Reconciliation of ventilation and production expansion in a potash mine

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Potash Corporation of Saskatchewan Inc. (PotashCorp) is developing an expansion of its Rocanville Division, a potash mine in southeastern Saskatchewan. The expansion is targeted to increase the sites output from the current 3.0 MMtpa to 5.7 MMtpa K_2O. In order to be compatible with the upgraded milling facilities, the current service shaft is being converted to a second production shaft. The increased milling and hoisting capacity has also meant an expansion of the mining fleet and mine footprint was required. The expansion also includes construction of a service shaft approximately 15 km from the existing site, meaning three shafts are available for mine ventilation. With an increased mine footprint and a much larger underground production fleet, the existing ventilation system had to be increased in capacity. This paper presents the many engineering innovations used to design an efficient and economic mine ventilation system. A completely new flow distribution was modeled, with the mine expanding from a two shaft system to a three shaft system. Extensive computer modeling was used to assist in fan selection and simulations were done to integrate production scheduling and ventilation requirements. Commissioning of the ventilation system upgrade is being implemented in phases to permit a controlled transfer of fresh air to the new shaft, and ramp up to full ventilation capacity with minimal disruption to mine operations.

Keywords: ventilation, primary fans, booster fans, circuit design

1. Introduction

Over the past decades, annual potassium intensive crop production has been driven upward by increases in world population, high rates of urbanization and decreases in arable land. Potash plays a central role in helping feed the world's growing population. Approximately 90% of world potash production is being used as fertilizer [5].

Rocanville Division, a potash mine in southeast Saskatchewan, is currently undergoing a major mine and mill expansion. The target site output for the expansion is 5.7 Million metric tonnes per annum (MMtpa) from the current 3.0 MMtpa K_20. In order to feed the mill, an estimated 50,000 metric tonnes per day (approximately doubling the current production) will need to be mined and hoisted. The expansion consists of three components, doubling the mill capacity by building a new mill, doubling the hoist capacity by converting the existing service shaft into a production shaft, and doubling the mine output by increasing the mining machine fleet and mine footprint, along with the sinking of a new remote shaft to act as a service shaft.

The mine currently operates two shafts, #1 production shaft and #2 service shaft. Because retro-fitting the hoist system in #1 Shaft to meet the planned feed rate would be impractical, the current service shaft is being converted to a production shaft containing two 46 metric tonne skips. In conjunction with the conversion of #2 Shaft to a production hoist, a third shaft (#3 Shaft) is currently being sunk 16 km from the Rocanville surface site. The #3 Shaft serves three significant purposes; it will act as a service shaft, providing access for workers and materials to the mine, secondly, due to its location, it will provide shorter access to active mining areas, and finally provide a new source for fresh air to the mine.

To meet the planned mine production the production mining machine fleet and the mine footprint approximately doubled.

A major component of the expansion program includes the design, construction, and development of an upgraded ventilation system to reconcile ventilation with mine production expectations. This paper presents a description of the ventilation design study. The mine ventilation system was designed by analyzing the minimum requirements for effective production on a 'per machine' basis, and then scaled up to account for the entire fleet. Shaft capacities for airflow were also analyzed based on construction and shaft conveyances. Mine resistance was also estimated using ventilation engineering principles. Design parameters were verified through ventilation computer modelling. Design factors were then used to generate specifications for fan systems to be purchased and installed.

2. The current and future ventilation system

Rocanville ventilation has fresh air downcast into the mine through its service shaft, and exhaust upcast through the production shaft. With the conversion of #2 Shaft to a production shaft, #3 Shaft will act as the primary source of fresh air for the entire Rocanville Mine, and #2 Shaft will be converted to a second exhaust shaft.

In the new ventilation layout the airflow will enter the mine ventilation system at #3 Shaft, through use of surface primary fresh air fans. At the potash station of #3 Shaft, sets of underground booster fans will draw air from the shaft and boost it out to the mine workings. New shaft bottom underground booster fans will be installed to draw air from the workings and exhaust it up the #1 and newly converted #2 Shafts. Surface fans on both of these shafts will then draw the exhaust air from these shafts and ventilate it to atmosphere.

3. Estimation of flow requirements

Mining at Rocanville is done using electrically powered mining equipment, and the ore is conveyed to the shaft using electrically driven conveyor belts. However, development mining does utilize diesel powered Torkar ore haulers when conveyor belt installation is impractical. Also, the equipment used to support the mining activities (loaders, scoops, telehandlers, etc.) are diesel powered, and the vast majority of the personnel transport and maintenance support equipment are diesel powered trucks. The Saskatchewan Mines Regulations require 0.0633 m^3/s of fresh air supplied for every diesel kilowatt underground [4].

One of current traits of the mine's ventilation circuit was that mining machines are independently ventilated in parallel, that is, each machine receives fresh air that has not been used by another machine. This feature guarantees a source of fresh air to each active face.

Estimations of flow requirements are based on the support diesel equipment utilized at the face during the different phases of panel development and production. Development mining utilizing Torkar and Loader mining is the most diesel intensive activity that takes place at the mine. Based on the diesel fleet and number of active mining machines, the current overall flow supply to the mine is 142 m^3/s [1].

Through the process of expanding the mine, additional mining machines will enter production. Based on the number of active miners and production schedule, target underground airflow volumes for the mining machines has been estimated at 236 m^3/s, not accounting for air leakage. Based on #3 Shaft ventilation capacity, the available fresh air flow volume at shaft bottom has been estimated at 254 m^3/s. A schematic of the overall flow distribution is presented in Figure 1.

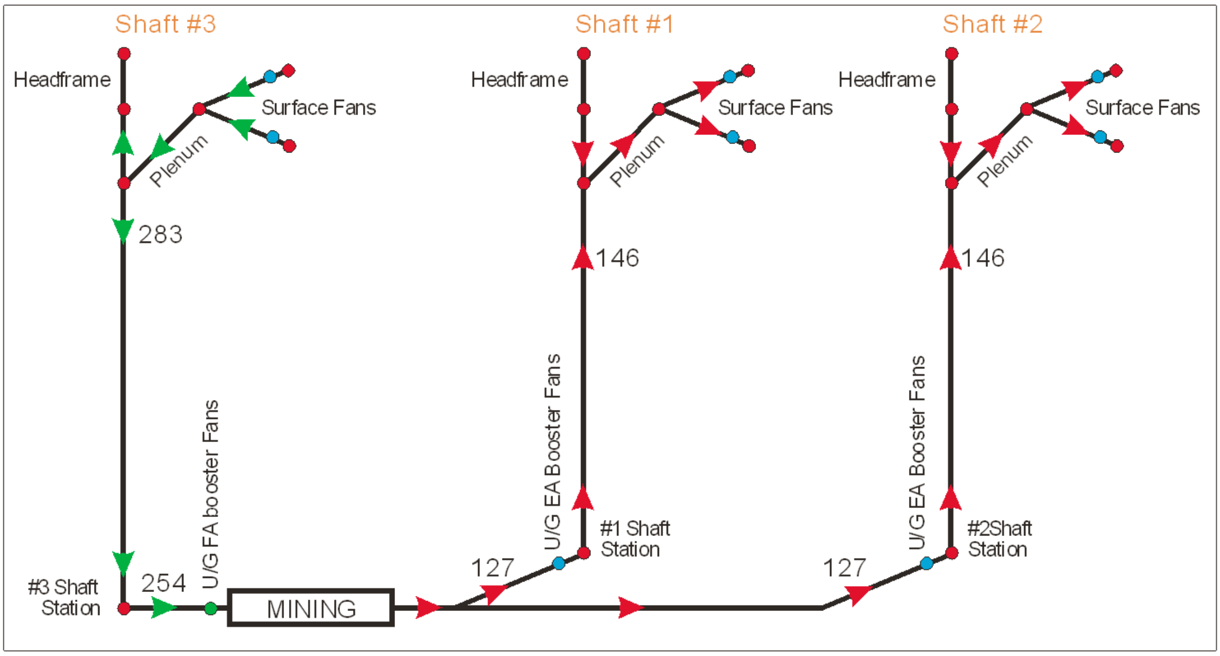

Figure 1. Future overall mine flow distribution.

4. Ventilation design

The mine ventilation system was designed such that the creation of large differential pressures was avoided to minimize the potential for leakage and recirculation. The flow distribution was devised to attain lower resistance pressures and to minimize operating costs.

The selection and sizing of all ventilation fans required a detailed assessment of shaft resistances [2]. The surface fresh air and exhaust air fans were sized to overcome the plenum resistances and to slightly pressurize each shaft. Three underground booster fan installations were designed to serve the three shafts. The booster fans were sized to overcome shaft and underground circuit resistances [3]. An additional consideration for fan selection was that common sizes for fan components should be utilized whenever possible to reduce the required inventory of spare parts.

Approximate locations of the main fresh air and exhaust air underground booster fans are shown in Figure 1.

4.1 #3 Shaft surface fresh air fans

The surface fresh air fans were designed to bring heated fresh air from surface to the #3 Shaft. Sizing of the #3 Shaft main surface fresh air fans considered a horizontal assembly of two fans in parallel configuration. The design air flow rate was 153 m^3/s. A fan total pressure 1 kPa was determined considering the plenum, heater and fan assemblage resistance pressures. Each fan will be fitted with a 225 kW motor and variable frequency drives (VFDs) will be installed to control the balance of pressures and distribution of flows.

Based on the fan design operating requirements vane axial fans, 2.6 m in diameter, with 1.27 m hub diameter, were selected.

4.2. #1 Shaft surface exhaust fans

The current #1 Shaft surface fans will continue to serve this exhaust airway in the future. The installation consists of two 2 m diameter, with 1.27 m hub diameter, vane axial fans, operating in parallel configuration. Each fan is fitted with a 112 kW motor. The surface exhaust fans were designed to draw exhaust air from the #1 Shaft via the plenum to the surface.

The design air flow rate was estimated at 85 m^3/s. A fan total pressure 0.55 kPa was determined considering the plenum and fan assemblage resistance pressures.

4.3. #2 Shaft surface exhaust fans

Sizing of the #2 Shaft main surface exhaust air fans considered a horizontal assembly of two fans in parallel configuration. The surface exhaust fans were designed to draw exhaust air from the #2 Shaft via the plenum to the surface.

The design air flow rate was estimated at 83 m^3/s. A fan total pressure 0.54 kPa was determined considering the plenum and fan assemblage resistance pressures. Each fan will be fitted with a 112 kW motor and VFDs will be installed to control the balance of pressures and distribution of flows.

Based on the fan design operating requirements vane axial fans, 2 m in diameter, with 0.76 m hub diameter, were selected.

4.4. #3 Shaft underground fresh air booster fans

The underground fresh air main booster fan installations were sized to overcome the #3 Shaft resistance and the underground circuit resistance. The shaft resistance was determined based on detailed shaft ventilation surveys. The underground circuit resistance was estimated based on the current circuit and on ventilation modelling for the future layout.

Two underground fresh air fan stations will serve #3 Shaft. Each station will be comprised of two fans operating in parallel configuration. Each fan was sized based on a flow of 71 m^3/s. A fan total pressure 1.5 kPa was determined considering the shaft, mine circuit and fan assemblage resistance pressures. VFDs will be installed to control the balance of pressures and distribution of flows.

Based on the fan design operating requirements, vane axial fans, 2 m in diameter, with 0.76 m hub diameter, were selected. Each fan will be fitted with a 150 kW motor.

4.5. #1 Shaft underground exhaust air booster fans

The underground exhaust air main booster fan installations were sized to overcome the #1 Shaft resistance and the underground circuit resistance. The shaft resistance was determined based on detailed shaft ventilation surveys.

The booster fan station will consist of two fans installed in parallel configuration. Each fan was sized based on a flow of 76 m^3/s. A fan total pressure 1.1 kPa was determined considering the shaft, mine circuit and fan assemblage resistance pressures. Based on the fan design operating requirements vane axial fans, 2 m in diameter, with 0.76 m hub diameter, were selected. Each fan will be fitted with a 150 kW motor. VFDs will be installed to control the balance of pressures and distribution of flows.

4.6. #2 Shaft underground exhaust air booster fans

The underground exhaust air main booster fan installations were sized to overcome the #2 Shaft resistance and the underground circuit resistance. The boosters fan station will consist of two fans installed in parallel configuration.

Each fan was sized based on a flow of 76 m^3/s. A fan total pressure 1.1 kPa was determined considering the shaft, mine circuit and fan assemblage resistance pressures.

Based on the fan design operating requirements vane axial fans, 2 m in diameter, with 0.76 m hub diameter, were selected. Each fan will be fitted with a 150 kW motor. VFDs will be installed to control the balance of pressures and distribution of flows.

4.7. Summary

Figure 2 presents a schematic for the main and booster fan design. A total of 6 main surface fans have been sized and selected with an installed brake power of 895 kW and a total of 8 underground booster fans have been sized with an installed brake power of 1194 kW. Overall, 14 fans have been sized and selected, with an installed brake power of 2089 kW. In addition, secondary underground booster fans will be necessary to achieve the required overall flow distribution. The goal of common fan sizing was also achieved, with all fans installed underground of the same size, make, manufacturer, and design. Only adjustments in blade angle were required to achieve design parameters for pressure and flow.

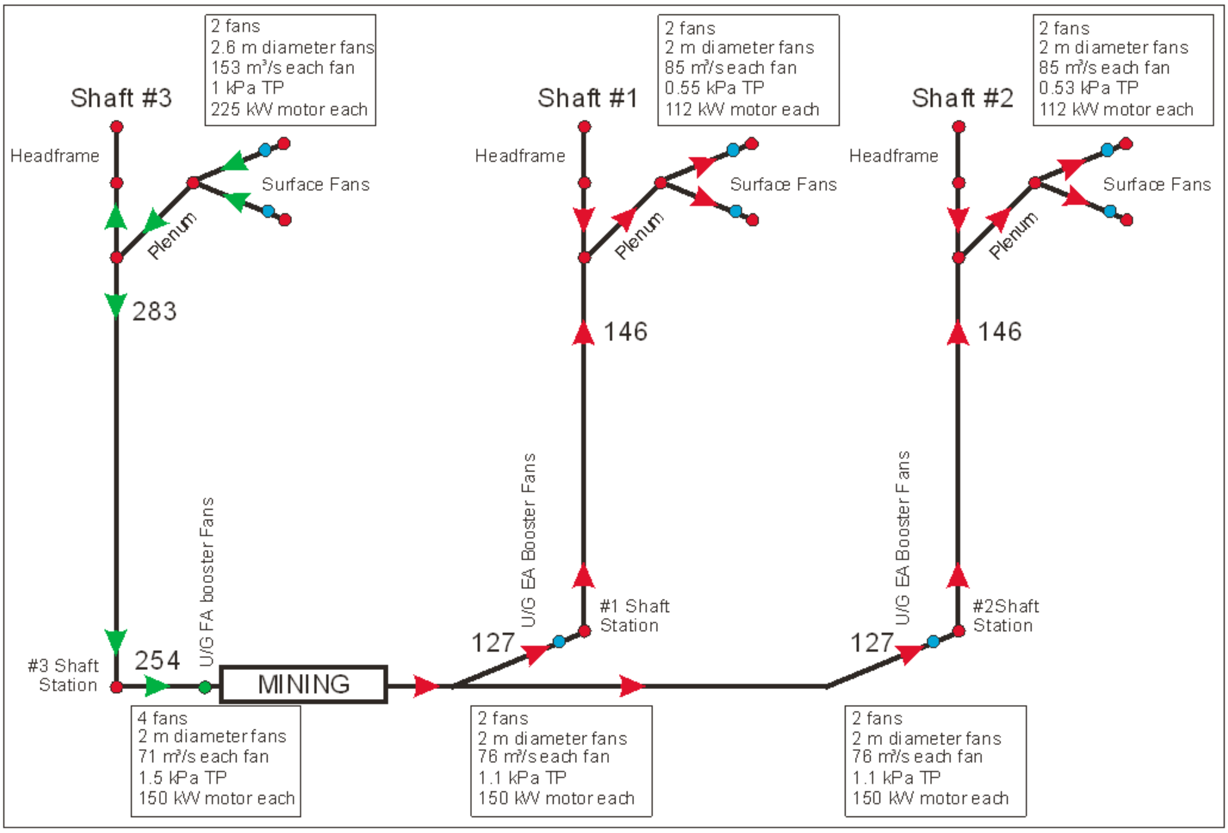

Figure 2. Mine primary and main booster fan requirements.

5. Design verification

Network modelling techniques were used to conduct simulations of the Rocanville mine ventilation system, and to verify the system design and fan requirements.

The computer model was updated to reflect current mine ventilation conditions (model verification) and checked for accuracy and correspondence with survey data (model calibration). Accurate verification and calibration of the ventilation network computer model developed by the mine are essential to produce models which provide a good representation of the current mine ventilation system and which provide a reasonable representation of the mine ventilation system at each planned stage.

A series of ventilation scenarios were developed to verify the fan sizing and selection work, and to verify if the required local flow distribution can be achieved based on mine scheduling.

Model simulation results closely reflected the estimated individual system resistances and resistance pressures and also validated all fan system design recommendations.

In order to achieve the planned regional flow distribution, required regional booster fan stations were configured and modelled. All borers could be successfully supplied with the required flows.

6. Planned phased system implementation

Throughout the entire expansion, Rocanville mine was required to maintain a consistent supply of potash production. In order to facilitate production, and meet regulatory requirements for ventilation, a phased implementation was planned for the various systems.

6.1 Phase 1 - Pre-breakthrough readiness & production expansion

The mining machine fleet expansion was completed prior to the opening of Shaft #3. In order to facilitate an increased number of mining machines, zone cascade (series-parallel) ventilation was established to increase air volumes in the areas of the mine with heavy construction going on. This change was adopted, along with several necessary network adjustments in preparations for shaft breakthrough and the reversal of airflow in the fresh-air entries of the expanded mine. As well, all of the shaft-bottom underground booster fans were installed, and commissioned. The fans located underground at #1 Shaft were to be made fully operational prior to breakthrough of #3 Shaft. #1 Shaft was not to change in resistance, capacity, or flow, and therefore could be used to commission and test the first set of new fans. Through this phase, #2 Shaft will be supplying 142 m^3/s of fresh air, and it will be exhausted up #1 Shaft.

6.2 Phase 2 - Breakthrough of Shaft #3

In order to start the transition process for the fresh air circuit, supply through #3 Shaft is to be slowly increased as the shaft becomes available and the circuit is tested. Congruently, supply from #2 Shaft is to be slowly reduced by using the VFD controls. #3 Shaft bottom is to be entirely air locked during the breakthrough process to prevent pressurized air from leaving the mine workings. The end goal for this phase is to supply up to 71 m^3/s to the mine from #3 Shaft, and reduce supply from #2 Shaft to a similar volume (one quarter of the final system capacity). #1 Shaft will still be the only exhaust shaft, flowing 142 m^3/s.

6.3 Phase 3 - Transition of fresh air supply to Shaft #3

The duty of servicing the mine with men and materials is planned to transfer to #3 Shaft as soon as the hoist is ready. When this happens, supply at #2 Shaft will cease, and flow at #3 Shaft will be increased (using VFD control) an additional 71 m^3/s, to the original system capacity of 142 m^3/s, and one half of the full system capacity. During Phase 3, #2 Shaft will be bulk-headed on the top and bottom to facilitate work replacing the headframe and hoist system on top, and the tie-in of the skip loadout system at the bottom. During this phase the current fresh air fans atop #2 Shaft will be removed and replaced with a new system, and the fresh air fans will be removed and relocated to mid-mine bulkheads, where they will provide pressure to supply mining blocks. #1 Shaft will still be the only exhaust shaft, flowing 142 m^3/s.

6.4 Phase 4 - Re-opening of #2 Shaft/conversion to exhaust shaft & system ramp up

When the mechanical conversion of #2 Shaft into a production shaft is complete, the bulkheads will be removed, and ventilation system ramp-up can begin. Supply of fresh air at #3 Shaft will be increased, and the additional volume will be taken by the new underground and surface booster fans at #2 shaft. #1 Shaft will still be exhausting 142 m^3/s. The goal for this phase is to ramp up the ventilation system to the full design capacity of 254 m^3/s ventilating the mine workings.

6.5 Phase 5 - Final commissioning & optimization

Once the main flows have been established and the design capacity realized, the system will be optimized. The system will be tested by manipulating manual and network adjustable variable-frequency drives, and the effects will be catalogued. The test results, and effects from other inputs, like ambient surface conditions, will be used to build an automated control narrative for the main fans, having the system react automatically to various scenarios that may exist.

6.6 Summary

Throughout the process, Rocanville Mine plans to produce potash, and all mining machines will be effectively ventilated. The primary goal of reconciling the ventilation system with the production requirements is being effectively achieved.

7. Summary

An engineering assessment and design of the Rocanville Division mine ventilation system upgrade has been presented in this paper. Overall, 14 fans have been sized and selected, with an installed brake horsepower of 2089 kW, in order to achieve an overall flow of 254 m^3/s.

An entirely new mine flow distribution was designed and modelled, with the mine expanding from a two shaft system to a three shaft system, and with the number of mining machines approximately doubling. Commissioning of the ventilation system is being successfully implemented in phases to permit a controlled ramp up to full ventilation capacity with minimal disruption to production and mine operations.

Computer model simulations demonstrated that the mine will, in the future, be able to meet all flow requirements, while meeting all regulatory and safety requirements.

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