Tunnel Dust Control Project

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ABSTRACT:

The case study describes the implementation of a new Wet Type Dust Extraction System to control fugitive dust generated at a large tunnel project in BC Canada. The tunneling project is designed to be 1000 meters in length and approximately 13-ft in diameter and was faced with dust and ventilation challenges during the initial phase of the project. Regulators had tested the air and found the dust levels to be unacceptable and required mitigation devices to be implemented before the project could commence.

The paper briefly describes the operation and expedient implementation of an exhaust ventilation and dust control system that would remove particulates at a high efficiency acceptable for emissions while providing proper ventilation and dust levels within the tunnel construction area. Although environmental operating conditions were a huge driving force for the control device, other operational advantages were quickly noticed that further drove this system to be fully implemented on a permanent basis.

The discussion will include the implementation of an exhaust ventilation and dust control device and the test data that illustrates the before and after results of dust levels at critical locations throughout the tunnel construction area.

1 INTRODUCTION

This paper presents a case study of a Road-header tunneling operation that regulators had noted experienced dust levels which contributed to poor air quality within their operations. The ventilation plan for the tunneling operation initially called for a blowing ventilation system. This is where the air is blown in from outside longitudinally along the tunnel up to the face. Blowing ventilation induced several issues, including poor air quality and visibility within the tunnel. Once the regulators tested the air quality and saw the high dust levels, the tunnel construction was immediately halted until a remedy could be found. The tunnel construction contractor contacted our company to provide some assistance with reducing the dust level emissions. Our company manufactures wet de-dusting equipment which can provide ventilation and air cleaning simultaneously. Several options were presented to the client as a mitigation plan the dirty air in order to resume the construction project. In working with the ventilation construction company’s ventilation engineer several concepts were discussed concerning best approaches and installation arrangement for the de-dusting unit. Basically the Wet De-Duster in a tunnel ventilation application can be affixed in three different arrangements.

- Equipment Mounted – *Figure 1-1*
- Trailing unit – *Figure 1-2 & 1-3*
- Fixed Mounted – *Figure 1-4*

1.1 *Equipment mounted. Advantages and Disadvantages…*

In this mounting arrangement the de-duster is mounted directly on the Road-header as close to the cutting head as possible. As you can see from Figure 1-1 the inlet to the de-duster extends as close to the cutting head. It can be either left or right mounted, depending on the space available on the Road-header, and/or the preferred air direction across the face. The advantage to this method is that it is always optimal to collect and control dust as close to the source as possible. This provides close proximity collection and exhausts clean air back into the tunnel. One typical disadvantage is that space constraints require that only smaller units be fitted. The inherent problem is that many times larger units are needed in order to maintain proper air volumes that are sized for the tunnel cross-sectional area and the various equipment needs within the tunnel. The other advantage with this method is the water discharge from the wet-deduster can be gravity fed onto the material handling conveyor wetting it down so that there can be additional dust control in the material handling process.

Figure 1-1 Equipment Mounted De-Duster

1.2 *Trailing unit*

A trailing unit is where the de-duster is positioned behind the Road-header or TBM and is essentially “parked” in an area out of the way of the operating equipment. In this arrangement inlet ducting is added to the inlet to the De-Duster so that the proximity of the inlet suction of the De-Duster is closer to the dust source which yields better control of air movement and air quality. Typically the ductwork travels 30-60 meters from the parked de-duster to as close to the cutting area as possible. The air is suctioned from the inlet of the ductwork and cleaned by the de-duster ; the clean air exhaust from the de-duster exiss into the tunnel, or another section of positive pressure duct is used to channel the clean air exhaust outside of the tunnel. The advantage to this method is that you can use a larger capacity machine, exhaust ventilation and dust control remain close to the source and the mobility of the unit provides some flexibility to the operations. The unit can be operated without the inlet duct as shown in Figures 1-2 and 1-3. Note that overall effectiveness of dust capture is reduced due to the expansion of the dust particles within the air stream. The downside is that the unit must be moved periodically in order to maintain the proper air flow/static pressure ratio and inlet ducting and usually exhaust ducting is needed. Also the parking location must be planned or a cut out made along the tunnel in order to locate the unit.

Figure 1-2 Trailing De-Duster

Figure 1-3 Trailing De-Duster

1.3 *Fixed mounted….*

A third option for locating the De-Duster is a fixed mounted machine outside of the tunnel as shown in Figure 1-4 . In this arrangement the unit sits on a permanent stand and inlet ducting as shown in Figure 1-4. The unit is extended into the entrance to the tunnel and the inlet is placed as close to the cutting area as possible. This method again assumes that "exhaust" ventilation is the preferred approach and the dirty air is suctioned from the face area and cleaned by the De-Duster before it exhausts to atmosphere. In this arrangement the fixed mounted unit can be easily accessed for maintenance; it is out of the tunnel construction area so no need for a parking space, and the air volume can be as much as needed to ventilate and clean the tunnel. The downside is that more horsepower is needed in order to overcome the static losses for the full length of the tunnel, so multiple units may be needed, or a booster in order to maintain air flow as the tunnel advances. All of the ducting must able to handle a high static pressure in order which tends to add to the overall cost of the system.

Figure 1-4 Fixed Mounted Deduster

Figure 1-5 Ducting Inside of Tunnel

In order to clarify, the most common ventilation methods there are basically two that are commonly used, namely blowing ventilation and exhaust ventilation.

1.4 *Blowing*

When the air entering the tunnel construction area is brought in under positive pressure using ventilation fans to blow the air in from outside the tunnel this is called “blowing” ventilation. The concept here is to use clean air under positive pressure to move air through the tunnel and across the tunnel face area exiting the other side of the tunnel. The disadvantage with this method is that it is very difficult to control the air movement unless ducting is carried forward to the face, and in many cases this positive pressure creates more dusting issues than it solves. The air still has to pass over all the diesel equipment in order to keep the air satisfactory for the workers so often this picks up dust under pressure and carries it throughout the tunnel. This can be used in conjunction with Exhaust ventilation techniques which helps it be more effective.

1.5 *Exhaust*

Exhaust ventilation is when the air is pulled from the face area using a series of exhaust fans or a combination of fans and/or De-Dusting equipment. The negative pressure created from the exhaust method in turn pulls air from the outside to sweep over the mobile equipment therefore creating a continuous stream of clean air which gradually moves across the tunnel face area and exits the tunnel.

2 SITUATION AT TUNNEL WITH BLOWING

In this case study the tunnel construction project was using a blowing ventilation system in their tunnel. As mentioned above this cause severe dusting issues in nearly every location of the tunnel area, which led to regulators shutting down the project until a remedy could be found.

2.1 *Dust an issue regulators shut them down*

According to the regulatory authority in BC-Work Safe BC the following requirements must be met for underground mining or tunneling projects.

Please see excerpts taken from the Worksafe BC dust safety manual referenced in Section 6 below.

(a) 22.81 Dust control

(1) Mechanical excavating devices, such as tunnel boring machines and road headers, must have an effective dust control and ventilation system which maintains workers' exposure to dust below the applicable exposure limits in this Regulation.

(2) Such systems must be maintained in good working order and must be operational whenever the mechanical excavating device is working.

When dealing with dust that contains silica there are specific silica limits outlined by Work Safe BC with control methods suggestions:

2.1.1.2 *Engineering controls*

Making physical modifications to facilities, equipment, and processes can reduce exposure. Some questions to consider:

- *Can local exhaust ventilation be used on all equipment that generates silica dust?*
- *Can water be used to prevent dust from becoming airborne?*
- *Can the areas that generate large amounts of dust be enclosed, and have proper ventilation to clean the air?*

This paper is not meant to detail all the regulatory compliance details for the various types of silica other than to point out that in this case study the limits for Amorphous Silica exceeded the 1.5 mg/m3 limit in the worker area.

In addition to concerns over silica dust exposure, WORKSAFE BC also notes total dust limits as described below:

The Board categorizes particulates that are insoluble or poorly soluble in water and do ***not*** *cause toxic effects other than by inflammation or the mechanism of "lung overload", as "nuisance dusts".*
A "nuisance dust" will have an exposure limit or TLV of 10 mg/m^3 for total particulate. It is recognized that the respirable fraction of "nuisance dusts" may also be measured. The equivalent exposure limit for respirable particulate is 3 mg/m^3. Respirable particulate refers to the fraction of inhaled dust that is capable of passing through the upper respiratory tract to the gas exchange region of the lung. Total particulate refers to a wide range of particle sizes capable of being deposited in the various regions of the respiratory tract

3 DE-DUSTER SELECTION

There are basically two main criteria for the selection of the proper De-Duster for an exhaust ventilation system; 1) Air Volume and 2) Static Pressure. The entire selection process boils down to those two main parameters. There are extensive calculations for determining the air volume requirements as discussed in Section 4 below which are for this discussion based on the tunnel dimensional parameters as listed in Table 1. The length of the tunnel is then used along with the desired duct carrying velocity for the specific type of dust particles to in turn provide the criteria to calculate the duct friction loss factors for total static pressure that the fan must overcome.

Table 1. Tunnel Dimensions

Initial Tunnel	Design Criteria	
	m	feet
Tunnel Length	1012	3320.2
Fan Dist. to Portal	15	49.2
Duct Dist to Face	18	59.1
Total Duct Length	1045	3428.5

4 AIR FLOW REQUIREMENT CALCULATIONS AND DEDUSTER PRINCIPLES OF OPERATION

The first step in determining the air flow requirements is to total up the amount of air needed for each piece of diesel equipment, and the recommended amount of air so to provide clean air at the face. The diesel equipment is determined by the size of each piece and empirical standards on how much air flow is needed to clear away the exhaust fumes from each piece as shown in Table 2 below. The dust level control requirements are based on the cross sectional area of the face and the velocity needed across the face in order to move the dust in a controlled manner. The larger of the two numbers is used for design purposes.

4.1 *Machinery & Dust Control Needs*

Table 2. Air Flow Requirements

	m3/sec	cfm
Equipment Airflow	20.58	43,600
Losses (10%)	2.06	4,360
Total Air for Diesel Loading*	22.63	47,960
Total Air for Dust Control	21.24	45,000

*Note Total air flow for diesel loading to be used for design purposes.

Secondly once the total air-flow requirements are determined and then it is necessary to calculate the static pressure of the system. This is done using standard principles from the Industrial Ventilation Handbook. The handbook combines the actual duct length with equivalent duct length factors such as exit losses and coupling losses. This will provide an effective duct length as shown in Table 3 below.

Table 3. Effective Duct Length Calculations

Duct Length and Equivalent Length Calculations

	m	Feet	NOTES
Duct Length	1009	3310	
Exit Loss	30.5	100	Equivalent Length
Coupling Losses	111	364	Equivalent Length
Total Duct Length	1150	3774	Includes Other Losses

Using Industrial Ventilation Handbook principles the static pressure is then calculated based on the "effective duct length", total air-flow requirements, duct diameter, and the calculated air velocity inside of the ductwork. Other losses in turn add to the total losses, such as the entrance losses on the duct inlet, elbows, and a velocity loss due to the air velocity in the ductwork. Table 4 shows the anticipated breakdown of these friction losses and the total design loss to be used in the De-Duster selection.

Table 4. Static Pressure Calculations

Criteria	Static Pressure	Dimensions	
	Inches WG	m	inches
Diameter of Duct		1.12	44
Static Resistance Total	18.87		
Safety Factor	3.77		
Entrance Losses	0.85		
Elbow Loss	0.65		
Velocity Loss	1.30		
Total Ventilation Losses	25.44		

4.2 *Principles of the wet De-Duster operation*

In Figure 1-6 below you will see the inlet ducting to the right side of the picture. This brings in the dirty air from the tunnel into the De-Duster inlet. The front portion of the machine mixes the water and the dust together in a very rapid exchange of pressure and the dynamic action of the integrated impeller, which is shown in Figure 1-7 below.

Figure 1-6 Fixed Mounted Demo Unit

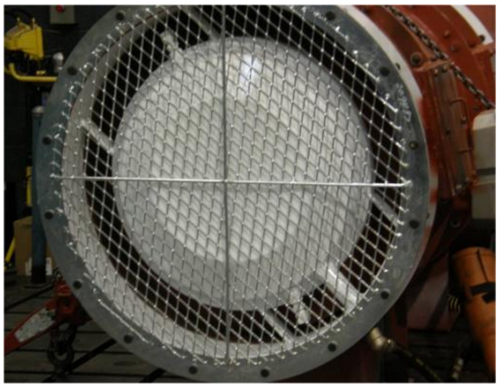

Figure 1-7 Integrated Impeller

After the rapid mixing of dust with the water the dust laden water travels around the motor in a sealed compartment so to keep the motor in the clean air as illustrated in Figure 1-8. After leaving this bifurcated section it is again sprayed with water using an internal water spray system as shown in Figure 1-9 in order to further saturate the dust particles and to provide better air cleaning the next step is to separate the dust laden water from the air stream. This is accomplished in the rear rectangular section of the machine using a unique series of mist eliminators and impingement panels.

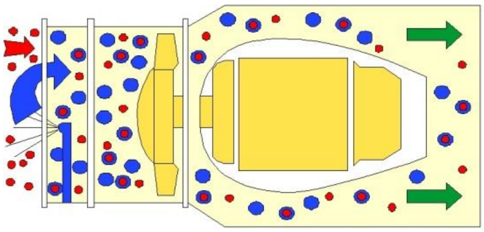

Figure 1-8 *Dust Capture Principles*

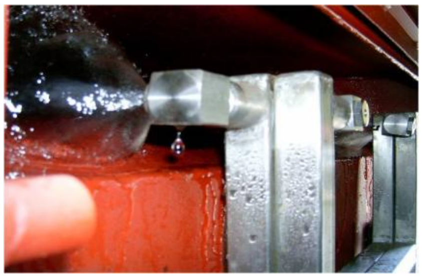

Figure 1-9 Internal Water Sprays

4.3 *Utility needs*

Utility need requirements must be evaluated for each project. In this particular case the amount of horsepower (kw) to power the Dedusting unit integrated impeller, the amount of supply water, and the drainage location all had to be evaluated prior to installing the unit on a permanent basis.

4.4 *Fan curve and power consumption*

Each Deduster has an integrated impeller that has a characteristic fan curve that relates air volume to static pressure of the system as illustrated in Figure 1-10. This curve also estimates power consumption based on the air volume and its relative static pressure which is shown on the red line in Figure 1-10 as well. Many times in order to achieve the total static pressure of the tunnel as it advances a booster fan placed in series with the Deduster may be needed. When placed in series the total static pressure is increased by the sum of the two units, while the volume curve remains. In effect as the tunnel advances and the duct length increases the additional static pressure is compensated with the addition of a booster.

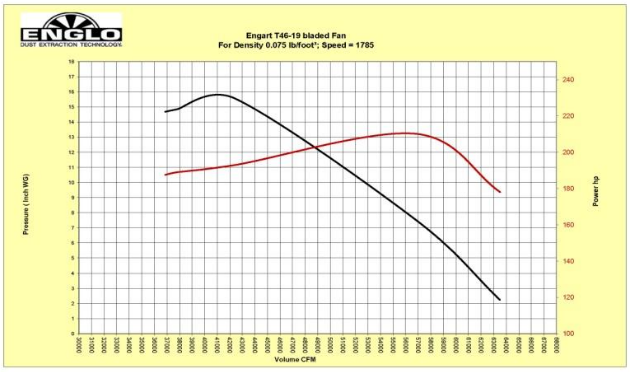

Figure 1-10 Fan curve illustration

In this application a VFD (Variable Frequency Drive) was used to vary the running speed of the impeller and in effect control the air volume more accurately. Each fan motor for the deduster and the booster was equipped with a VFD. This allows the running speed to be increased as the tunnel advances and therefore provides an additional control mechanism for the ventilation system. The fan performance and static pressure capability increase based on standard fan laws as the running speed increases.

5 IN SITU TESTING

Final results of the system proved successful for total dust control. Dust level readings were taken at various locations throughout the tunnel to determine if it met the regulators' approval and the system was approved and tunnel construction was allowed to proceed. Airflow readings were taken with a Fluke digital anemometer and the results met the required minimum design values. These results are shown in Table 5 below. In-situ dust level readings were measured in milligram per cubic meter and are shown below in Table 6 below. In effect all of the dust and air flow requirements were met and the system was approved for use on a permanent basis.

Table 5. In-Situ Air Flow Results

	Design Criteria	
	m3/sec	cfm
Airflow - In Duct (avg)	20.501	52,400
Airflow Above Roadheader	25.34	53,700

Table 6. In-Situ Dust Testing Results

Dust Results	mg/m3 Before De-duster	mg/m3 After De-duster
Roadheader (avg)	7.325	0.344
Scoop #1	3.321	0.030
Scoop #2	2.15	0.02

6. CONCLUSION

In conclusion using exhaust ventilation dust control this tunnel construction project was able to reduce ambient dust levels at the cutting area of the tunnel by 95.3% and over the man-operated equipment by over 98%. The dust levels including silica exposure limits allowed the tunnel to maintain air quality compliance and therefore operations could resume. The exhaust ventilation and dust control method also improved visibility at the cutting face and improved productivity. The equipment selected to mitigate the dusting issue also met air quality standards on the "cleaned" exhaust air that is returned back into the atmosphere. Lesson learned, blowing ventilation without a means to control dust is detrimental to the workers and productivity. Exhaust "Dedusting" systems provide better overall worker environmental conditions.

6. REFERENCES

Worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-policies/policies-part-05

Englo Dust Extractor Operating Manual dated Rev 3 Dated October 1, 2010.