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Ventilation planning at Energy West's Deer Creek Mine

L. Tonc
Pacific Corp, Deer Creek Mine, Huntington, Utah USA

B. Prosser
Mine Ventilation Services, Inc., Fresno California USA

G. Gamble
TLT Babcock, Inc., Akron, Ohio USA

Abstract: In 2004, the engineers at the Deer Creek Mine located near Huntington, Utah initiated the ventilation planning to exploit a remote area of the mine's reserves. This area was located under a mountain which would not allow for the incorporation of an additional shaft or portal access near the proposed longwall panels. With this constraint along with the desire to maintain a two entry gate road system and the expected condition of frequent coal wash outs a ventilation plan was established. Different options were examined that included; increasing the current exhaust fan power, adding another exhaust fan installation, converting the ventilation fans in the active portion of the mine to a forcing system, and modifying the ventilation system in the active area of the mine to a push-pull system. The push-pull ventilation system was ultimately selected. This paper details the design process of the ventilation system upgrade, the procurement process for the new fans, and the new fan startup testing.

1 Introduction

The Deer Creek Mine, located near Huntington, Utah, initiated the planning for the relocation of the longwall face from the main portion of the mine to the more remote Mill Fork Area in 2004. Because of the surface ownership and topographical considerations no additional shafts could be considered for ventilation purposes. Because of the remoteness of the reserves, it was anticipated that the ventilation system would require a significant amount of restructuring in order to operate the longwall and up to three development sections. In order to achieve the necessary ventilation in this area a modified push/pull ventilation system was designed and two additional 1,490 kW (2,000 hp) fans were installed.

2 Survey

In May of 2005, Mine Ventilation Services, Inc. (MVS), was requested to conduct a ventilation survey of the mine and develop a correlated network model of the ventilation system. The initial ventilation survey was conducted over five days and a model with a correlation error of approximately 4%. The ventilation model was then used to examine methods by which the existing ventilation system could be more efficiently utilized and act as a platform for longwall operations in the remote Mill Fork area. Figure 1 shows the ventilation model established for this study.

3 Initial Optimizations

Based upon the data obtained during the ventilation survey several immediate observations were made that would be critical for the future of the mine. These observations were:

<u>Stopping Resistance in Mill Fork Access</u>

The stopping resistance in the Mill Fork Access intakes and belt was fairly low at a value of approximately 3355 Ns^2/m^8 (3,000 PU) which is fairly low considering the average value for stopping resistance at this operation is 19,000 (17,000 PU) for a sprayed and properly sealed stopping. In the future when this area becomes a main ventilation route and the differential pressures are increased, leakage into the belt will become a major factor. These stoppings were resealed/sprayed and the access doors refitted to ensure proper closure.

<u>Rilda Exhaust Fan Pressure Loss</u>

The pressure loss associated with the Rilda exhaust portal was noted to be excessively high 0.3 Pa over 150 m (1.2 in. w.g. over approximately 500 ft). This is because of the small cross sectional area and related steel set ground support. The steel sets not only take up valuable space in the airway cross-section, they also create a very irregular surface in the airway causing a very high pressure loss. As the airflow in this entry is increased to meet future ventilation demands the pressure loss in the entry

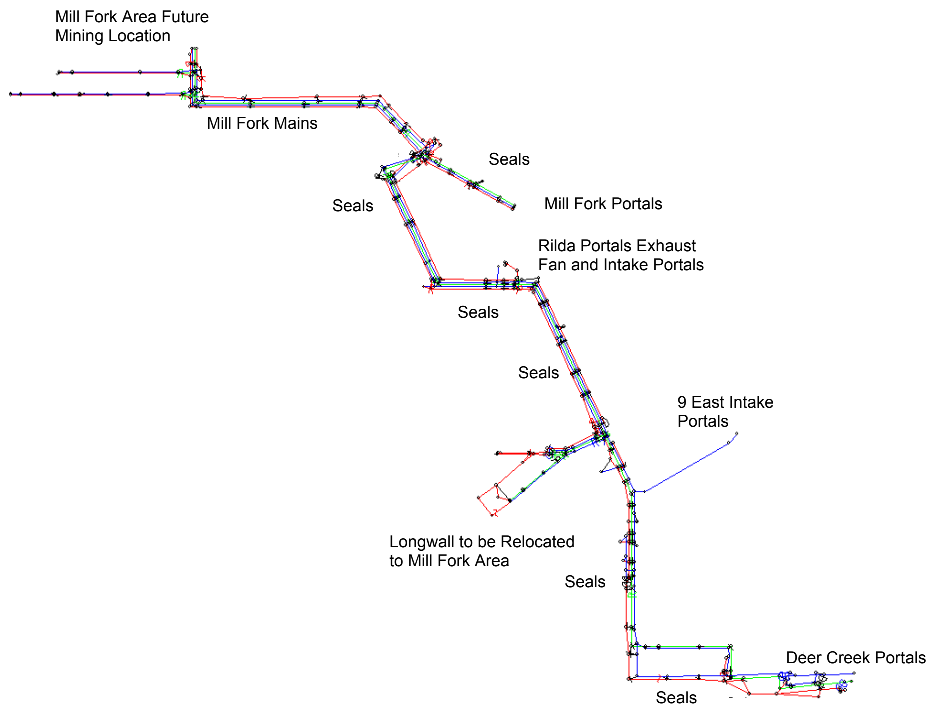

Figure 1. Ventilation Schematic Developed for the Deer Creek Mine

increases exponentially. Although this resistance was fixed for the portal since this could not be rehabilitated without creating a production interruption, minimizing the impact of steel sets was kept in mind when designing the new portals in 1st Right that serve mining in the Mill Fork area.

<u>Continuation of "Fish Tail" Ventilation in Mains</u>
The ventilation scheme used most frequently in the mains is the "fish tail" ventilation system where fresh air is brought up through the center of the mains and returned along both perimeter entries. This ventilation scheme works very well while supporting a development section as it greatly easies the burden on the auxiliary ventilation at the face. However, by returning air down both sides of the mains leakage is greatly increased. If the "fish tail" ventilation scheme is being used because of the demands of the face ventilation, then it is recommended that the system be used along stretches not to exceed 300 to 460 m (1,000 to 1,500 ft). For any airways longer than this then the mains should be converted to their "long term" ventilation configuration where airways in the mains should be grouped such that intakes and returns are separated by the belt or neutral airway. The belt/neutral airway then acts as a buffer between the intake and return and will help to reduce the leakage. The Mill Fork access mains were reconfigured in this manner.

4 Options

In order to significantly increase airflow in the Mill Fork area to support a longwall face and three development sections along with the airflow required for recovery and setup operations, the ventilation system required significant modifications. Four different scenarios were examined;

1. Installing an exhaust fan on the existing Rilda Intake Portal
2. Installing an intake fan on the existing Rilda Intake Portal
3. Installing an exhaust fan on the new 1st Right Portal (Mill Fork Services)
4. Installing an intake fan on the new 1st Right Portal

The first option was suggested as a way to mitigate the extreme losses encountered in the existing Rilda exhaust portal, however, the benefit was not very substantial as the leakage between intake and return from the portal to the Mill Fork Access mains was significant. This problem was also used to remove the second option from consideration. The mains between the Mill Fork access mains and the Rilda portals are too restrictive and the pressures necessary to achieve adequate airflows in the Mill Fork area were predicted to be prohibitively high. An exhaust fan could be installed on the new 1st Right portal (option 3) but that would limit the intake capacity and increase leakage, since at least one entry of the 1st Right Mains had to become an intake haulageway.

Because of the existing seals along the mains near the Rilda Portals it was desirable to keep the existing Rilda exhaust fan operating. This left the installation of a forcing fan on the new 1st Right portal as the only viable option. By utilizing a forcing fan on the new 1st Right portal the pressure losses in the Mill Fork mains could be overcome without increasing the differential pressures in the mains leading to the Rilda exhaust fan. This would allow the conversion of one of the existing intake entries to exhaust in the mains leading to the Rilda Exhaust Fan.

5 Recommended System

The recommended ventilation system called for the installation of an intake fan on the new 1st Right Portal. The new fan would need to be capable of passing 217 m^3/s (460,000 cfm) at a fan pressure of 2.4 kPa (9.8 in. w.g.). This would allow for the continued use of the Rilda Exhaust fan at an operational duty within its motor limitations. The operating point of the Deer Creek Fan located at the main entrance to the mine saw only minute changes between any of the scenarios. Its zone of influence is limited to the ventilation of the outby belts, haulageway, and seals.

Modifications Required for the Existing Mine
The following modifications to the ventilation infrastructure are required to achieve the airflows in this scenario:

- The entrance to the Mill Fork Access intake entry is obstructed by old, inactive overcasts. These should removed and airflow allowed to move through all intake entries in parallel.
- Convert the Mill Fork Access #6 entry from return to intake. This will put three entries in parallel.
- Remove the belt in entry #1 in the 1st Right Submains and convert to intake. This provides three parallel intakes up to the intersection of the Mill Fork Access. Under the current configuration this intersection provides a substantial constriction. By judiciously placing stoppings and relocating some stockpiled gob, improvements can be made in this area.
- A third intake entry between cross-cuts 61 and 64 in the Mill Fork Access should be developed through the sandstone channel or a bypass constructed (the intake entries were pinched from three to two in this area due to a sandstone channel).
- The Mill Fork Access entries should be configured such that the returns are grouped together. For this model the returns were modeled in entries #1 and #2, and the intakes are in entries #4, #5, and #6. This will allow the neutral/belt in entry #3 to act as a buffer between the intake and return entries. This will eliminate several stopping lines and substantially decrease leakage. With the high differential pressures encountered in this scenario, minimizing the number of stoppings is a necessity.
- The configuration of the mains between the Mill Fork Access Slope and the Rilda exhaust fans needs to maximize the exhaust capacity. Entries #1, #4, and #5 need to be configured as returns. Entry #2 will need to stay configured as an intake to provide access for the belt and as a travel way but will serve no purpose for the ventilation system. The intake to return stoppings will need to be monitored to ensure their integrity.

Potential Problems with this Scenario
Although this scenario can provide adequate ventilation there are several operational problems that will need to be resolved prior to the initiation of the system:

- High pressure differentials are predicted at the new intake portals. Because of the close proximity of the new forcing fan to the access portal the differential pressure across the portal doors will effectively be equivalent to the intake fan pressure. This will range between 2.2 and 3.0 kPa (9 and 12 in. w.g.). This represents a potential danger from an egress perspective. A set of airlocked equipment doors will need to be installed in the portal area.
- The differential pressures across the intake to return stoppings will be very high. In order to minimize leakage, these stoppings will need to be reinforced and continuously maintained and the access airlocks examined for proper operation.
- The design of the airlock in the rock slope leading to 4th North (Hiawatha Access) will need to be properly reinforced to ensure adequate operation at the high pressure predicted in this area.
- The belt air will need to be sufficiently regulated. Because of the high pressure differentials predicted, leakage into the belt can become substantial if not properly monitored and controlled through the use of belt checks.

6 Fan Procurement Process

The procedure for the tendering process was specifically defined in the bid documents and followed a prescribed set of steps. The suppliers utilized the information in the sections to prepare comprehensive tender offers. The sections included the following:

- Technical data regarding the requirements of the fan performance and site specific data necessary to minimize the possibility of error in equipment selection
- A clear definition of the responsibilities of the bidder and the responsibilities of the installation contractor, thus reducing the possibility of duplicating or omitting a piece of equipment
- A list of items to be considered during the tender evaluation, including Quality Control and testing procedures, ability to deliver, warranty terms and length, and references demonstrating the reliability of design

- The importance of sound suppression was emphasized. The specifications provided a target level of noise, an eight (8) hour time weighted average sound level of 85 dBA, and the opportunity for the potential suppliers to propose other sound levels.

The single most important item of information included in the specification was the statement “Due to site constraints, the fan layout and design shall minimize the construction area required for system installation”. Providing the information in the specification gave the potential suppliers a point of focus for their selection effort and it provided the opportunity to demonstrate their ability to offer unique solutions.

6.1 Selected Equipment Configuration

Two TLT Babcock, Inc. Model GA 25/12.5-1 axial flow fans with individual blade adjustment at rest were ultimately selected by Energy West. The features included:

Dual fan system - A single fan would operate at any one time supplying air to the mine while a spare fan would be installed alongside as a back-up. The back-up fan included a separate duct system connected to a common intake point, the mine portal.

Hub mounted motors – 1,490 kW (2,000 hp), 1,200 RPM motors were installed in each fan housing hub area to eliminate the need for separate motor foundations and connecting shafts located outside the fan. The compact hub mounted motor design was chosen to satisfy the specification requirement to minimize the area required for the system installation. The fan rotor assemblies are mounted directly on the motor shafts. In addition to saving space the compact hub mounted motor design also eliminated the fan bearings, coupling and shaft guards, and the safety hazard of the rotating shaft located outside the fan.

Inlet box – To save additional field layout space an inlet box incorporating a 90° vertical turn was installed at the fan inlet. The purpose of the box was to provide a connection flange for an inlet silencer and rain hood mounted above ground level. Another benefit of the inlet box is that it directs the fan airborne inlet noise up and away from ground level, thus reducing the cost and pressure loss of an inlet silencer.

Sound suppression – The suppression of the fan sound was challenging. Predicting the actual noise levels at the site is very difficult considering the unknown interaction of the fan noise with the topographical features of the surrounding area. In addition, atmospheric conditions, such as an air inversion, can also affect noise transmission. The strategy to address the problem was to proceed in steps to suppress each component of noise one at a time until the required noise level is met. Initially acoustic enclosures were installed around the fan housings to attenuate the ground level housing noise. The vertical fan inlet box directing the fan airborne inlet air stream noise upward also provides a degree of attenuation at ground level. If additional noise suppression is required sound attenuators will be installed at the fan inlet and acoustic enclosures or acoustic insulation and lagging can be applied to the connecting ductwork.

Air-lock doors – Typically air-lock door systems are not a primary design feature but the system for the Deer Creek installation did receive added attention. Energy West Mining specified that the system must be designed with adequate space to accommodate two men and a stretcher to enter and exit during an emergency. The cost was minimal for the benefit, if the doors are ever utilized in an emergency.

6.2 Initial Commissioning

The initial start-up of the fan equipment was problematic. The motor thrust bearing on the non-drive end of the motor shaft failed shortly after initial operation. TLT Babcock was notified and they set in motion an investigation with the motor and bearing manufacturer to determine the cause of the failure. Both fan motors were sent to a local repair shop for repair and analysis of the condition of the bearing.

The investigation of the failure indicated that the thrust bearing was carrying a disproportionate amount of axial load in relation to the radial load and that the radial load was below the lower limit. The bearing system was reviewed and a different type of bearing was installed on the motor shaft non-drive end. In addition, a new type of grease was installed in the bearings. The motors were re-installed in the fans and shipped back to the mine site.

The fans were reinstalled at the site and the commissioning activities started for a second time. Analysis of the bearing vibration during start-up revealed that although no high levels of velocity were present the peak levels of acceleration were high enough to warrant further investigation. The fans were removed from service and sent to the TLT Babcock assembly facility for further analysis and testing.

The fans were tested at the factory in the presence of a consultant provided by the motor manufacturer. The motors continued to exhibit high levels of acceleration indicating possible early stages of failure. It is worth mentioning that the bearing system installed in the motors was reviewed by the bearing manufacturer and all bearing loads were found to be within acceptable limits. In addition, the bearing system was successfully operating at another site with a similar but smaller fan/motor arrangement. The absence of a clear cause of the excessive bearing vibration and the evaluation of the facts gathered during the investigation indicated that additional outside consultation was required. A well known manufacturer of rotating machinery with extensive experience designing shafts with overhung loads was consulted for assistance. They recommended a completely different bearing arrangement that increased the stiffness of the system. The new bearing arrangement was installed in the motors and the fan/motor assemblies were successfully started-up with a minimum of problems.

6.3 Field Performance Testing

A fan performance test was conducted at the site in July, 2007. The test was carried out in accordance with the Air Movement and Control Association (AMCA) standard for field testing. Pitot measurements were taken at the fan inlet evase and the fan outlet diffuser and additional static pressure measurements were taken at the outlet of the rain hood, at the "Y" in the connecting duct, and the mine portal.

Although the testing was successful and the fan efficiency at the test points was demonstrated to be accurate the following points should be observed when considering performance field testing of new equipment.

Mine fan equipment is generally selected for conditions of air flow volume and pressure that will be required at a future time. At the initial installation of the equipment the fan blade pitch is adjusted to a point to deliver lower airflow volume and pressure, i.e. at a point well below the selection operating point. The blade pitch could be adjusted to the final operating angle but the actual mine resistance will likely not be high enough to generate the final system resistance curve, thus the fan will not operate at the point selected. If a field performance test is to be conducted after installation, consideration should be given to providing some means to artificially increase the mine resistance to the point forecast for future operation. Closing dampers in the duct system, a blanking plate at the mine portal, or some means to obstruct the air flow in the mine would serve to increase the resistance as long as the obstruction is not close to the fan outlet.

7 Conclusion

The development of the push/pull ventilation system was necessary to allow for the mining and development in the remote Mill Fork area. Utilizing a dedicated forcing or exhausting ventilation system would not have been possible due to the excessive leakages and pressure differentials encountered. The system has been installed and running for approximately one year and has achieved good success.

Although there were a considerable number of problems with the equipment during start-up the problems were ultimately resolved. Bearing vibration, especially vibration acceleration, continues to be measured and closely monitored at the mine site.