Improving mine ventilation and ground support performance with thin spray-on liners

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Abstract: The use of a spray-on liner agent, Mineguard^{TM}, to provide reduction in power and ventilation costs, to provide support and control brine migration in potash mine shafts, and to block diffusive flows of radon in uranium mines, has been evaluated. Mineguard^{TM} lining was installed in a primary airway within an underground hard rock mine to evaluate airway friction factor and roughness conditions existing before and after liner application. The field test results have indicated that thin spray-on liner coatings, when applied to airway rock surfaces, may reduce the friction factor of mine airways by approximately 7%. An experimental investigation has demonstrated that Mineguard^{TM} is capable of providing effective support for soft rocks and is capable of controlling the dissolution of potash rock by inflow brine. Additional study has been conducted to evaluate the potential gas blocking capabilities of Mineguard™. Based upon laboratory measurements, typical Mineguard™ layer thicknesses of 1.0 mm were demonstrated to be capable of blocking diffusive flowsof radon by approximately 99.85%.

1 Introduction

Mineguard™ is a polyurethane-based agent which is sprayed to create an effective thin rock support liner. Its inception has resulted in development of a support technique which has been shown to significantly reduce the time necessary for support installation, minimize rock pre-conditioning requirements, decrease materials handling/labour requirements and promote a high degree of automated handling capability. Mineguard™ has been the subject of performance review for a multitude of purposes as presented in this paper.

This paper outlines an investigation of the ventilation gains that application of Mineguard^{TM} in a ventilation drift at an underground hardrock mine would produce, and of the ventilation properties of Mineguard^{TM}. This paper provides an evaluation of the friction factor before and after liner application; an evaluation of the improvement in ventilation conditions (lined drift versus raw drift); and an assessment of ventilation power cost savings when Mineguard^{TM} is used as a liner in ventilation airways.

In an experimental investigation, designed to assess the support performance and dissolution control capabilities of Mineguard^{TM}, unlined and lined potash specimens were subject to uniaxial and triaxial loading. Such study has determined that Mineguard^{TM} is unaffected by the presence brine, provides effective control to creep deformation, and eliminates any dissolution potential of potash rock by inflow brine.

An evaluation of potential gas blocking capabilities of Mineguard™ is also presented. On the basis of laboratory investigations, emplaced coatings of Mineguard™ have shown to significantly reduce levels of radon flux and diffusion flow occurring between highly emanating sources and radon-free environments. A case example is presented to illustrate the effects of installing Mineguard™ upon emanating rock surfaces within mining environments. Simulation studies of a uranium mine network indicate that a substantial Working Level reduction, in the order of 60 percent, may be realized following installation ofMineguard™.

2 Ventilation management with spray-on liners

Ventilation power costs have a direct relationship with friction head losses in mine airways; a reduction in airway friction factor would produce a corresponding reduction in power costs. This section outlines a field experimental program conducted in an underground hardrock mine aimed at improving ventilation conditions and at reducing power costs. The test airway, passing a flow of 24.7 m^3/s before lining application, averaged 3.2 m in width and 2.8 m in height. The stable fresh air drift was supported with rock bolts, metal straps and screen mesh. The sprayed section of the airway measured 91 m in length(Figure 1).

The resistance of the airway, before and after material application, was calculated from direct measurements of static head drop associated with measured flow rates. Barometric pressure and humidity conditions were also measured to determine local air densities. Barometric pressures were determined using a Wallace & Tiernan altimeter Model FA181 and dry and wet air temperatures were measured using a Psychrodyne psychrometer. Photoprofiling was used at stations established every 7.6 m along the airway to determine true drift dimensions (cross-sectional area and perimeter). Air velocities were determined using an AV2 anemometer fitted with a 100 mm head and pressure drops were measured using the gauge and tube method. An AP230A manometer and two 1.22 m x 9.525 mm pitot tubes fitted with 106.7 m of 4.76 mm inside diameter tygon tubing were used for the measurement of differential pressures.

Three ventilation surveys were performed in the testing program. Two surveys (surveys #1 and #2) were performed prior to, and one (survey #3) after Mineguard^{TM} application. From the survey data, the airway resistance, friction factor and roughness height were calculated. The airway property evaluation results, converted to standard density conditions, are presented in Table 1. Results indicate average decreases in airway resistance of 7.44%, in friction factor of 7.42% and roughness of 12.19% as a result of the application of the liner, even though only a relatively short length of airway was lined. The introduction of this lining material in mine airways could therefore serve to reduce system friction head losses while maintaining good environmental quality (dust reduction and lighting enhancement) and improved mechanical support performance.

Table 1. Summary of ventilation survey results.

	Flow (m^3\s)	Head (kPa)	Resistance ($N.s^2/m^4$)	K factor ($N.s^2/m^4$)	roughness height (m)
Survey #1	35.13	0.0264	0.02078	0.01709	0.3847
Survey #2	24.78	0.01494	0.02351	0.01932	0.472
Survey #3	24.69	0.01295	0.02052	0.01687	0.3763

An economic assessment was performed to verify the feasibility of Mineguard^{TM} applications for savings in ventilation power. Cost calculations were performed for an airway handling different airflow rates before and after Mineguard^{TM} application. The case study considered an airway of 3 m x 3 m nominal size and designed to handle an airflow rate of 47 m^3/s. The direct and indirect airway development costs were C\$50/m^3 and \$130/m respectively. The fan cost was \$450/kW installed, the fan maintenance cost \$80/kW/year, and the power cost was \$280/kW/year. The fan efficiency was 65%. The airway friction factors before and after Mineguard^{TM} application were 0.018205 $N.s^2/m^4$ and 0.01687 $N.s^2/m^4$ respectively. The project life was 20 years and the interest rate was 10%. The cost of application of Mineguard^{TM} was estimated as \$22 /m^2.

The analysis procedure involved a comparison of alternatives where the additional cost of installing Mineguard^{TM} would be offset by the reduced power costs involved in circulating the air. It involved establishing all variable costs (annual initial cost, annual operating cost and total cost) by analyzing how costs vary with changes in airway friction factor and airflow volume. The annual initial cost for the sprayed airway is higher than the cost for the raw airway for all airflow conditions but the annual operating cost for the sprayed airway is consistently lower than the raw airway. Plots of total annual cost per unit length of airway versus flow rate are shown in Figure 2. Evaluation results indicate that the total annual ventilation cost for the lined 3 m x 3 m airway is higher for flows below 118 m^3/s. For the given conditions, for airflow rates above 118 m^3/s the application of Mineguard^{TM} becomes a feasible alternative. The percent gain/loss in total annual cost was also estimated. For a flow of 47 m^3/s, although the annual operating costs are reduced, a 20% increase in total annual cost is experienced. This is mainly due to the cost of installing Mineguard^{TM}. For a flow of 118 m^3/s, the total annual costs are approximately the same, and for a flow of 142 m^3/s, a 3% reduction in total annual cost, associated with Mineguard^{TM} application, will result.

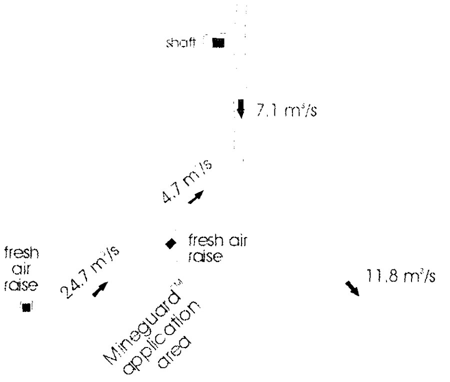

Figure 1. Mine level plan schematic.

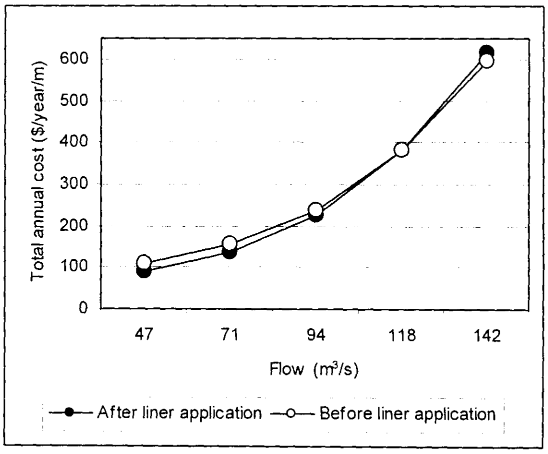

Figure 2. Total annual cost as a function of flow rate.

The above evaluation of ventilation power reductions and cost savings associated with coated mine airways has indicated that Mineguard^{TM} may reduce the annual ventilation operating costs for typical mine primary airways passing relatively large flow rates while also providing additional ground support.

3 Liner support in potash mine shafts

During shaft sinking operations of Saskatchewan potash mines, of the first four shafts started, three were flooded before completion, because of the presence of several water bearing units, at relatively high pressures, both underlying and overlying the potash level. To alleviate the water inflow problems, all shafts used watertight iron linings through zones most prone to water inflow, and one shaft was concrete lined throughout. The presence of brine in the shafts, however has a long term detrimental effect on the support by decaying the lining.

Experimental testing has demonstrated that the strength and mechanical properties of Mineguard^{TM} are unaffected by the presence of brine. Dumbbell shaped straps of Mineguard^{TM} were prepared according to the American Society for Testing and Materials standard (ASTM, 1998) and placed in brine at temperatures of 20°C, 40°C and 60°C for an 8-hour period. After the tests, no changes were found in their length, thickness, weight and tensile strength properties. Test results indicated that no reaction, either chemical or physical, occurred between Mineguard^{TM} and brine (Shende, 2003). Such results have indicated that Mineguard^{TM}, when used as a support liner in shafts, would not be detrimentally affected by the presence of brine.

Additional testing was performed to assess the effectiveness of Mineguard^{TM} in controlling dissolution and in increasing the strength characteristics of potash under loading conditions (Shende, 2003). Mineguard^{TM} was uniformly sprayed to the surface of potash cores at a thickness of 2 mm. The cores were immersed in brine at different temperatures and loaded under uniaxial and triaxial conditions. Table 2 presents a summary of results for uniaxialy loaded specimens at 8.75 MPa in the presence of brine at 20°C. Test results indicated that Mineguard^{TM} could completely isolate the potash rock from the brine this preventing its dissolution and strength deterioration. Testing also indicated that Mineguard^{TM} could withstand substantial deformation during creep testing

Table 2. Properties of potash rock in the presence of brine.

	Dissolution (%)	UCS (MPa)	Secondary creep (s^{-1})
Without Mineguard^{TM}	2.2	15.9	2.23E-06
With Mineguard^{TM}	0.0	35.0	5.00E-07

4 Liner barrier for mitigating radon gas inflows

An experimental study has been conducted to evaluate potential gas blocking capabilities of Mineguard™. A contaminant gas of concern in mining is radon, which occurs naturally in both uranium and non-uranium mines. Radon is capable of diffusing through porous rock into mine openings and generating worker exposure at levels above regulated occupational limits, should appropriate ventilation controls not exist. Traditional area support media, such as concrete or shotcrete, offer minimal resistance to diffusive movement of radon into mine workings. Such materials are also unable to penetrate and seal fractures when applied to rock surfaces. Mineguard™ coatings, alternately, have demonstrated the ability to significantly penetrate rock fractures, when sprayed in liquid form, and to seal fractures when cured. Radon gas permeability trials were conducted using Mineguard™. From this work, a proportionality parameter (R) was calculated and used to determine the potential radon blocking capacity of Mineguard™ in the form: Diffusion Blocking Capacity = (1 - R) x 100%. Based upon experimental measurements, typical Mineguard™ layer thicknesses of 1.0 mm were demonstrated to be capable of blocking diffusive flows of radon by approximately 99.85%.

An active mining layout, illustrated in Figure 3, represented by mining activity within a multi-branch airflow and stope network has been simulated. The equivalent mine circuit which was modeled using network analysis and radon growth theory, as well the results of the simulations, are presented in Figure 4. Typical radon emanating characteristics for ore and waste materials used in the simulations were: intact ore (roof and walls) - 9.02 $Bq/m^2/s$; broken ore (floor) - 11.77 $Bq/m^2/s$; intact waste (roof and walls) - 6.24 $Bq/m^2/s$; broken waste (floor) - 7.70 $Bq/m^2/s$. Two stages of simulation were performed; the first stage involved the estimation of Working Level conditions for the mining scenario where no mitigation measures have been implemented and the second stage considered conditions following membrane installation on all emanating walls and back. No membrane application was assumed to occur upon floors. For this reason, some residual level of radon and daughter contamination will always be developed within emanating work places. The simulation process for radon barrier application was performed by reducing the emanation parameters of treated rock surfaces within the airways; the following emanating characteristics were assumed: treated intact ore (roof and walls) – 0.18 Bq/m^2/s; treated intact waste (roof and walls) – 0.125 Bq/m^2/s.

Simulation results indicate that a substantial Working Level reduction, in the order of 60%, may be realized following installation of Mineguard™. Such results are of particular importance within working stopes where, for example, daughter concentration levels had been shown to reach over 60 percent of the maximum permissible levels prior to rock treatment.

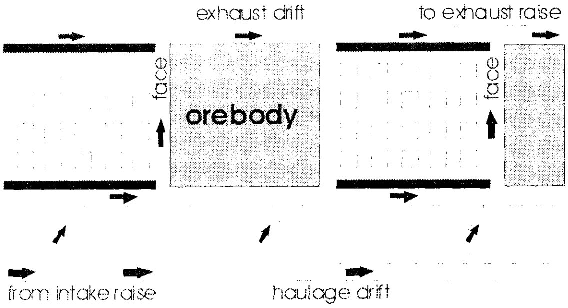

Figure 3. Simulated mine layout.

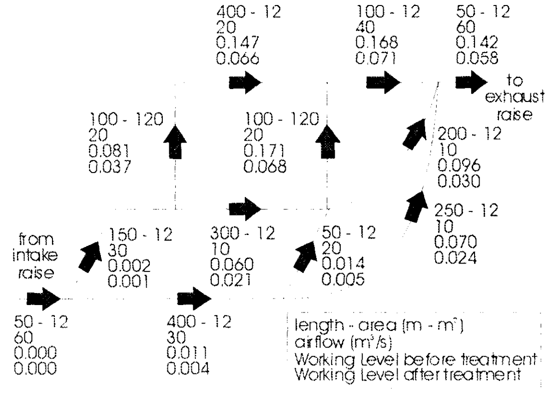

Figure 4. Mine network with conditions before and after rock treatment.

5 Conclusions

Extensive field and experimental investigations, outlined in this paper, have indicated that:

- Mineguard^{TM} may reduce the friction factor of mine airways by approximately 7% and that, although the application of Mineguard^{TM} under certain airway and airflow conditions may not be economically feasible for ventilation power savings alone, the many other advantages of the product (support performance, improved lighting conditions, radon mitigation, etc.) may easily justify its application.
- Mineguard^{TM} is capable of providing effective support for soft rocks and is capable of controlling the dissolution of potash rock by inflow brine.
- Mineguard^{TM} could be effectively used to cover existing shaft linings to prevent corrosion of the lining and subsequent dissolution of the rock.
- Mineguard™ is capable of effectively blocking diffusive flows of radon in uranium and non-uranium mines.

Acknowledgements

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