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Evaluation of Ventilation On Demand (VOD) in Sudbury Mines

By

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Abstract

Since its inception CEMI (Centre for Excellence in Mining Innovation) has focused on facilitating innovative solutions to the mining industry in six strategic research areas; GeoRisk, ConstructMine, ValueMine, FindMine, SustainMine and MineTech (visit www.miningexcellence.ca for details). This paper focuses on CEMI's largest project to date, Ventilation on Demand (VOD). Energy consumption in mines can account for upwards of 40% of a mines operating cost, with a significant portion of this been consumed by the ventilation requirements. VOD provides a significant opportunity to reduce overall mine ventilation requirements and subsequently energy costs, while potentially increasing mine productivity.

CEMI is currently in year 2 of an assessment of VOD, focusing on the financial, physical and equipment viability of utilizing such systems in both new and existing mines. This two year program, to be completed by March 31, 2011, is designed to systematically assess such a system to determine if and when it could effectively be applied in underground mines. The paper will describe the process by which the project was initiated, the demonstration projects established to capture data, the means to interpret the data and the modelling developed to calibrate and predict ventilation system requirements.

1. Introduction

The Centre for Excellence in Mining Innovation (CEMI), located in Sudbury, is a not for profit corporation born through industry and research discussions in the early to mid 2000's. The Canadian mining industry believed a mining Centre for Excellence, created in a significant mining camp such as Sudbury, could successfully focus on bringing and leading significant research initiatives associated with industry identified problems. CEMI was incorporated in 2005 and has focused on facilitating innovative solutions to the mining industry through six strategic research programs. This paper focuses on CEMI's largest project to date, Ventilation on Demand (VOD).

In 2009 CEMI, through the federal Economic Action Plan - Community Adjustment Fund (CAF) applied for funding to conduct research to determine the economic viability of full system VOD in new and existing mines. In order to develop a research model which addresses the financial, operational and technical aspects of a VOD system, CEMI was able to assemble a collaborative team involving mining companies, mining industry providers, government organizations and academic institutions to deliver and manage this $8.5M project. These collaborators include, Vale and Xstrata Nickel as the two primary industrial sponsors, with the on site work being conducted at the Coleman and Nickel Rim South mines. FedNor is the overseer for the CAF funding and ongoing government project review, CANMET provides technical expertise based on their background work over the past 20+ years in VOD, with Bestech and Simsmart as the two SME's responsible for the installation and implementation at the Vale and Xstrata Nickel sites respectively. Additional SME's such as Symboticware, Pierre Labrecque Technologies and Objectivity, as well as consultants and academic institutions are involved in the project, ensuring we have strong collaboration through multiple facets of industry, academia, SME's and consultants.

The primary purpose in developing the VOD project is to validate the economics and technical aspects of instituting VOD at a new or existing mine site as a core means of reducing energy requirements and improving operational productivity. A rigorous process of testing the different aspects of VOD, independently and as a system will be assessed in order to determine at what level and under what circumstances a mine site would financially consider different levels of VOD.

The project is also expected to identify critical areas requiring additional study in order to further improve VOD systems. At the time of writing, the project is in the second year of its 2 year mandate, with completion scheduled for March 31, 2011, at which point a full report will be submitted to our core industry sponsors, with limited availability to the public. A limited dataset will also be made available to allow additional research to be undertaken by interested parties.

2. Test Site Overviews

2.1 Vale - Coleman Mine

The VOD project work centers on two underground test sites. Vale's Coleman mine located in the North West range of the Sudbury Basin is a 5,000T/day Nickel/Cu mine with a footwall Copper zone contributing 1,000T/day. Testing of the system will be located in the Copper zone (153 ore body) which consists of a series of narrow vein copper stringers feeding a central remuck and thus requires ventilation through the main drift, augmented with auxiliary fans throughout the active stringers. Bestech, a local SME specializing in system integration and industrial automation, is providing the technical expertise and resources for the sourcing and installation of sensors and acquisition and sending of information to a central computer located on surface.

Two of the levels (4550 and 4700) will be outfitted with multiple sensor arrays sampling for CO, CO2, NO, Relative Humidity, differential pressure, airflow and temperature. The fans providing air to the level are variable speed with remotely operated, adjustable louvers. The fans providing auxiliary ventilation to the specific headings are also variable speed. The CAF VOD project was able to build on and add to existing and planned work at the mine. Vale has been working on the VOD challenges for the last 5 years and this project provided the opportunity to support and enhance their on-going program.

2.2 Xstrata Nickel – Nickel Rim South Mine

The second site is Xstrata Nickel's, Nickel Rim South mine (NRS), which is located on the North East side of the Sudbury Basin. This is a Nickel/Copper/PM mine producing approximately 3,000T/day. Project work will be located on 1280L, 1480 and 1660 levels - the main levels directly linked to the intake and exhaust raises. The primary level under study is 1280L as it has the bulk of the current mining activity. The mine operates 2 ventilation shafts, intake via the main shaft containing the cage and skip units and the exhaust shaft, specifically designed for ventilation. The system is a primary pull type system with minimal support from the ventilation intake raise. Ancillary fans provide air to the active faces within the sub levels. Ventilation is controlled via the main exhaust fans on surface in conjunction with U/G louvers, U/G fans are not variable frequency drive units.

Simsmart, utilizing their ventilation optimization team, and in partnership with Xstrata Nickel developed and installed the initial VOD system. The existing system will have additional sensors installed to increase the density of information and tracking locations. This will provide the necessary level of data to properly assess the real time impact of changes in the ventilation system. It also allows for greater variation in sensor testing, a critical part of the longer term requirements of an on demand ventilation system. Information will be transferred to surface via fibre, and available for real time analysis through the existing Control Room.

2.3 Site Expectations at Project Completion

Upon project completion (March 31, 2011), a formal report will be distributed to the participants outlining the financial impact of installing varying degrees of VOD at their sites (the final report). The report, in addition to the project deliverables, will also include specific information summarizing key findings at each site. This will include all information related to ventilation flows, recommendations for improved circuits as determined by the modelling and testing, observations noted in the field (i.e. damaged tubing, incorrectly placed auxiliary fans, etc.) related to improved efficient operation of the ventilation system, regardless of whether operated via VOD or not.

3. Project Structure

In order to ensure project success, a project structure was established at the outset of the project. This consists of 3 core teams, in a hierarchical form as shown in Figure 1 below. The purpose of the first team (Project Steering Team) is to ensure the project remains focused, is following the agreed to goals and meets the expectations of the project owner. This team is internal to CEMI and meets as required.

The second team (Technical Team) is comprised of individuals from Xstrata Nickel (NRS mine personnel directly linked to the VOD and planning groups), Vale (Vale Sudbury - ventilation specialists), Objectivity (decision support consultancy was contracted to provide the demonstration project management), CANMET (providing ventilation expertise out of their Sudbury office and diesel engine testing out of their Bells Corner labs) and CEMI. The team was formed to ensure:

1. the technical aspects of the project were valid and remained so for the duration of the project,
2. ensured the requirements of the sponsor companies were being addressed, and
3. benefited from CANMET's and SME's knowledge associated with this type of work. The team meets on a monthly basis.

The third team (Steering Team) is comprised of senior staff from Xstrata Nickel, Vale, CANMET and CEMI. Their purpose is to provide guidance to the project and remove barriers to ensure the project advances within the established guidelines. This team meets on a quarterly basis, or as required if significant issues arise.

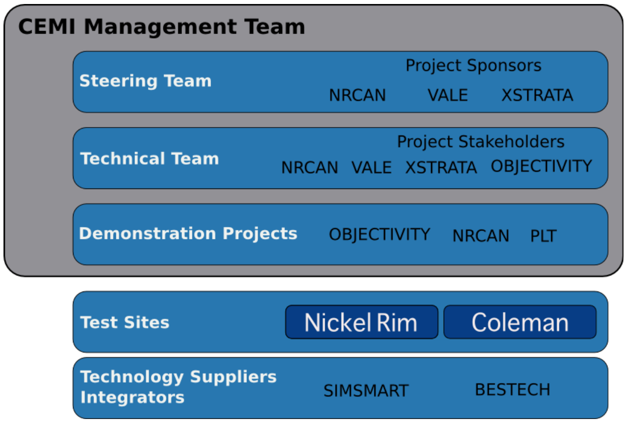

Figure 1: Management structure

The functionality of the three teams is working very well with strong communication and collaboration existing. Critical to the functionality of this structure is the CEMI project manager being a member of each team.

3.1 Project Goals

In order to establish project structure and quantify project goals a set of demonstration projects were established by the technical team. Following awarding of the contract and prior to performing any work, the technical team met several times to brainstorm the desired outcomes from these projects. These sessions resulted in a prioritized list of objectives as well as a purpose statement for each of the demonstration projects.

The Technical Team identified three major objectives for the VOD demonstration projects:

- VOD Business Case
- Quality of air Vs. Quantity of air
- Sensor selection based on compatibility, reliability (initial testing only) and Sensor density

The goals for the Business Case are to determine, for a variety of mining operations, what level of VOD should be considered and what the expected payback could be. The premise for this part of the study is that the payback of any VOD investment will depend on the life of mine, the mining method and the general layout of the mine, coupled with the control and monitoring system that would need to be installed.

3.2 Project Rationale

The life and design of a mine will affect the cost of implementing VOD technology as it's often less expensive to include significant infrastructure early in the design than it is to retrofit an existing operation. Part of these costs are related to displacing or enhancing existing technologies that may meet some of the requirements but need to have additional capabilities added in order to support VOD. Another important cost factor is the disruption that may occur to production while VOD monitoring and control equipment are installed.

The current methods used to evaluate these types of scenarios typically do not have the capability of determining how system changes may dramatically affect the operating costs or operational issues. Ventilation solvers, originally developed to balance flow characteristics within a network, are generally used to calculate the pressure losses and flows for a number of static scenarios in order to develop a valid design.

The potential of VOD is not only to decrease overall power costs by providing the appropriate amount of air at the appropriate locations of the mine, but potentially to increase the level of production attained by better distribution of available air to the mining locations. By supplying air to the required mining locations, rather than a set amount to the mine as a whole, the overall mine ventilation requirements drop. This in turn allows the mine operator to utilize the "saved" air in alternate mining horizons with the net impact of increased production (assuming ventilation is the restricting production factor).

The CAF VOD business case is based on the development of a software "rules engine" that can link the output of a production simulator, a production process model and a ventilation solver as depicted in Figure 2. The "rules engine" has an internal data flow structured to allow the modeling of sensor and communication networks, the performance of power plants (and their after treatment devices), and the levels of required air to meet legislated or corporate air quantity/quality levels.

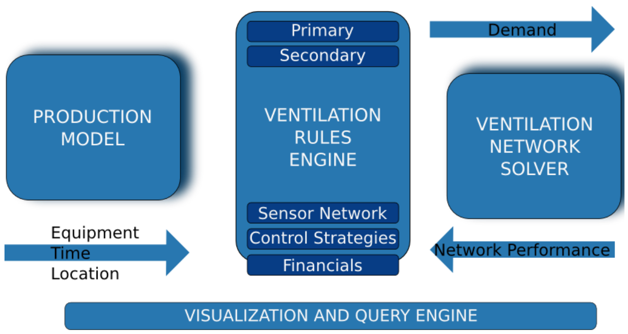

Figure 2: VREX Ventilation Rule's Engine Data Flow

This type of plug-in architecture allows a framework to be built that can easily be modified to evaluate the financial performance of commercially available VOD control systems and more importantly to evaluate the relative benefits associated to incremental capital investment. Thus a model can be developed that evaluates the benefits of instrumenting auxiliary ventilation systems with Variable Frequency Drives (VFD) vs. two speed or on/off fans.

Given the number of realizations that the model must be able to solve to determine the dynamics of the network, and evaluate control algorithms, a custom query engine and user interface have also been created to help evaluate the benefits of VOD.

3.3 Technologies

The technologies required to support VOD supplement existing communication, monitoring and control systems. In the case of the two test sites the installation of WIFI communication backbones, RFID tracking technology and VFD fans and automated regulators was possible with minimum work disruption.

One of the major areas of assessment will be determining what technologies, and in certain cases what density of monitoring technology, will be required to gain the best payback when using VOD. This analysis should also be capable of determining performance criteria for a number of VOD technologies. One example of this could be documenting the duty cycles of surface fans.

The test sites provide a testing ground for hardware, but just as importantly provide a location where algorithms can be tested in a working operation. The sensor network both at Nickel Rim and Coleman will provide redundant data that will provide researchers with important data to be able to assess the value that can be created by VOD.

The algorithm testing is particularly important as VOD systems and ventilation requirements progress to a quality criteria. The exploration of quantity vs. quality as a control criteria was one of the high priority areas identified by the technical team. The field studies are being designed to address this area by creating a number of detailed studies that will collect data to assess the issues related to quality control of ventilation.

3.4 Field Studies

The Quality vs. Quantity and Sensors objectives are being evaluated through field studies conducted at both test sites. The data from these field locations, collected during eight months of production, will be used to calibrate the performance of the models and will provide a scientific dataset to contribute to the "Quantity vs. Quality" based assessment of VOD is several ways:

- Provide a spectrum of real-time engine operational data including such items as the "load" data, which could be used to assess where the vehicle routinely operates in relation to its maximum power/fuel usage.

- Provide real-time exhaust multi-pollutant data to be compared against the Canadian Safety Association (CSA) certification values and be used to generate the exhaust map.
- Support in determining whether continuous monitoring of a few selected engine and exhaust parameters can be used to predict exhaust quality and hence, the required air volume with reasonable accuracy. If proven, this can justify the installation of an "interface" on the mobile equipment transmitting "air quality" related data to the tag readers.
- Determine what degree of intelligence is required on the mobile equipment and within the working areas to support the varying control levels of VOD. For example, what are the additional benefits of knowing how much air is required according to the operational mode of the vehicle as opposed to just knowing whether it's on or off?
- Determine the location, density, type of gas monitoring, or surrogate, for a qualitative measurement to ensure that the ventilation provided and controlled by the VOD system is effective and the feedback representative of exposure.
- Determine whether environmental monitoring as opposed to equipment monitoring could be used quantitatively to determine the required airflow.
- Compare the current fixed ventilation design criteria, based upon engine power, against a more qualitative approach, namely that based on the CSA certification procedure relating to exhaust quality, to determine how it would change a worker's exposure to particulates (mineral and diesel).

Within the two test locations the mining levels are being "over-instrumented" to ensure the level of information collected is sufficient to allow a statistically significant level of sensor performance comparison. The structure of the field studies has been established such that efficient collection of data occurs, and we minimize the disruption to the sites. Figure 3 depicts the structure of the field studies.

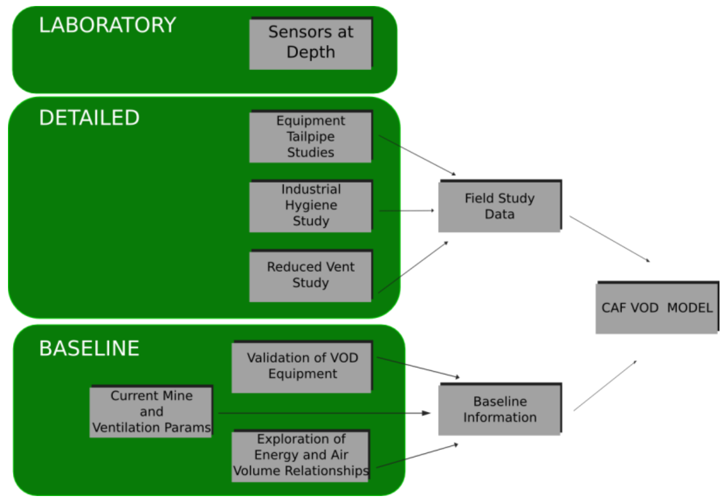

Figure 3: Field Studies Structure

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3.5 Exploring Future Technologies

The field study component of the project will also try to determine how VOD can be attained with the minimum number of sensors and actuators. To meet this goal both test sites are being over-instrumented. The collection of field study data in combination with the model will allow post analysis to develop algorithms that can improve the effectiveness of VOD (quality and quantity of air to the workplace at minimal costs) using novel monitoring and control mechanisms.

An example of this research focuses on determining the value of real-time exhaust monitoring. Given that one of the primary roles of mine ventilation is the removal of diesel contaminants, knowing the quantity and character of the exhaust in real-time could be a significant data source to develop new controls.

The detailed tailpipe field study will look at bridging the gap between the quality assessment that engines undergo when being certified for underground use and determining the engine's performance in an operating mine. The tailpipe study, done in partnership with the equipment provider (see section 4.1), will log the detailed duty cycle of production equipment in order to be able to reproduce the cycle on a dynamometer. The duty cycle can then be used to map the performance of the engine, under "mining load" with the data gathered during the certification tests.

The tailpipe study will then close the loop by monitoring the tailpipe exhaust and engine performance in real time. Production equipment at both test sites is being instrumented with Symboticware's Symbots to log engine performance data and ambient gas measurements to help determine operator exposure.

The CAF funding has allowed one of the most comprehensive ventilation data collection campaigns to be undertaken internationally. The longer term benefits to researches will be the availability of clean data once released by the sponsor companies. This data should prove invaluable for additional research on VOD, and potentially for related work on environmental contaminants and equipment emissions.

4. Project Risks

During the course of project planning a number of risks were identified and mitigation's initiated to minimize the overall risk to the project. Risks were categorized within the areas of people, organizational, financial, reputation, management, project, nature, technical, operational and political. For each of these major headings a brainstorming session was held to identify what could happen, how it could happen, what would be the impact (safety, financial, etc.) and what current control strategies are proposed. For each of the items identified, the likelihood, consequence and current risk level were gauged. Using common risk ranking techniques the highest scoring risks were identified and mitigating strategies were identified.

The most critical risks identified at the project start were the Vale work stoppage and ability to collect sufficient relevant data to allow for effective project evaluation, Also, delays in the development of the contract between CEMI, Xstrata Nickel and Vale were of concern. At the time of writing no new risks have been identified to the project and our current mitigation plans have proven effective.

4.1 Data Collection

Following project initiation it became apparent focus was required on the data collection phase of the project. Currently data collected at the sensors located throughout the active mining levels is stored in PI (common data storage platform used by Vale and Xstrata Nickel). While accessing the data it was noted the sample frequency was too coarse and therefore insufficient data density was being captured in order to assess changing conditions with the necessary precision. Work continues to try and resolve this problem.

A second concern resides with the ability to capture relevant data (Co, No2, etc.) from the LHD's. As noted, this information is required to understand the operating parameters of the unit and the interaction they has with the surrounding environment. Currently the VIMS systems supplied on the LHD's by CAT to capture equipment specific parameters have too coarse a sample rate for the project requirements. Therefore Symboticware Symbots are being installed on the LHD's in order to capture real time data related to the LHD's and environment. This info will be sent to surface via packets once the unit passes a data capture point. This data transfer rate is dependant on the number of data transfer points and activity of the LHD's. Future work to provide "real time" or "near real time" data transfer may be undertaken but is not part of this project phase. Figure 4 is an example of data collected from the underground sensors at NRS.

As noted the primary muck movers at both mines are Caterpillar. Caterpillar have expressed an interest in working on the project and will be providing additional engine data during the detailed field studies. One aspect of the data collection will be to look at the percentage of time an individual machine works within specific portions of the engine speed torque curve. Combining this knowledge with the results of laboratory testing of engine emissions (as tested by CANMET Bell Corners Laboratories) will allow us to develop a detailed map of engine emissions over time and allow us to compare this to data recorded in the field.

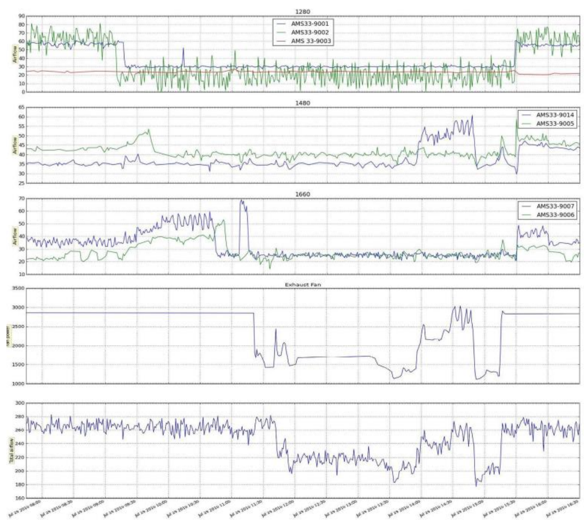

Figure 4: NRS Data Capture Sample

4.2 Peer Review

A peer review was held in late June where the Technical Team presented the project to prominent experts in the field of ventilation from Mine Ventilation Services and Mine Ventilation Australia, plus an Occupational Health & Safety Engineer - Mining, from the Ontario Ministry of Labour. The most significant comments captured during this review include:

- No other mine was introducing VOD to the degree being assessed in this project and the project should benefit the mining industry through analyzing the advantages and challenges of such a control system.
- VOD, depending on the degree introduced, has a tremendous upside for ensuring miner safety with the added benefit of energy savings however the system must be shown to facilitate rather than constrain production.
- Many jurisdictions outside of Canada are moving away from prescriptive regulations such as a fixed air quantity per engine power unit to more quality based on exposure. Here a VOD system can create a "win-win" situation that provides both more comprehensive exposure control and airflow distribution flexibility.
- Modelling was considered essential to establish the business case for VOD.

The peer review also stressed the following which would need to be considered by the mining companies themselves or follow-on work:

- A systematic major hazard review would be required assessing the risks, maintenance and reliability of the system and its components.
- The trials will produce a significant body of data, the full value of which may only be assessed after the project end.
- The breadth of objectives for the project was very ambitious considering the time-line and although it could produce many valuable outcomes, clear focus should be given to the specific goals that are attainable, and setting the foundation for the future work.

5. Conclusions

The Community Adjustment Fund was a federal incentive to assist with the post global financial crisis. CEMI working with local corporate and research partners was able, on very short notice, to put together a research proposal accepted for funding. As project manager, CEMI worked with the project sponsors, mining companies and equipment suppliers to structure the project for delivery within a very tight time frame.

The project has been independently assessed by recognized ventilation experts, who noted the project contributes significantly to understanding the value of VOD within the industry. Specifically, the reviewers highlighted the value associated with the depth of the study being undertaken, the recognized need for integrated modelling and the value from the data and analysis if further pursuing the Quality vs. Quantity issue.

The work on the CAF VOD project has provided a strong foundation for future work in Mine Ventilation. Additional sensors have been installed at two Sudbury mine sites; a ventilation model and discrete event simulator have been developed for these mines; and the detailed field studies are well underway.

A significant aspect of the project has been the development of an interactive system which links an event simulator with a ventilation simulator through a rules engine. This powerful tool provides reliable and fast assessment of differing mining scenarios and how the ventilation system can be adjusted optimally and quickly. Once this had been proven to be stable and accurate, its ability to adjust ventilation in real time becomes a distinct possibility. Through this the opportunity to conduct financial evaluations becomes a reality and thus provides a strong tool for the engineer in assessing existing and new ventilation systems.

The end of this CAF VOD project will not be the end of the Ventilation on Demand work as the data collected during the studies will provide a basis for additional work. Further detailed analysis of the data will be required to understand the issues in moving to quality criteria from quantity criteria. The development of an understanding around a quality criteria is important given the advances that are taking place in the development of low (or zero) emission power trains.

The model can also be extended to provide insights into the financial ramifications of expected future energy costs and their effect on mining. Further work to define the savings using VOD from a given investment will be required and the findings need to be tested at another mine.

CEMI is currently developing the scope and possible funding stream for the next phase of the project.

CEMI has been pleased to work with our partners on the project to deliver this worthwhile project to the mining industry. CEMI will continue to identify opportunities with our industry partners, scope out the research required, source out the funding, and apply project management for the success of these new exciting projects.