Winter ventilation scenarios at Golden Giant mine

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ABSTRACT: Golden Giant mine, Newmont Canada Limited, is situated in North Western Ontario, Canada. Due to operational needs, the capacity of the exhaust ventilation system in the upper part of the mine was increased by 25% by partly utilizing the exhaust system of a neighboring mine. The increase in exhaust capacity in the upper mine was not followed by an equal decrease in exhaust capacity in the lower mine. The total exhaust capacity surpassed the intake capacity of the mine. This newly created imbalance caused the mineshaft airflows to downcast. Under the climatological conditions of North Western Ontario it is imperative that during the cold season warm, heated air travels upshaft. This paper describes the methodology used to achieve and maintain upcast flow conditions in the production shaft.

1 INTRODUCTION

The Golden Giant mine, located in the province of Ontario, Canada, began production in 1985. The ore body is part of the Hemlo gold deposit which is shared among three mines: Williams mine (Williams Operating Corporation), Golden Giant mine (Newmont Canada Ltd.) and David Bell mine (Teck Corona Operating Corporation).

Williams mine, extracting the Western side of the orebody, operates at 6,600 tonnes per day from 32.15 million tonnes of reserves grading 5 g/t. Golden Giant mine, extracting the Central part of the ore body, operates at 2,800 tonnes per day from 9.15 million tonnes of reserves grading 9.96 g/t. David Bell mine, extracting the Eastern side of the orebody, operates at 1,200 tonnes per day from 5.06 million tonnes of reserves grading 9.98 g/t.

The Golden Giant primary ventilation system is a complex network of raises capable of handling 481 m^3/s. Any changes to such complex and very sensitive ventilation network must be well planned, in particular because the ventilation systems of the three mines are interconnected. The original mine ventilation system is schematised in Figure 1.

In order to increase its ventilating capacity in the upper areas, the Golden Giant mine established a parallel connection to Williams exhaust system. Such modification to the ventilation layout resulted in the reversal of flow in the mine production shaft. This situation is not permitted because of the freezing air temperatures normally developed during the long winter season. Because of the variation in pressures along the production shaft, the maintenance of flow direction within the shaft is not an easy task. The several studies and attempts made to achieve steady upcast conditions in the shaft are presented in this paper.

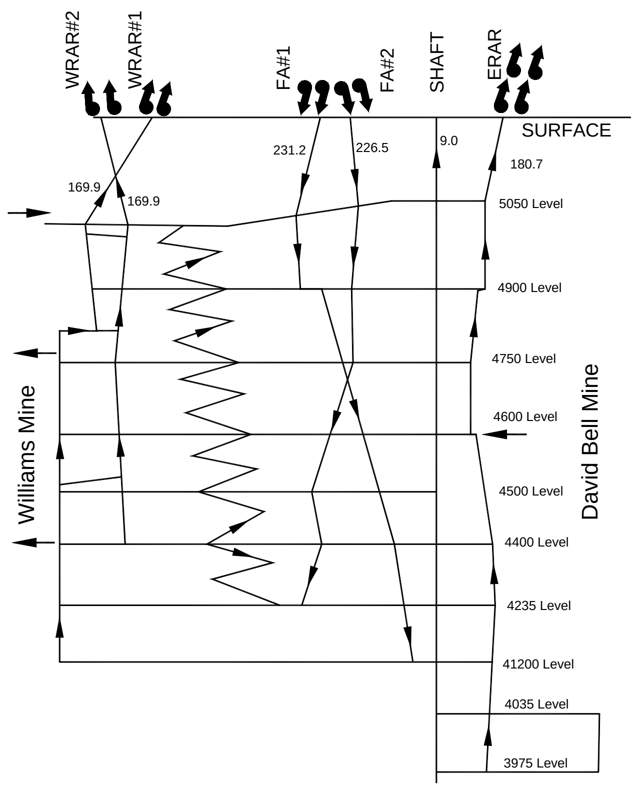

Figure 1. Caption of the original mine main ventilation system. Airflows in m^3/s.

2 THE SHAFT FLOW REVERSAL PROBLEM

As Golden Giant mine approaches an extraction rate of 84 %, the average stope size has decreased. In order to maintain a planned production rate of 2,800 tonnes/day, it was necessary to increase the number of stopes mined, therefore the number of active workplaces has greatly increased. In addition, Golden Giant mine started mining activity in its crown pillar, located under the Williams mine exhaust system.

At this late stage in the mine life, production requirements at Golden Giant demanded that the primary exhaust ventilation system be optimized:

- To increase its exhaust capacity in the upper mine, the Golden Giant mine came to an agreement with the neighboring Williams mine to share its existing exhaust raise.
- To decrease the exhaust volume in the lower mine, a Return Air Efficiency Plan was devised. The plan aimed to manage the exhaust volumes by equipping underground return air fans with computer controlled auto shut-off controls. In other words the plan was designed to eliminate excess exhausted air in inactive workplaces.

The Golden Giant mine extended its internal ramp to intersect one of Williams' primary exhaust raises. By sharing Williams' exhaust raise, Golden Giant increased its exhaust capacity in the upper mine by 61.3 m^3/s. The Return Air Efficiency Plan was, however, aborted as a result of union opposition. The union expressed concerns about sudden airflow changes in case of an underground emergency. At this point the total exhaust capacity of the mine increased by 10%.

After the ramp connection was established, the shaft flows were reversed as the increased exhaust capacity surpassed the intake capacity of the mine. This newly created imbalance between the intake and exhaust capacities caused the mineshaft to downcast at a rate of 28.3 m^3/s. Under the climatological conditions of North Western Ontario it is imperative that during the cold season there is warm, heated air traveling through the shaft. This paper presents a step by step approach followed for reaching and maintaining upcasting flow conditions in the production shaft.

3 THE MINE MAIN VENTILATION SYSTEM

The primary ventilation system is a complex network of raises capable of handling 481 m^3/s. The intake capacity of the mine was surpassed by approximately 28.3 m^3/s since the sharing of the Williams' raise.

3.1 *The fresh air system*

The fresh air system, located on the eastern side of the mine, and near the production shaft, is comprised of two raises, the Fresh Air #1 (FA#1), and the Fresh Air #2 (FA#2) which supply 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: 4900 level, 4750 level, 4600 level 4500 level, and 4400 level. FA#2 supplies air to the lower sections of the mine: 4500 level, 4400 level, 4235 level, 4035 level, and 3975 level.

The fresh air system is driven by surface fans 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 231.2 m^3/s underground. The fans are belt driven by four 186.4 kW motors. Each fan operates at a break power of 268.4 kW, 1.74 kPa static pressure and 74% efficiency.

FA#2 uses two centrifugal fans operating in parallel to supply 226.5 m^3/s underground. The fans are direct driven by two 522 kW variable frequency motors. Each fan operates at a break power of 309.5 kW, 2.24 kPa static pressure and 80% efficiency.

3.2 *The exhaust air system*

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 40% of the total exhaust air volume, respectively.

The East Return Air Raise system (ERAR) uses surface fans to generate the pressure required to exhaust the air volume from the bottom of the mine. Regulators are used to control individual level exhaust flows. The ERAR uses four 1.98m diameter axial flow fans operating in series-parallel, in two stacks, to exhaust 180.7 m^3/s. The fans are driven by four 186.4 kW motors. Each stack operates at a break power of 257.3 kW, 2.04 kPa total pressure and 75% total efficiency.

The West Return Air Raise system (WRAR) uses surface fans in combination with underground booster fans to exhaust the airflow from the mine. Two raises are used to exhaust mine air to surface. The two raises are interconnected on three separate levels in order to equalize the pressure in the WRAR raises. WRAR #1 uses two 1.98m diameter axial flow fans operating in two parallel stacks, to exhaust 169.9 m^3/s. The fans are driven by two 186.4 kW motors. The fans operate at a break power of 298.3 kW, 1.42 kPa total pressure and 78% efficiency. WRAR#2 uses two 2.13m diameter axial flow fans operating in parallel, in two stacks. The fans are driven by two 261 kW variable frequency motors. The fans exhaust 169.9 m^3/s at a total pressure of 1.27 kPa, break power of 268.4 kW, and a total efficiency of 78%.

The return air raise that is shared with Williams mine (William raise) uses booster fans installed on various levels underground. Golden Giant mine connects to the Williams' raise at 5072 Level via a 1.83 m diameter axivane fan (Williams fan) driven by a 111.8 kW motor. The fan exhausts 61.3 m^3/s at a total pressure of 1.14 kPa, break power of 96.9 kW, and a total efficiency of 74%. This relatively high fan suction pressure has influence on the crown pillar area, with this influence extending to the shaft, main ramp and various shaft stations. Depending on pressure differences along the shaft, the Williams fan could readily reverse the shaft airflow direction.

The ventilation system of the mine including the shared return air raise is schematized in Figure 2.

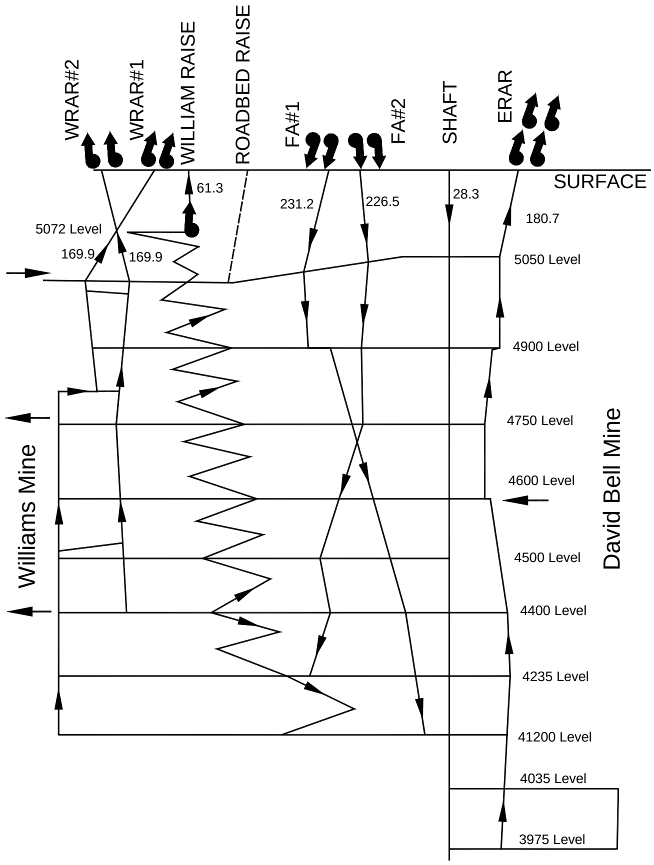

Figure 2. Caption of the mine main ventilation system, including the effects of the Williams fan. Airflows in m^3/s.

4 A PRESENTATION OF SOLUTIONS

A number of possible scenarios were initially examined in order to achieve the most practical solution to the shaft flow direction reversal problem. Advantages and disadvantages for each of the proposed solutions are listed below.

4.1 *Option 1: FA#2 upgrade*

Option 1 involved changing the rotors from 85% to 100% width on the existing surface fans at FA#2.

This option required retrofitting both FA#2 fans with new 100% rotors, installing new fan inlets, changing motors (597 kW,710RPM 3/60/4160 WP II motors), and installing new starters. This option would allow the fresh air intake of the mine to be increased by approximately 47.2 m^3/s, but required extensive electrical and civil work. Cost, time and impact on production were inhibiting factors.

4.2 *Option 2: Additional fan at FA#2*

The second option involved adding a third surface fan in parallel at FA#2.

This option required purchasing an additional 223.7 kW fan, and extensive civil work. Although, being a more cost efficient solution than Option 1, cost, time and impact on production were still inhibiting factors.

4.3 *Option 3: Changing the mining sequence*

Keeping the crown pillar area inactive during the winter season was another option. By utilizing the Williams' exhaust raise in the summer months only, there would be no need for reversing the direction of the shaft flow. This option would, however, result in significant loss of revenue.

4.4 *Option 4: Heaters in the headframe*

This option involved installing heaters in the shaft headframe to raise the temperature of the incasting air above the freezing point. This option, was cost effective, but had associated safety concerns. Having propane heaters in the headframe was deemed undesirable as the mineshaft is the primary access route to underground workplaces. This option would also require extensive construction work.

4.5 *Option 5: New fresh air raise*

Option 5 involved converting a roadbed raise into an additional fresh air raise for the duration of the winter months. The Golden Giant mine normally uses a 2m by 2m square Alimak raise to transfer roadbed material from surface to 5035 Level. By stockpiling roadbed material before the winter month, the mine could temporarily convert the roadbed raise into an air raise. This was seen as a feasible option.

5 ENGINEERING ASSESSMENT AND DESIGN OF A VENTILATION SOLUTION

A practical approach, based on underground testing and ventilation surveys, rather than on theoretical modeling, was used for solving the shaft flow reversal problem.

As mentioned earlier, the relatively high suction pressure from the Williams fan influenced the 5050-5035-5023 level complex as well as the shaft and ramp system. In the lower levels, at 4900 level and 4750 level, shaft pressures were under the influence of the WRAR and the Williams fan. At 4750 level and 4900 level, the air was drawn from the shaft to these levels. At the 5050 level, shaft pressures were under the influence from the Williams fan. Air was also drawn from the shaft into this level.

In an attempt to reverse the shaft flows the Golden Giant mine conducted a test trial. The purpose of the test was to determine whether the shaft flows would indeed reverse after introducing an additional fresh air source, by opening up the roadbed raise.

Figure 3 illustrates the airflow distribution in the upper part of the mine prior to the test.

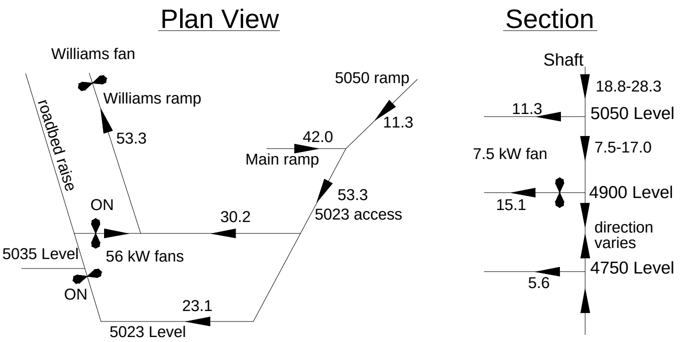

Figure 3. Caption of original airflow distribution in the upper part of the mine before the test. Airflows in m^3/s

5.1 *Underground testing*

The test included the following implementations:

- the roadbed raise was mucked open to provide a parallel supply of fresh air to the 5035, 5023 and 5058 levels, and
- a 55.9 kW fan (Joy series 2000, 42-26-1770) was installed in the 5050 ramp to force air flow toward the shaft.

The test trial was not entirely successful. The shaft was still downcasting, however, the volume of incasting air was reduced to 6.1 m^3/s. Opening the roadbed raise created a path of very low resistance (parallel to the shaft) causing a fresh air supply of 40.1 m^3/s to the 5035 Level.

The following new flow conditions, illustrated in Figure 4, were developed in the area. The exhaust flows at the Williams fan increased to 55.7 m^3/s from 53.3 m^3/s. Flows at the mine ramp decreased to 36.3 m^3/s from the original 42.0 m^3/s. Flows in the 5023 level reversed to 21.7 m^3/s East from 23.1 m^3/s West. Mine ramp flows, above 5023 level, also reversed from 11.3 m^3/s downramp to 20.8 m^3/s upramp. The flow reversal in this section of the ramp was induced by the action of the 55.9 kW fan installed for the purpose of testing. The shaft still downcasted, with 6.1 m^3/s entering from surface, and 26.9 m^3/s flowing between 5050 level and 4900 level.

The following conclusions were inferred from the test:

- The 55.9 kW fan installed in the 5050 ramp has little effect on the Williams fan.
- The fan installed in the 5050 ramp would not necessarily reverse the flow direction in the shaft, depending on the fan pressure. The 5050 fan (Joy series 2000, 42-26-1770 equipped with a 60 kW motor) with a blade setting of 2.5 provided an airflow of 20.8 m^3/s. The corresponding total pressure was 2.04 kPa. A higher pressure fan, such as the tested 5050 fan, would pressurize the 5050 level shaft station and, depending on the relative pressure at the lower shaft stations, the shaft would continue to downcast.
- The Williams fan would preferentially draw air from the roadbed raise than from the main ramp.
- It was also assumed that, during the underground test some of the shaft downcast flow below 5050 level exhausted at 4900 level and 4750 level.

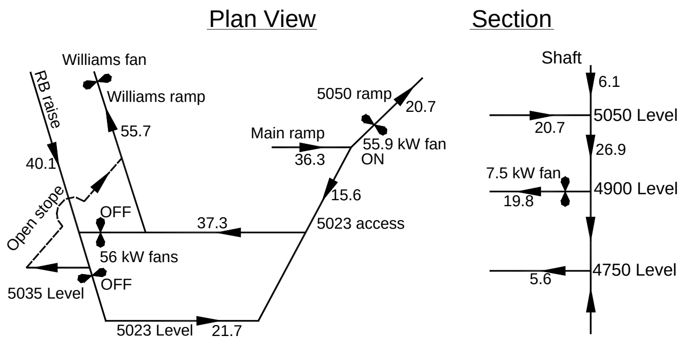

Figure 4. Caption of airflow distribution in the upper part of the mine during the test trial. Airflows in m^3/s

5.2 *Underground ventilation survey*

After the test trial, a detailed flow and pressure survey was conducted at shaft stations located in the upper area of the mine. The survey was required to better understand the conditions along the shaft and the sensitivities to changes in airflow volumes and pressures.

5.2.2 *4750 level survey*

The surveys performed at the 4750 level indicated the following:

– with the ERAR regulators open at 0.8m x 0.5m, 2.9 m^3/s will leak from the shaft into the level. The total flow into the ERAR was 12.0 m^3/s. The pressure measured across the ERAR regulator was 0.80 kPa, and across the shaft doors were 0.07 kPa.

– with the ERAR regulators fully closed, the shaft leakage decreased to 0.9 m^3/s and the level flows reduced to zero. The pressure measured across the ERAR regulator approximated 1.00 kPa and across the shaft doors was < 0.02 kPa.

Airflow and pressure conditions at 4750 level are schematized in Figure 5.

As earlier mentioned in section 5.1, it was presumed that, during the underground test, some of the shaft downcast flow below 5050 level exhausted via this route to the ERAR.

It was predicted that, with a fan installed on the 4750 shaft station door, and with the ERAR regulators closed, the 4750 level could be ventilated and air exhausted into the shaft instead of having it exhausted via the ERAR. In other words the fan would serve a double purpose: pressurize the shaft and provide level ventilation.

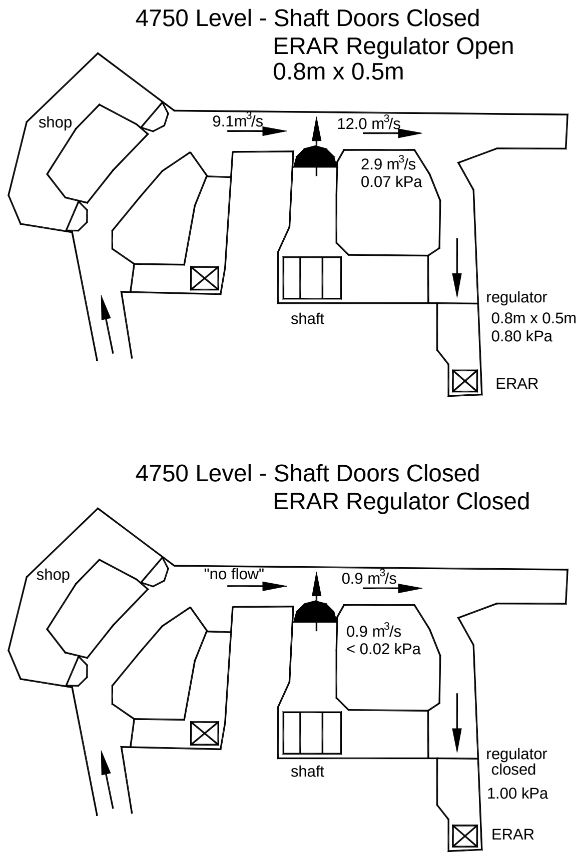

Figure 5. Caption of 4750 level survey

Surveys performed below 4750 level, at 4600 level, indicated that air will leak into the shaft. Also, an upcast flow was confirmed below the 4600 shaft station.

5.2.3 *4900 level survey*

The 4900 level shaft station is fitted with a Woods 48J 48-16 875 fan drawing air from the shaft into the level. The fan is fitted with a 7.5 kW motor and the blade setting is 26 degrees. At this blade setting, the operating flow range of the fan is between 14.2 m^3/s and 21.7 m^3/s at a maximum static pressure of 0.40 kPa. Tests performed at the 4900 level indicated the following:

- with the shaft station fan on, 21.3 m^3/s will flow from the shaft. The pressure across the shaft doors was 0.12 kPa. Air leaks into the ERAR at 3.5 m^3/s; the ERAR bulkhead pressure is 1.00 kPa. An upcast flow volume approximating 19.8 m^3/s was measured in the shaft below the 4900 level shaft station.
- with the shaft station fan off, 14.4 m^3/s will flow from the shaft. The pressure across the shaft station doors was 0.17 kPa. Air still leaks into ERAR at 3.5 m^3/s; the ERAR bulkhead pressure was 1.00 kPa. An upcast flow approximating 18.0 m^3/s was measured in the shaft below the 4900 level shaft station.

The relatively high pressure existing at the shaft station can be attributed to a suction pressure influence from the WRAR and from the Williams fan.

5.2.4 *5050 level survey*

The survey performed at the 5050 level have indicated the following:

- with the shaft door regulators open, 10.5 m^3/s would flow into the level. The pressure measured across the shaft doors approximated 0.15 kPa. Downcast shaft flows from surface to the 5050 level were measured at 19.8 m^3/s.
- With the shaft door regulators closed, there was no flow into the level. The pressure measured across the doors approximated 0.17 kPa.

It was noted that relatively high suction pressure existed at the 5050 level shaft station. This pressure seemed to be generated by the Williams fan. It must also be noted that the measured pressure across the 4900 level shaft doors was 0.17 kPa and that it was attributed to the Williams fan (and possibly to WRAR). This is consistent with expected pressures in parallel airways. This also confirms why there was no flow in the shaft between the two levels.

6 THE IMPLEMENTED STRATEGY FOR SHAFT FLOW REVERSAL

The underground testing and ventilation surveys determined that the Williams fan had a suction influence at the 5050 and 4900 shaft stations, thus creating a downcast flow condition in the upper section of the shaft. The 4900 level shaft station fan further maintained the downcast situation. The suction pressure influence of the ERAR at the 4750 level also affected the position of the shaft neutral pressure point. As the exhaust capacity of the Williams fan had to be maintained at present levels (future production requirements of the area), no changes could be planned for that site.

In order to counteract the effect of the above conditions, and to ensure continuous upcasting of the shaft, the following implementations were made.

6.1 *4900 level.*

On 4900 level the fan blade was reduced to 10 degrees. This way the flow level from the shaft was reduced from 21.3 m^3/s to no more than 9.4 m^3/s.

It was previously mentioned that airflow from the shaft without the fan operating was 14.1 m^3/s due to the suction effect of the Williams fan. However, with the roadbed raise open, this volume dropped to unacceptable levels, requiring the continued use of this fan. Also, in order to maximize the air volume available for level ventilation, the setting of the ERAR regulator was reduced.

6.2 *4750 level.*

On 4750 level a 44.7 kW, Joy series 2000, 36-26-1770 fan was installed on the shaft station bulkhead. The operating point of the fan (blade angle 2) is 15.1 m^3/s at a total pressure of 1.62 kPa, static pressure of 1.37 kPa, and velocity pressure of 0.25 kPa.

The purpose of this fan is to generate positive shaft pressure and force air into the shaft. The sizing of the fan was based on the pressure measured at the ERAR bulkhead. A static pressure of 0.80 kPa was measured for a flow of 11.8 m^3/s. Because of restrictions in hole size at the shaft door, it was necessary to equip the fan with a 0.9 m to 0.6 m reducer. A backdraft damper was also required as part of the company’s firedoor policy. Losses associated with the reducer and accessories were over 0.37 kPa. With exit losses the static pressure requirement of the fan was minimum 1.37 kPa. The fan installation is shown in Figure 6.

Figure 6. Caption of 4750 fan installation.

6.2. *Roadbed raise/surface structure.*

The roadbed raise was equipped with a propane fired heater with maximum capacity of 2,345 kW, to provide heated fresh air down the raise. In order to ensure a uniform airflow across the burners the raise was also equipped with a 55.9 kW fan, Temprite model TMA-148-750-BNPO. The surface installation is shown in Figure 7.

Figure 7. Caption of the roadbed raise surface installation.

The above implementations resulted in the desired reversal of the airflow in the mine shaft. The mine shaft started to upcast at a rate of 14.2 m^3/s. A schematic of the achieved flow distribution at the upper section of the mine is shown in Figure 8.

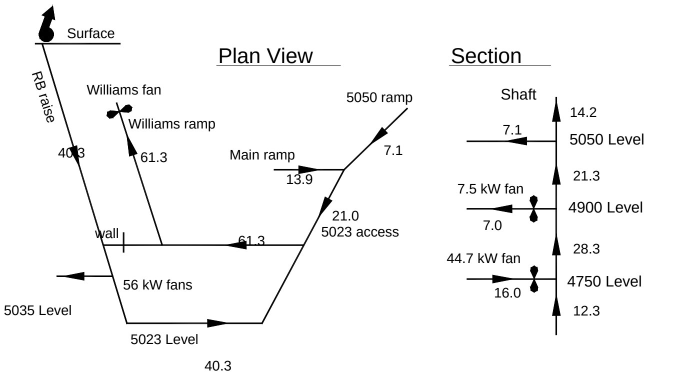

Figure 8. Caption of the airflow in the upper part of the mine following the implementations from section 6. Airflows in m^3/s.

7 CONCLUSIONS

This paper presented how the application of an applied ventilation assessment approach, based on extensive practical experience, was successful in reaching and maintaining upcast flow conditions in the Golden Giant production shaft. The achieved solution may not, in all cases, be the optimum, but will be one that is guaranteed to work, as a precondition of the production operator. Modeling approaches do not always guarantee the level of success required by the practical engineer.

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