When 0.5 mol/L oxalic acid was used to neutralize the red mud prior to acetic acid leaching, the lithium leaching efficiencies were in the range of 42.41 to 46.88 percent, close to that of calcium and much higher than those of other main elements like sodium, aluminum, iron and magnesium. It can be concluded that oxalic acid was effectively used to treat red mud in this study, as it is acidic enough for the removal of sodium and can precipitate calcium.

The findings are instructive for the subsequent recovery, separation and purification of lithium from red mud. The optimum conditions for the extraction of lithium from oxalic acid–neutralized HN red mud were found to be acetic acid concentration of 25 percent (v/v), temperature of 85 °C and time of 60 minutes.

Conclusion

The leaching behavior of lithium from HN red mud using acetic acid was found to be significantly dependent on the neutralization pretreatment. Neutralization using oxalic acid was effective in removing sodium and aluminum and realizing higher lithium leaching efficiency. ■

References

1. Borra CR, Blanpain B, Pontikes Y, Binnemans K, Van Gerven T (2017) Recovery of rare earths and major metals from bauxite residue (red mud) by alkali roasting, smelting, and leaching. J Sustain Metall 3(2):393-404
2. Narayanan RP, Kazantzis NK, Emmert MH (2018) Selective process steps for the recovery of scandium from Jamaican bauxite residue (red mud). ACS Sustain Chem Eng 6(1):1478-1488
3. Lu F, Xiao T, Lin J, Li A, Long Q, Huang F, Xiao L, Li X, Wang J, Xiao Q, Chen H (2018) Recovery of gallium from Bayer red mud through acidic-leaching-ion-exchange process under normal atmospheric pressure. Hydrometallurgy 175:124-132
4. Gu H, Wang N, Hargreaves JSJ (2018) Sequential extraction of valuable trace elements from Bayer Process-derived waste red mud samples. J Sustain Metall 4(1):147-154
5. Guo T, Yang H, Liu Q, Gu H, Wang N, Yu W, Dai Y (2018) Adsorptive removal of phosphate from aqueous solutions using different types of red mud. Water Sci Technol 2017(2):570-577

Cryogenic air supply for cooling built-in-place refuge alternatives in hot mines

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To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Built-in-place (BIP) refuge alternatives (RAs) are designed to provide a secure space for miners who cannot escape during a mine emergency. Heat and humidity buildup within RAs may expose miners to physiological hazards such as heat stress. To minimize the risk of heat stress, Title 30 Code of Federal Regulations (CFR), or 30 CFR, mandates a maximum allowable apparent temperature (AT) for an occupied RA of 35 °C (95 °F). The National Institute for Occupational Safety and Health (NIOSH) has conducted extensive research on the thermal environment of occupied RAs intended for use in underground coal mines. NIOSH research has demonstrated that a fully occupied BIP RA can exceed the AT limit by more than 5.6 °C (10 °F) in mines with elevated mine strata and air temperatures. In this circumstance, an RA cooling system could provide a solution. This paper provides an overview of test methodology and findings as well as guidance on improving the performance of a cryogenic air system prototype by optimizing the flow rate, increasing the tank storage capacity, and improving the efficiency of the heat exchanger of the cryogenic system. This may enable BIP RAs to meet the 35 °C (95 °F) AT limit in mines with elevated temperatures. The information in this paper is useful for RA manufacturers and mines that may choose to implement a cryogenic air system as a heat mitigation strategy.

Background

The apparent temperature inside an occupied RA could be significantly affected by the surrounding environment's thermal conditions, such as mine air temperature and mine strata temperature. Apparent temperature (AT) is a temperature-humidity metric for the perceived temperature caused by the combined effects of air temperature, relative humidity (RH) and air velocity. It is used to assess the perception of indoor temperatures.

Depending on factors such as geographic location and season, mine air temperature, relative humidity and mine strata, temperatures can vary significantly. RAs located in cold mines may pass the 96-hour 35 °C (95 °F) AT limit test that poses a challenge for RAs located in hot mines. One solution in these cases is that the occupancy of the RA could be derated — that is, the RA occupancy could be reduced — to ensure the AT limit is not reached. However, this would require mines to purchase additional RAs to accommodate all personnel in the mine. For mines with high temperatures (above 26.7 °C, or 80 °F), the occupancy might have to be reduced so much that the necessary number of additional RAs would be impractical. In these cases, RA cooling systems could provide a solution.

This paper describes the testing of such a system, referred to as the Cryogenic Refuge Alternative Supply System (CryoRASS), by BCS Life Support, LLC. The CryoRASS system stores liquid air that can be used to provide cooling to an RA as the liquid air is delivered to a heat exchanger, which vaporizes the liquid air. The CryoRASS utilizes a 2,000-L (70.6-cu ft) volume of liquid air that is maintained in a stable, zero-loss condition. Liquid air consists of 79 percent nitrogen and 21 percent oxygen that have been cooled to below −195 °C (−318 °F).

Methodology

A CryoRASS, including a 2,000-L (70.6-cu ft) tank, an air-handler box and a hose connecting them, was used as a cooling source for an RA. The liquid air was stored in a dewar, which is a well-insulated, double-walled, low-pressure vessel specifically designed to store liquids at temperatures below the ambient temperature using an electrically powered cryo cooler. When it was being used to provide cool air, electrical power to the unit was shut off. The pressurized liquid air fed a heat exchanger inside the RA through a vacuum-jacketed hose.

At the heat exchanger, the liquid air is vaporized as it absorbs heat from within the RA. This causes the heat exchanger to cool and moisture from the air inside the RA to condense on the heat exchanger, thereby decreasing the humidity inside the RA. The vaporized air is then released from the heat exchanger into the RA.

Table 1 — Summary of test results. For all the tests, the mine air temperature was elevated to 85 °F. The mine strata temperature was elevated to 75 °F at 24 in. deep.

	Test #1	Test #2	Test #3	Test #4
No. of simulated miners	24	16	12	12
Testing hours	96	96	96	8
Cryo used?	Yes	Yes	Yes	No
When cryo air supply was depleted (h)	91	96	91	—
Interior AT when cryo air was depleted (°C/°F)	37.4/ 99.4	—	30.3/ 86.6	—
Interior AT at the end of the test (°C/°F)	48.1/ 118.6	35.2/ 95.3	37.9/ 100.3	40.7/ 105.2

The BIP interior mine air temperature and mine strata temperature were elevated to simulate a hot mine environment by using several heaters.

Results

Four tests were conducted to evaluate the cooling performance of the cryogenic system for the 30-person BIP RA. The BIP RA was occupied by various numbers of simulated miners to investigate the CryoRASS' capabilities as a heat mitigation strategy. Those tests include 24 simulated miners with CryoRASS (Test #1), 16 simulated miners with CryoRASS (Test #2), 12 simulated miners with CryoRASS (Test #3) and 12 simulated miners without CryoRASS (Test #4).

The test conditions and test results are listed in Table 1. In summary, the CryoRASS demonstrated its capacity to maintain the BIP RA interior AT below the 35 °C (95 °F) limit, but only when there was sufficient cryogenic air supply. The difference in RA interior thermal conditions was significant with and without the CryoRASS. The cooling performance of the cryogenic air system could be improved by optimizing the flow rate, increasing the tank storage capacity and improving the heat exchanger design.

Overall, the tests demonstrated that the cryogenic air prototype system has the cooling capacity for a 30-person BIP RA, given the system has enough liquid air supply for the 96-hour duration.

Limitations

Even though the liquid air tank had a nominal storage of 2,000 L (70.6 cu ft), it was nearly impossible to completely fill it to full capacity. In fact, the maximum storage capacity was about 1,800 L (63.6 cu ft). The inaccuracy of the liquid air gauge also made it difficult to determine the liquid air volume stored in the tank. An alternative way of determining this volume is to install a scale so that the weight of the liquid air can be tracked. The air delivery rate would then be able to be controlled more accurately. As reflected in the testing data, the air-flow sensor used in the tests might have had issues in the low-temperature environment and may have given an inaccurate measurement. Also, this system used a needle valve on the air box. An easily adjusted control type for air flow is needed to extend the air usage and to improve cooling performance.

All of the tests discussed in this paper were conducted to investigate only the cooling capability of the cryogenic air system. No tests have been performed to examine the use of the cryogenic air supply for harmful gas removal or to provide breathable air.

Conclusions

The information in this paper is useful for RA manufacturers and mines that are considering the use of a cryogenic air system as a heat-mitigation strategy to meet the 35 °C (95 °F) AT limit in mines with elevated temperatures. Work must still be conducted to demonstrate a field-worthy system capable of supplying the amount of cooled air at flow rates that can effectively control the temperatures to stay below the 35 °C (95 °F) AT. However, these tests demonstrate that the use of heat-mitigation strategies, such as cryogenic cooling systems, can provide another effective solution where reducing occupancy for RAs is not desired or possible. ■

Disclaimer

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by NIOSH.

Reference

A list of references is available in the full paper.

Managing geologic uncertainty in pit shell optimization using a heuristic algorithm and stochastic dominance

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To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Optimizing final pit limits for stochastic models provides access to geologic and economic uncertainty in the pit-optimization stages of a mining project. This paper presents an approach for optimizing final pit limits concurrently over all realizations in a stochastic model and using a risk-management framework to manage the geologic and economic uncertainty. A heuristic pit optimizer is used to find multiple uncertainty-rated pit shells. These uncertainty-rated pit shells follow the mean-variance criterion to approximate the efficient frontier for final pit limits. Stochastic dominance rules are then used in a risk-management framework to further eliminate suboptimal solutions along the efficient frontier. This results in a smaller set of final pit shells that can be further analyzed for production scheduling. Additionally, the original solutions are analyzed for changes in the mining limits, and two regions are targeted as potential regions for further exploration.

Background

Many mining projects are economically marginal, and components of the mining project must be optimized with an understanding of the relevant risks. In an openpit mining project, the life-of-mine plan incorporates a geologic model, mining limits and economic parameters to determine the mining limits of the final pit, which are then used in a production plan to estimate the project value [1]. Stochastic modeling is one approach to model the uncertainty in the resource models where simulation is used to create multiple equally probable realizations of the geological variables [2]. Traditional pit optimizers cannot concurrently handle the multiple realizations from a stochastic model.

Incorporating the uncertainty from stages of a business plan into the decision-making process is not a new concept. The mean-variance criterion, proposed by Markowitz [3] and commonly known as the efficient frontier, is one risk-management tool commonly used to rank solutions that maximize the expected return for a given measurement of risk. Additionally, stochastic dominance rules can be used to help choose between solutions that have an associated probability distribution for a response value [4].

Methods

The proposed approach presented in this paper consists of two main steps. First, multiple uncertainty-rated pit shells are found. A heuristic pit optimizer is used for this stage of the process. Second, the solutions are ranked using the mean-variance criterion, and stochastic dominance rules are applied to the associated response value probability distributions. In the presented case for each uncertainty-rated pit shell the response value probability distributions are the resource value of that pit shell for each stochastic model.

Heuristic pit optimizer. A heuristic pit optimization algorithm (HPO) for optimizing a pit shell over all realizations from a stochastic workflow is presented in Acorn and Deutsch [5] and is used in this study to find the multiple uncertainty-rated pit shells. The HPO maximizes the expected net value and uses a penalization factor, ω_{pv}, to manage the uncertainty in the total reserves within the pit. Changing the ω_{pv} results in different uncertainty-rated pit shells. By increasing ω_{pv}, a more stringent constraint is applied to