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Ventilation on demand (VOD) auxiliary fan project – Vale Inco Limited, Creighton Mine

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ABSTRACT: The ever increasing energy costs associated with mining at depth has become an important issue that needs to be addressed for future sustainable production. Vale Inco Limited's Creighton Mine being the deepest has the highest energy cost per ton due to the ventilation system requirements. A review of the ventilation systems was undertaken with respect to current practices and identification of opportunities to the practical application of technology that would facilitate energy savings. Energy conservation initiatives such as time of day controls have been implemented; however there still remained some opportunity for further reduction. Based on previous studies that identified opportunities due to actual time spent in the workplace, our mining method and ventilation design, it was determined that Ventilation on Demand (VOD) could provide further additional energy reductions with respect to our auxiliary fans. A pilot project has recently been initiated to apply a Ventilation on Demand concept to two 112 kW auxiliary fans and their related workings located on the 2340m level of Creighton Mine. The project objective is to determine the practical methodology and application of this technology in the field. This project involves the installation of variable frequency drive (VFD) starters on the auxiliary fans to allow variable volume (through speed control) based on demand. The required flow is determined based on equipment and/or personnel via identification tags. The Fans adjust to the flow requirements as measured by flow sensors. Since the fans are sized for the final requirements the required flows can be achieved regardless of system length. Energy savings are realized by supplying only the volumes (power) as required and only when required. This paper discusses the rational and program being tested at the VALE Inco Limited, Creighton Mine.

1 Introduction

Creighton Mine is a base metal mine located on the SW rim of the Sudbury basin. The mine has been in production since 1901 starting on surface and has now reached a depth of 2420 m and is continuing to develop to 3048m. One of the key components in providing the necessary environment to allow mining to this depth is ventilation & its associated cost. The mine's ventilation system can be broken down into 3 major components, namely; Main Ventilation system & fans, level ventilation system & controls and auxiliary systems & fans. The mine utilizes a natural bulk cooling system consisting of the original surface pit to meet the ever increasing temperatures as the mining horizon moves deeper into the ore body. Based on this bulk cooling method and increasing temperatures at depth the auxiliary systems are required to supply more volume to remove the heat load and therefore more power.

This paper describes a project to apply a Ventilation on Demand (VOD) concept to control the amount of ventilation & power to reduce the energy requirements as mining depth increases.

2 Mining & Ventilation Process

The mining method in use at Creighton Mine is vertical retreat mining with levels being required at 40m intervals. The levels are ventilated with through flow of air from the main fresh air raise located on the east side of the ore body to the exhaust raise located on the west end of the ore body. The auxiliary fans draw air from the main footwall drift and supplies it via ducting to the development headings or production stopes in the ore zone as per Figure 1. The exhaust air returns through the drifts to the footwall and then exhaust raise.

Current practice is for the auxiliary fans to operate continuously regardless of whether mining activity is being conducted in the area or not. The fans are sized to meet the required volume and maximum distance to be driven. This result in excess power being used when not required

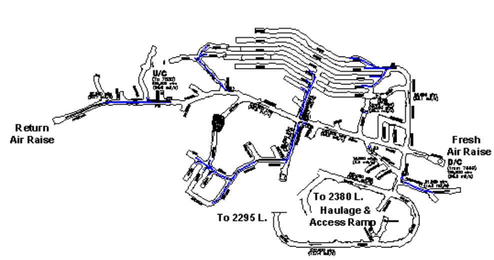

Figure 1. 2340m Level – Creighton Mine

The auxiliary system and fan design is based on the volume requirements for diesel equipment needed to meet the development/production schedule as well as the final distance to be driven. This is typically 300m with available volume of 23.6 m^3/s. This system will provide for 3 active headings including 14.6 m3/s for the mucking cycle as well as 2 additional headings with 4.7 m3/s for drilling, bolting, etc. This auxiliary system consists of a 112 kW fan and 1220mm diameter ducting as per Figure 2. Based on previous time studies the life cycle of a typical auxiliary system is 10 years as depicted in Table A.

Figure 2. 112 kW fan c/w 1220mm Ø Duct

Table A – Mining Sequence& Auxiliary Ventilation

Development Phase - 2 yrs
122 m/month;
26 operating days = 15'/d
Scoop mucking = 8 hrs, 33% of time @ 23.6 m^3/s
Drilling, loading, bolting = 16 hrs, 66% of time @ 14.1 m^3/s
Production Phase 8 yrs
Scoop tram mucking = 56% of day @ 23.6 m^3/s
Drilling, cleaning = 44% of day @ 9.4 m^3/s

3 Projected Energy Savings

The projected energy savings for a single 112 kW fan based on the production requirements listed in Table A for a ten year period is given in Tables B and C. The projected energy savings take into account the time of day management program that is already in place. The power requirements for the fan varies as the distance or length of duct increases during the first 2 years of development and reduces over the 8 year production period as the stoping retreats back towards the main footwall drift. The projected savings indicated are conservative based on past studies however substantial enough to warrant further investigation into the practical application to implement the control technologies that would produce these results.

4 System Management

To achieve the energy savings and meet the required environmental conditions for sustainable production a

Table B – VFD Opportunity for Secondary Ventilation Fans

Life Cycle Phase	No. of Ho	Fan hp est. @ 50,000	Fan hp est. @ 30,000	Fan hp est. @20,000	100% Existing kWh	Scoop Mucking kWh	Drilling, Loading, Bolting	Drilling, Cleaning kWh
2 Year Development (@ 26 operating days/month)						8 hr/d @ 50,000 cfm	16 hr/d @ 30,000 cfm	
100'	160	50	19.5	9.5	5,968	1,989	1,552	
200'	160	60	23.4	11.4	7,162	2,387	1,862	
300'	160	70	27.3	13.3	8,355	2,785	2,172	
400'	160	80	31.2	15.2	9,549	3,183	2,483	
500'	160	90	35.1	17.1	10,742	3,581	2,793	
600'	160	102	39.8	19.38	12,175	4,058	3,165	
700'	160	114	44.5	21.66	13,607	4,536	3,538	
800'	160	126	49.1	23.94	15,039	5,013	3,910	
900'	160	138	53.8	26.22	16,472	5,491	4,283	
1000'	13,536	150	58.5	28.5	1,514,678	504,893	393,816	
TOTALS	14,976				1,613,747	537,916	419,574	
8 Year Production (less 2,007 hrs/yr fan shutdown)						56% @ 50,000 cfm		44% @ 20,000 cfm
TOTALS	54,024	150	58.5	28.5	6,045,286	3,385,360		505,386

Table C – VFD Opportunity for Secondary Ventilation Fans

Projected kWh differences with VFD Control	
Development	656,257
Production	2,154,540
Total kWh	2,810,797
Projected Cost Impact @ \$0.06/kWh per fan	\$168,648
Over a ten year period equals a per fan per year savings of:	\$16,865

control protocol was needed. The following protocol was developed to meet legal and company standards.

4.1 Fan Operating Protocol

4.1.1 Full Volume (23.6 m^3/s)
- a. Scoop (tag) or combination of up to 4 x misc. vehicles (tag) entering heading
- b. CO > 25 ppm
- c. Temperature > 32^0 C or 90^0 F

4.1.2 Partial Volume (14.1 m^3/s)
- d. NO R1700G scoop (tag)
- e. Up to 3 x misc. vehicles (tag) entering heading
- f. CO < 25 ppm
- g. Temperature < 32^0 C or 90^0 F

4.1.3 Partial Volume (9.4 m^3/s)
- h. NO scoop (tag)
- i. Up to 2 x misc. vehicles (tag) entering heading
- j. CO < 25 ppm
- k. Temperature < 32^0 C

4.1.4 Fan Off (0 m^3/s)
- l. NO vehicles (tag) read entering in last 15 minutes
- m. CO < 25 ppm
- n. Temperature < 32^0 C or 90^0 F

4.1.5 Loss of Control Power

o. Fan ramps up to full speed

4.2 System Control

The above protocol is based on the ability to control the volume of air and thus power requirements of the specific activities required for the mining process. To accomplish this the fan needs to be informed of what (equipment or personnel) is in the headings being supplied by a particular fan. This is accomplished using "tags" to identify both equipment & personnel. The tags are coded with specific data such as equipment or personnel number, hp or volume requirements, etc. as required. Tags "readers" are strategically located within the zone of influence of the fan, the reader identifies the equipment & manpower entering or leaving the zone. A program translates the data into the required volumes as per the above protocol, which in turn adjusts the speed (hertz) of the fan until the volume requested is satisfied. An airflow monitor in the duct system is used and feed back to the program to ensure the proper requirements are met. Monitoring is also installed for gases & temperatures to ensure that adequate flows are supplied to meet acceptable environmental conditions.

4.3 System Components

The following system components are required to implement this type of control:

- Dedicated computer hardware
- Software program developed to respond to fan protocol listed above
- Human Machine Interface (HMI) programming and interface (computer screen)
- Communication network
- Local Program Logic Control (PCL)
- Tag Readers (Exciters)
- Equipment & Personal Tags
- Sensors for airflow, Gas & Temperature
- Access Points

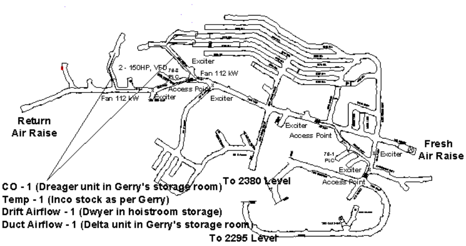

Figure 3. 2340 Level VOD Field Installation

5 System Operation

The master Ventilation on Demand (VOD) program is set up and resident in the main PLC on the 2133m level, all communications with surface travel through this unit. The local PLC on the 2340 level is used to collect and transfer the data. Should the communication link fail between surface and 2133m horizon PLC the program will continue to function. Similarly, should the communication between

Components set-up as per Figure 2 below:

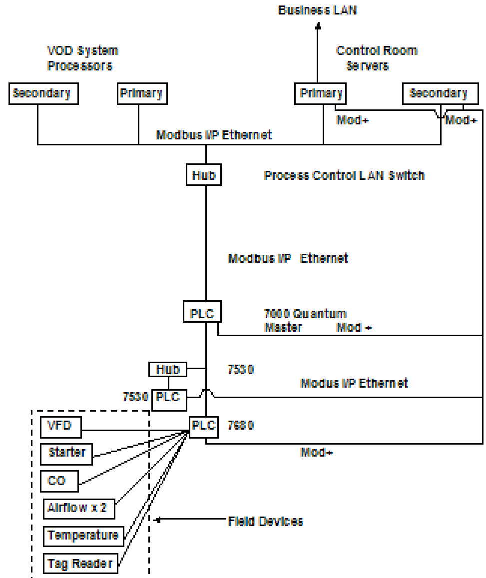

Figure 4. Creighton Mine VOD Schematic

the 2133m PLC and the 2340 level PLC be interrupted the local PLC will maintain the system. This provides a secure system that is once proven can be duplicated for every fan and multiple mining horizons utilizing the same program.

5.1 Field Components

The field components consist of tag readers (Exciters) that are located at strategic points in the various drifts to identify a) location & type of tag and b) direction of movement based on last exciter that was activated. The Exciter as well as the monitoring sensors for volume, gas & temperatures are hard wired into a field box (access point). The access point is then wired into the nearest PLC, which contains the program that interfaces with the fans variable frequency drive. The data is transmitted to surface computer where it is displayed on the SCADA screens and also trended.

6 Communications & Training

6.1 Development

The development of this project involved the collaboration of several disciplines including ventilation engineers, site electrical technologists & electricians, operating personnel, programmers, project engineers as well as suppliers. The project was outlined and presented to operations personnel. This was essential for the project to succeed as it is based on the tagging of both equipment & personnel working in this area.

6.2 Safety

The project followed the corporate safety requirements of conducting a) a management of change (MOC) as this project affects the method of fan/environment control and b) a Process Hazard Review (PHR) was performed to identify the possible hazards that may be introduced by the new protocol and what additional controls are required or are in place to safe guard employees.

This process is used to identify any change from the existing components that need to be addressed such as: protocols, procedures, training, communications, revised electrical or engineering drawings, etc. and to evaluate the risk associated with implementing this new technology.

A Process Hazard Review (PHR) is conducted as required from the MOC process. The project group, consisting of the various disciplines is assembled to addresses this item. Participants may include: manufacturer of components, programmers, worker safety rep., electricians, electrical technologists, operators, safety, training department and ventilation (underground Environment) group. The PHR is a detailed breakdown of all possible hazards that the new protocols and/or technology could introduce. What is the hazard; what is the consequence; what is currently in place to reduce or eliminate the risk; what is required in addition to what is currently in place.

A 3rd party consultant can also be involved to review the PHR and system operation to ensure no hazard and associated risks have been omitted.

The following is an example of the PHR process used by Vale Inco:

WHAT IF / CHECKLIST FORM

LOCATION / PROCESS: Creighton Mine Ventilation On Demand	No: 17-2-152 DATE: March 8, 2005
LEADER / SCRIBE: Doug O'Connor	Page: 2 of 3
TEAM MEMBERS: G. Cook, B. Gascon, M. Bond, E. Henderson, G. Duffy, T. Gattoni	

ITEM #	MAJOR / MINOR	"WHAT IF"	CONSEQUENCES	EXISTING PROTECTION INDICATION	RECOMMENDATIONS	RESPONSIBILITY	ACTION BY / STATUS
5	Minor	Loss of Control	Failure of airflow sensor (volume levels could be lower than required levels)	Existing procedure in place, Co & Temp. sensor override, regular maintenance inspections & calibration	None	Creighton	
6	Major	Loss of Control	PLC fails which leads to loss of monitoring & remote operation of the fans (delay of production, reduced airflow)	Existing procedure in place, local start/stop buttons, fans fail in last operating mode, regular maintenance inspections	None	Creighton	
7	Minor	Utilities Failure	Electrical power loss (fans not operating)	Existing procedure in place	none	Creighton	Complete
8	Minor	Logic Systems	PLC program gets changed	Existing procedure in place	Ensure authorized users are aware of procedures to change PLC logic	Creighton	
9	Minor	Logic Systems	PLC Communications are lost	Back up computer	PLC logic to have a "heartbeat", if communications are lost fans to continue operating, master read/writes not to be incorporated in logic	GED	

Figure 4. PHR example sheet for VOD System

6.3 Training

Training needs were identified as part of the PHR process and packages were developed for the following:

a) System operation – control room operators regarding the main Human Machine Interface (HMI) screens and control; operators regarding the use of tags and fan control/response; underground ventilation technologists for monitoring and calibration
b) System components - beat electricians for field installation & repair as well as mechanics for equipment tag installation & repair; underground ventilation technologists calibration
c) System Programming – site technologist & electrician for functionality & operation and maintenance.

7 Conclusion

This pilot project has begun with field installation in January 2008. The system operation is scheduled for start-up in March 2008 and will be closely monitored for 3 months. This project does not rely on any actions by the operators to succeed. The maintenance and ventilation personnel's commitment to design implement and maintain the system is the base for the success of this project.