PARALLEL SURFACE FAN OPERATION AT HOYLE POND MINE

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ABSTRACT

The Hoyle Pond underground mine, located in the Porcupine Gold Camp, east of the city of Timmins, Ontario, Canada, is the cornerstone of Goldcorp Canada Ltd's Porcupine Gold Mines. Cut and fill, shrinkage, longhole and panel mining methods are employed to excavate the narrow gold bearing structures. In order to meet increased flow requirements of 256 m^3/s at the mine, a new fresh air raise and new surface fans were commissioned in early 2005. The main surface fans were selected and sized to operate at a total pressure ranging between 1.5 and 2.0 kPa, based on an estimated mine resistance curve. When the fans were commissioned the total pressure at the fans was found to be approximately twice the originally estimated and consequently only one surface fan could be operated at any given time providing about half the required volume of air. Extensive work was immediately started aimed at reducing the system resistance in order to permit operation of the two fans in parallel and achieve the required mine flows. Larger booster fans were installed in parallel at the 900m level, a 3 m raise bore linking the 450m and 900m levels was developed to twin the existing fresh air circuit, and the fresh air raise from surface to the 450m level was twinned with the original fresh air raise. This strategy, completed in 2012, resulted in a drastic reduction in system resistance and pressures, allowing the two surface fresh air fans to be safely operated in parallel and meeting the flow requirements. This paper describes details of the engineering design work and commissioning of the modified ventilation system, successfully ensuring the long term viability of the project.

KEYWORDS

Mine ventilation, main fans, booster fans, system resistance, system optimization

INTRODUCTION

The Hoyle Pond underground mine is located in the Porcupine Gold Camp, east of the city of Timmins, Ontario, Canada. Cut and fill, shrinkage, longhole and panel mining methods are employed to excavate the narrow gold bearing structures.

Operations began in earnest at the original Hoyle Pond Mine in 1985, with underground access via a portal. Experience garnered while mining this deposit as well as the earlier Bell Creek mine (the same trend) in addition to early diamond drilling results had led the operation to expect and plan for a shallow mine, extending to approximately 700m of depth. The narrow vein and nuggety ore body also mandated a labor intensive approach that minimized the use of large equipment; with much of the ore handling being performed by 1.5 yard and 2.5 yard scoops. In 1994 following a diamond drilling campaign the 1060 vein system was discovered 400 meters southeast of the original Hoyle Pond mine infrastructure. Between 1995 and 1999, aggressive development of the 815 meter deep Number One shaft, secondary ramp access, and 3 haulage levels – at the 200, 440, and 720 meter levels - was completed to exploit this system. As such a ventilation system was planned and put into effect that would deliver the required volume (approximately 160 m^3/s) of air down to the 720m level.

This paper examines both the sequence of events that lead to the high system pressures encountered at the Hoyle Pond Mine, as well as the efforts aimed at reducing them.

New surface fans as well as a new Fresh Air Raise (FAR) were commissioned in early 2005. The projected mine resistance curve lead the system designers to expect to see 1.5 to 2 kPa of total fan pressure. Once the two new fans were in place and online, the old FAR had to be sealed to prevent short-circuiting, resulting in a drastically steepened mine resistance curve. In effect the total pressure at the fan rose from 1.5 kPa to 3 kPa. Consequently only one surface fan could be operated at any given time providing only half the possible volume of air. The question quickly became one of how to reduce the system resistance as well as how to get the desired volume of air down to the face.

THE INITIAL CONFIGURATION

The initial installed system were four (2 in series 2 in parallel) 78-30-1170 150 kW fans, in series-parallel configuration, sitting atop a multiple stage fresh air raise starting with a circular Alimak raise 3.65m in diameter extending from surface to the 200m level. From here the FAR was again excavated by Alimak; this time as a 3.7m x 3.7m raise to the 240m level. The following leg of the FAR was a 3.7m x 3.7m drop raise down to the 255m level. This section then connected to a 3m diameter raise bore hole extending down to 440m level. Yet another jog in the raise was from 440m to 450m levels via a 3.7m x 3.7m drop raise. With consideration towards economics as well as the opinion that the mine would not go much deeper than the 720m level the following leg of the FAR was a 2.7m x 2.7m conventional raise connecting the 450m to the 720m level. All subsequent and future legs of the FAR are 3m diameter raise bore holes. The Fresh Air Raise system is shown in Figure 1 and the main surface fan curve and operating point is shown in Figure 2.

Reaching the Limit

By the time the mine had reached the 900m level, pressures encountered by the main fans had drastically risen (approaching 3 kPa); and as a consequence the fans were teetering on the edge of the performance curve, close to stall. A solution was needed in order to decrease the pressure in the FAR, and consequently return volumes at the bottom of the FAR to previous levels. The agreed upon solution was install two 78-26-1770 187 kW fans into a bulkhead in the fresh air raise on 720m level (Figure 1). This did indeed allow operations to continue unimpeded for a period of time. This solution did not however solve the myriad problems plaguing the ventilation system; not the least of which was an ever open ore body at depth.

NEW SYSTEM PLANNED

Drilling success had projected the orebody to extend at further depths, and in November of 2004 the mine commissioned an engineering study to determine the feasibility of the existing ventilation system to provide the mine with the anticipated needed volume of 256 m^3/s to a proposed depth of 1800m. Although the study determined that upgrading the current intake fans with more powerful units (261 kW) in conjunction with twinning the FAR between 450m and 720m levels would support mining activity as deep as 1800m level it was decided that a better, more permanent solution, was needed. This study suggested that an alternative plan would be to drill a 4.3m diameter raise bore hole from surface to act as a new fresh air raise. Underground development as well as preparing the surface site for the raise bore was completed by the end of 2005. Starting in early 2006 the 4.3m diameter raise bore from surface to 280m level, followed by a raise bore hole from 280m to the 440m FAR transfer drift, was completed by August of that year. Assembly and installation of the new 8400-AMF-5000 fans begun shortly after raise completion and the fans were commissioned on January 23rd, 2007 (Figure 3). It was at this time that the 720m fans were disconnected and removed from the 720m level; with the reasoning that the installation of two 671 kW surface fans had made the booster fans obsolete.

First Signs...

The initial setup had both surface fans operating in parallel with a blade tip angle of 35^0 and at approximately 1100 RPM; although both fans were operating along a stable point of the curve there was much short circuiting and leaking on 440m level between the new FAR and the old FAR; as well as through the vent doors on the 450m fresh air transfer drift. This leakage allowed for a much lower resistance curve that was actually present. In March of that year the surface fans failed due to bearing vibration. Very quickly it was ascertained that the lack of lubrication had caused the failure.

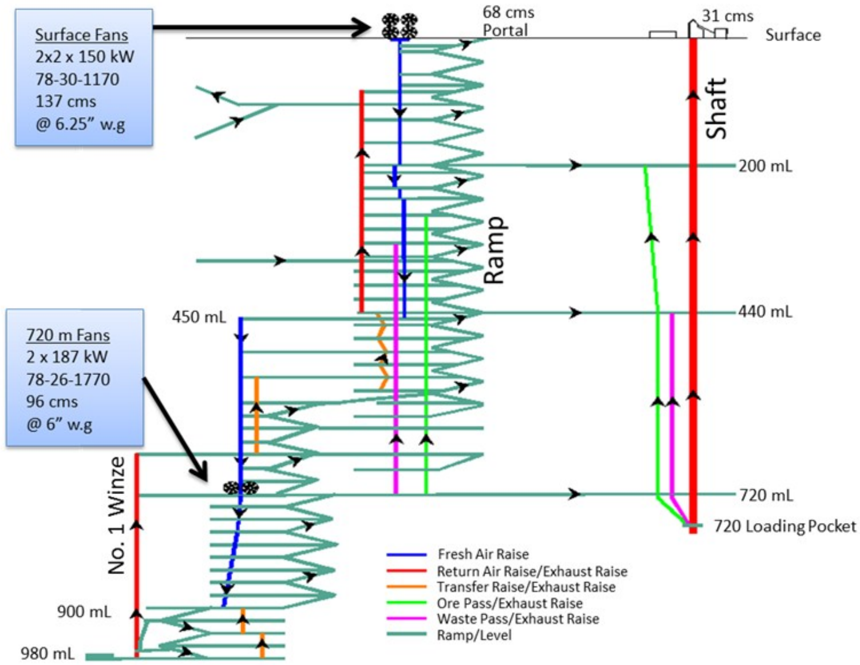

Figure 1 - Original ventilation schematic to 980m level

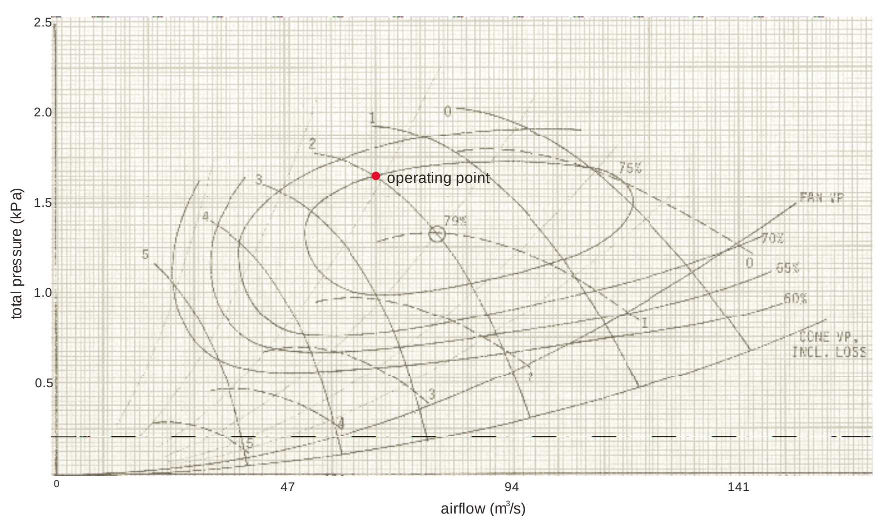

Figure 2 - 78-30-1200 150 kW fan curve

Increasing Pressure

With the fan maintenance issue resolved, in April 2007 it was decided that mine would now address the short-circuiting and leakage issues in the fresh air system. On April 26th, 2007 the construction crew began sealing the ventilation doors connecting the 450m fresh air transfer drift with the mine's main ramp system. By April 29th the surface fans began to oscillate. At this time, mechanics at the 440mL level shop reported feeling a low frequency drumming. Efforts to seal the 450m level continued through this period as no evidence of correlation between these two events was present. Finally on May 1st the surface fans automatically shut down due to a vibration alarm. Maintenance was unable to return fans to parallel operation as the ignition of the second fan immediately caused both fans to enter stall mode.

Figure 3 - New surface fresh air fan installation

A Temporary Reprieve

In response to this new development, on May 8th, 2007, the decision was made to change the surface fans blade angle to 25^0. This seemingly satisfactory arrangement enabled both fans to operate concurrently; however system pressures had yet to reach an apex. By May 10th all areas short-circuiting and all leakage points had been sealed. These actions further elevated the system curve placing the surface intake fans into stall. Further altering of the blade tip angles in a multitude of variations did not result in the safe re-initiation of the surface intake fans. In studying the fan performance chart a reluctant decision was made to operate only one fan, at a point on the curve that would most closely approximate the volume required at depth and still be on a very stable point of the curve. Adjustments were made and the fan was placed at 35^0 and 1200 rpm. This arrangement resulted in supplying 45 m^3/s to the bottom of the 1140m FAR; just enough to allow continued development of the ramp.

RETHINKING THE PROBLEM

Soon afterwards, the fan manufacturer was contacted in hopes that a ready solution could be discovered. For their part the fan manufacturer contacted and hired Fan Dynamic Ltd to conduct an in-depth inspection of the fan system as well as perform airflow tests on the newly acquired surface fans. Pressure surveys on the fan house as well as at the collar of the new FAR provided Fan Dynamic Ltd with information on the static pressure encountered by the surface fans (Duley, 2007). In addition, a pitot traverse at the end of the fan conical diffuser supplied the velocity pressures. These findings concluded that between the fan house (resistance pressure of 0.36 kPa) and raise collar (resistance pressure of 2.38 kPa), the velocity pressure was 0.35 kPa and the fan total pressure was 3.14 kPa. Having also accurately measured the volume of air being provided by the fan (173.7 m^3/s), this allowed Fan Dynamic Ltd to provide the mine with its true system curve. Figure 4 shows the determined system resistance curve and fan operating point. When the operating points of the surface fan were plotted against the system curve it clearly showed that there were no points at which both intake fans could operate in parallel. Fan Dynamic Ltd. also demonstrated that with the mine's fan configuration it would have required approximately 5.6 kPa to meet the initial design airflow of 234 m^3/s

and 7.97 kPa to satisfy the final design airflow of 283 m^3/s; an impossible task even with modern fan technology.

A New Model

Dr. De Souza, President of Airfinders Inc., was contacted in July 2007 to assess the mine's ventilation system as well as to construct a new ventilation model based on an updated mine layout (Figure 5). As a result of Dr. De Souza's work it was identified that 80% of the mine's resistance was between 450m and 900m levels, with the majority (64%) occurring between 450m and 720m level (Figure 6). In addition, Dr. De Souza confirmed that the current surface fans were indeed undersized and could not possibly operate in a parallel configuration given the current resistances encountered. Dr. De Souza also recommended larger booster fans underground as opposed to increasing the size of the two surface fans; the reasoning behind this being potential leakage from surface down would nullify any gains made by having larger, more powerful fans (De Souza, 2007).

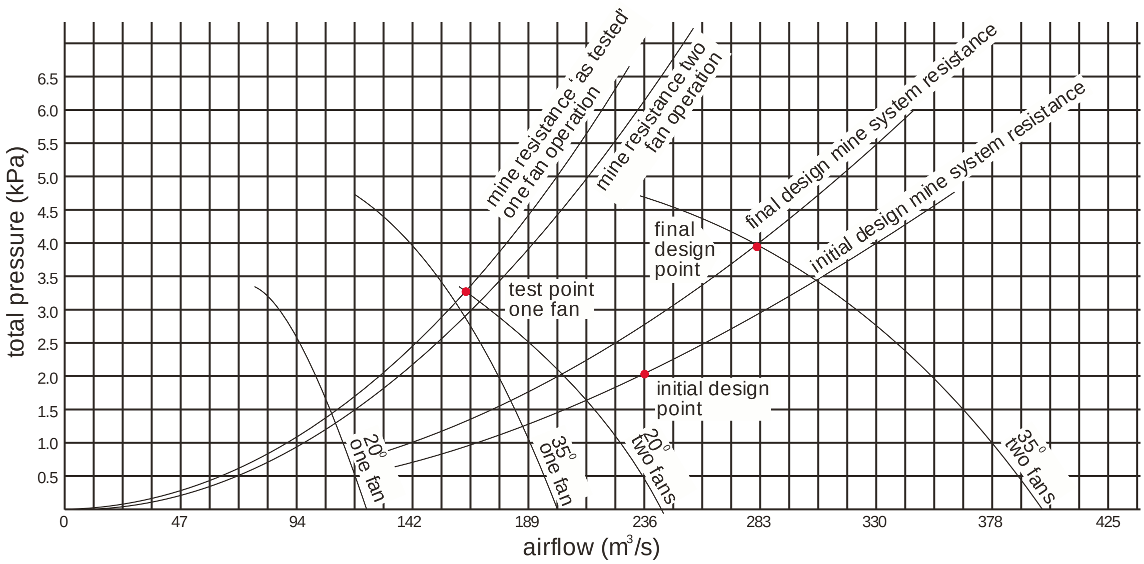

Figure 4 - Actual system resistance curve (Duley, 2007)

New Booster Fans Installed

Following this recommendation it was decided to relocate the original surface fans (78-30-1170 150 kW) down to the 900m level as booster fans. Figure 7 shows the 900m level booster fan installation. At the time it was decided to install all four fans (two parallel stacks of two fans in series); however only one bank was to operate at a time. This change had at best a marginal effect on the mine system pressure (0.25 kPa), it did however provide the much required air volume to the 1140m level FAR. The result was dramatic; an increase of over 45 m^3/s, from 35 m^3/s to over 80 m^3/s.

Twinning the Fresh Air Raise

In addition to the installation of the 900m level booster fans, a raise bore program that would eventually link 450m level to 900m level with a 3.0m diameter raise was also recommended (De Souza, 2007) and initiated. This would finally twin the existing fresh air circuit and would result in lowering the overall mine resistance curve. The project took almost a full year; beginning in November of 2007 with the final breakthrough happening in August of 2008. Immediately following the linkage of the twin FAR to the existing FAR, pressure readings were taken on surface, and it was discovered that overall mine pressure had dropped to approximately 2 kPa.

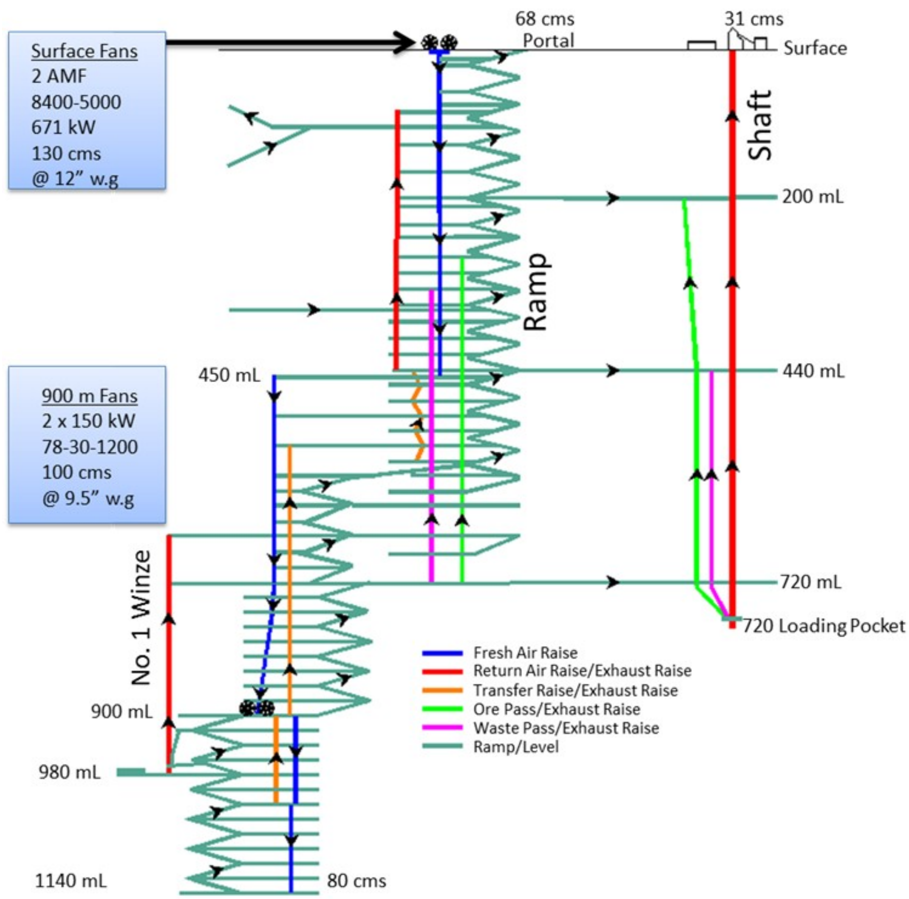

Figure 5 - Hoyle Pond schematic to 1140m level

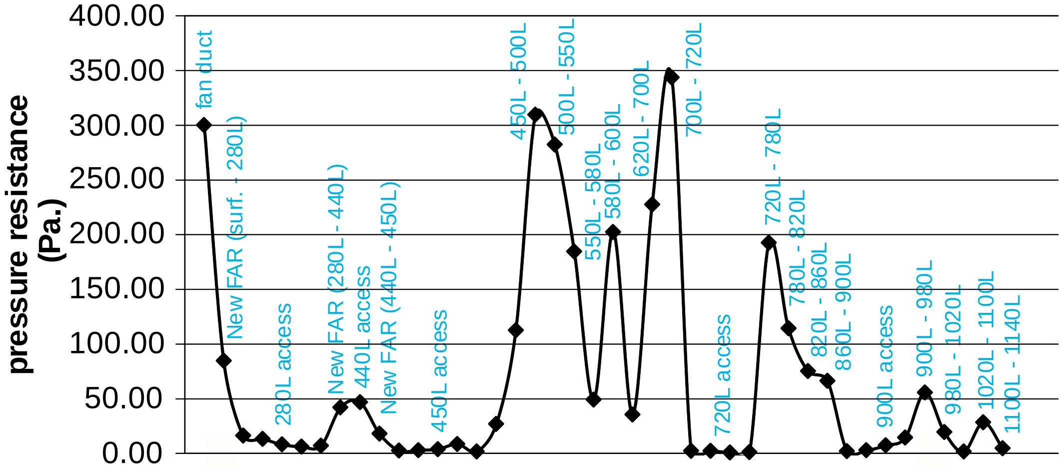

Figure 6 - System pressure resistance (De Souza, 2007)

Figure 7 - 900m level booster fans

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AMPERAGE DROPS

The electrical department soon noted that the amperage draw on one of the booster fans on 900m level had dropped dramatically from 160 amps to approximately 50 amps. This was directly related to the suddenly lowered system pressures.

Booster Fan Re-Configured

It was also during this raise boring campaign that the existing FAR was extended to the 1220m level. The ventilation configuration on 1140m level had made it so that fresh air was drawn from the 1140 FAR onto the level itself; thereby reducing the total volume of air reaching the bottom of the 1220m FAR. By modeling different scenarios, a decision was made to alter the configuration of 900mL level booster fans. These fans had previously been arranged into two banks of two fans in series; with only one bank running at one time. The new arrangement had the two exterior fans removed and therefore only two fans in parallel would operate. Previously the booster fans in series increased the pressure in the raise system below 900m, which allowed a certain volume of air to be pushed further than without the presence of the fans; however this arrangement did not really affect the pressure being exerted on the surface fans. This new configuration now pushed a greater volume to depths below 900mL, therefore resulting in a reduced static pressure at the collar of the FAR from 2 kPa to 1.37 kPa. This lowered system resistance pressure resulted in increased volumes of air both at the fans as well as lower in the fresh air circuit. For example volumes increased on the 450m level from 150 m^3/s to 185 m^3/s, as well as on 900m level from 114 m^3/s to 144 m^3/s, and finally an increase of over 20 m^3/s was recorded on 1220m level; bringing the total volume flow from 50 m^3/s to 73 m^3/s. This change also resulted in both active booster fans drawing more equal amps; clearly showing that they were both now doing effective work (Figure 8).

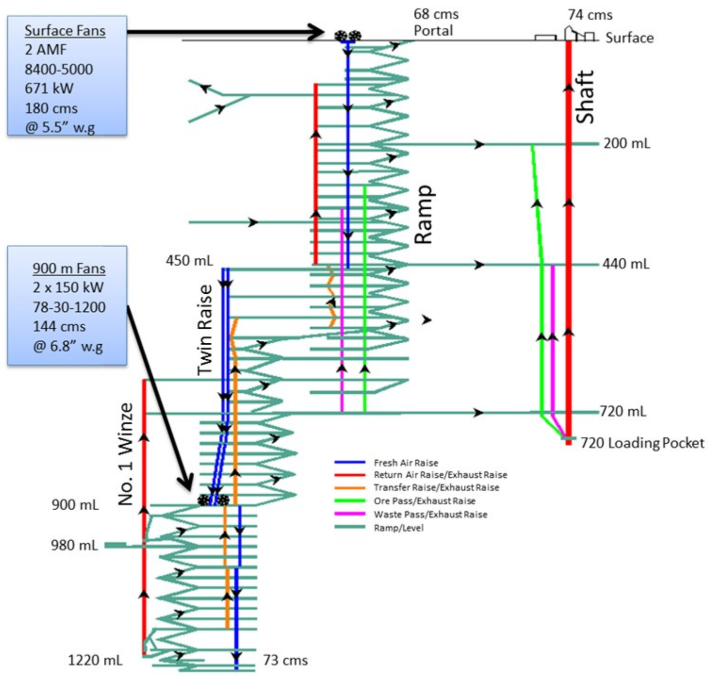

Figure 8 - Hoyle Pond schematic to 1220m level

REPURPOSING THE OLD FAR

In November 2010 a bi-annual audit of our Ventilation system was conducted by Airfinders Inc. (De Souza, 2010). During the course of discussing the current limits of the mine's ventilation system and experimenting with a 3D ventilation model of the mine, the notion of repurposing the old fresh air raise was brought forward. By connecting both the old and new fresh air raises on 80m level as well as on 280m and 450m levels, one would be able to lower the system resistance to a point where one could finally have both surface fans operating concurrently.

Pushing Fresh Air Deeper

In March of 2011 a contractor was brought on site to further extend the reach of our current ventilation system via a 3m diameter raise bore hole down to 1370m. This work was necessary as the mine's main ramp continued to be excavated at depth in order to exploit and expose the ore body. The project was completed by June 2011 and resulted in delivering approximately 100 m^3/s down to 1370m level. Although this latest change did not affect the surface fans it did result the 900m booster fans seeing an increase of 0.124 kPa total pressure (from 1.74 kPa to 1.87 kPa). During the initial planning stages of this latest extension it was hoped that we could not only start the repurposing of the old fresh air raise but that the work would be finished in conjunction with the completion of the raise bore campaign. Regrettably this was just not to be; limited resources and other higher priority work made it so that twinning the FAR from 80m to 450m took just over a year to complete.

Making the Best of a Bad Situation

Although the new extension did allow us to push approximately 100 m^3/s down to 1370m level; larger and more efficient machinery permitted our ramp crews to develop the ramp much further than expected; resulting in making our most recent leg of the FAR redundant much sooner than would have been preferred. An expedient solution was required, one that we could manage internally without needing to source out a raise bore machine. The solution was to drive a 3.3m x 2.1m Alimak raise from 1410m level to 1370m level, once completed the raise would then be slashed out to 3.3m x 2.6m to lower the resistance as much as possible. This new raise did indeed allow us to continue pushing the down ramp by providing 90 m^3/s to 1410m; however it did place further strain on the 900m level booster fans. A 91.44 cm diameter fan insert was installed in the 1370m FAR and left open to allow 20 m^3/s on the level as well as bleed off some pressure. Even with these measures the 900m fans were now steadily approaching the edge of the fan curve. In fact, were we to attempt to extend the FAR from 1410-1540m level as planned we would need to put two additional 78-30-1200 150 kW fans in series behind the two already operating in parallel.

VICTORY ON THE HORIZON

In July of 2012 the new twinning project was finally completed reconnecting the Old and New FARs from 80m to 450m. These changes resulted in the total pressure decreasing to 1.37 kPa and the static pressure at the raise collar was now 0.75 kPa. In addition, surface volumes increased from 180 m^3/s to 220 m^3/s. This represents an approximate flow increase of 20% at the collar and is directly attributed to lower pressures encountered by the surface fan.

Testing the Surface Fans

At this time Dr De Souza was invited to visit the site and, in addition to completing his usual system audit, was asked to assist with testing and commissioning the surface fans. After careful examination of our model and re-establishing the system curve we decided to attempt to initiate parallel operation of both systems fans at the most aggressive angle possible for the fans of 35^0 (De Souza, 2012). We used a stepped approach, starting both fans at 70% rpm and slowly ramping them up to 100% rpm.
Some limits were set, beyond which the testing would be stopped:

1. Fan vibration - 0.3 in/s (0.5 in/s set point would trip the fan)
2. Fan total pressure limit – 4.31 kPa
3. Fan static pressure limit – 3.49 kPa

Test results indicated stable fan operating conditions of 262 m^3/s @ 4.28 kPa total pressure, at 100% rpm. Although the test was successful, the fan operation was far too close to falling off the curve, and the fans teetered on the edge of stalling (Figure 9). It was decided to plan for a second test at a lower blade setting of 30^0.

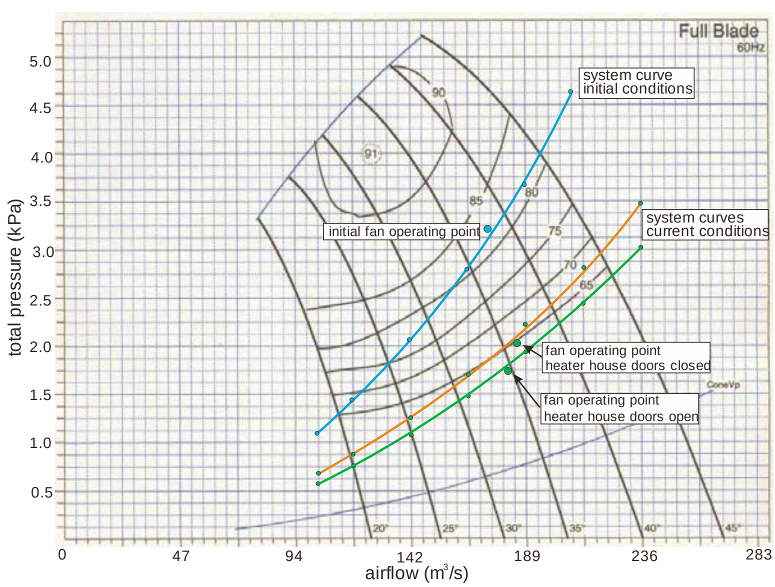

Figure 9 - Parallel fan curve vs system curve @ 35^0 (De Souza, 2012)

Re-configuring and Re-Testing

On August 14th, 2012 a second test was conducted. We followed the exact same methodology as we had during the previous test and the following limits were set, beyond which the testing would be stopped:

1. Fan vibration - 0.3 in/s (0.5 in/s set point would trip the fan)
2. Fan total pressure limit – 4 kPa
3. Fan static pressure limit – 3.26 kPa

Test results indicated a stable fan operating point of 246 m^3/s at 3.61 kPa total pressure. The fans predicted and actual operating points are shown in Figure 10.

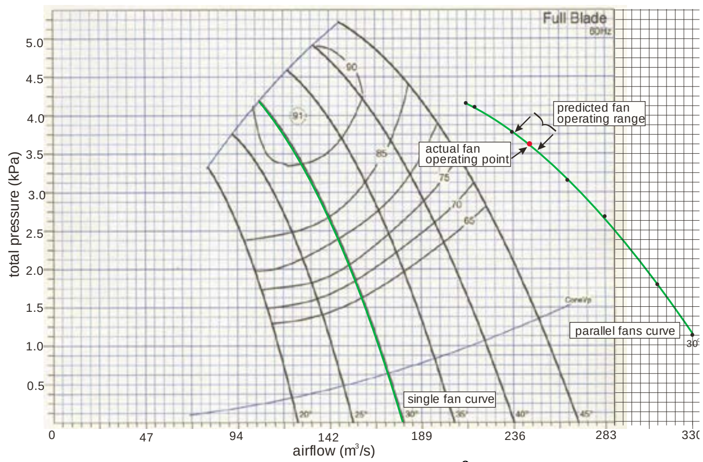

Figure 10 - Parallel fan operation @ 30^0 (De Souza, 2012)

FLUSH WITH VICTORY

The combination of twinning and joining the FAR as well as changing the configuration of the booster fans on 900m provided lowered the system curve substantially so that finally, after more than 5 years, the system fans were able to operate as originally designed.

Continuing Improvements

Although we succeeded in placing both surface fans online there is still the issue of the surface heater house which is responsible for more than 0.25 kPa of static pressure resistance. This will be addressed in the future in a bid to further reduce the system resistance pressure and therefore provide greater flows underground.

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