Tunnel Dust Control Project

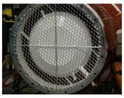
Tim Warden, Caleb Warden

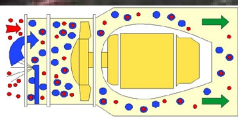
Engineering Division, ENGLO Inc

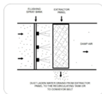
Problem: Hazardous environmental conditions and dangerous levels of dust shut down a tunneling project. Potential delay may break the project budget.

Analysis: Blowing ventilation caused incoming airflow to stir up dust causing poor air quality and reduced visibility; both were unacceptable safety concerns.

Goal: Develop safe, cost-effective dust extraction and ventilation system through detailed engineering case study.







Solution: Wet-Type Dust Extraction System

Mission Accomplished…

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

Tunnel Dust Control Project

T.W Warden, C.M. Warden

Engineering Division, Englo Inc. 194 Shott Court, Bluefield, WV 24701 USA, Phone: +1-304-253-0777, E-mail: twarden@engloinc.com

ABSTRACT: The case study describes implementation of a new Wet Type Dust Extraction System designed to control fugitive dust generated at a large tunnel project in British Columbia, Canada. Tunnel specifications called for a tunnel 1000m in length and approximately 14m diameter. Regulators found unacceptable levels of dust and required mitigation devices to be implemented before the project could commence again. The paper briefly describes expedient implementation and operation of a highly efficient exhaust ventilation and dust control system that would remove particulates to meet both emission and ventilation parameters for the construction area. The discussion includes the implementation of the exhaust ventilation and dust control device and the corresponding test data to illustrate dust levels before and after implementation at critical tunnel locations in the 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 mitigation options were presented to the client in order address the dust issues and 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. In essence the Wet De-Duster in a tunnel ventilation application can be affixed in three different arrangements.

- Equipment Mounted – *Figure 1*
- Trailing unit – *Figure 2 and Figure 3*
- Fixed Mounted – *Figure 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 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 De-duster 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. 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 exists 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 2 and 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 2. Trailing De-Duster

Figure 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 4. In this arrangement the unit sits on a permanent stand and inlet ducting as shown in Figure 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 4 Fixed Mounted De-duster

Figure 5 Ducting Inside of Tunnel

Recapitulating, the most common ventilation methods are blowing ventilation and exhaust ventilation.

1.4 *Blowing*

Air entering the tunnel construction area is brought in under positive pressure using ventilation fans from outside the tunnel; this is called "blowing" ventilation. The concept 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. In many cases this positive pressure creates more dusting issues than it solves. The air still passes over all the diesel equipment in order to maintain breathable air quality for the workers. Note that this often this picks up dust under pressure and carries it throughout the tunnel. This can be used in conjunction with exhaust ventilation techniques, increasing effectiveness.

1.5 *Exhaust*

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

2 SITUATION AT TUNNEL WITH BLOWING

In this case study the tunnel construction project employed a blowing ventilation system in the tunnel. As previously mentioned this caused severe dusting issues in nearly every location of the tunnel, which led to regulators shutting down the project until an effective remedy could be found.

2.1 *Regulators shut project down due to dusting issues*

According to the regional regulatory authority, Work Safe BC, the following dust control requirements must be met for underground mining or tunneling projects:

a) 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.
b) Such systems must be maintained in good working order and must be operational whenever the mechanical excavating device is working[i].

Dust containing silica has specific silica limits as outlined by Work Safe BC with control method suggestions. These control methods are framed via a series of questions[ii]:

a) Can local exhaust ventilation be used on all equipment that generates silica dust?
b) Can water be used to prevent dust from becoming airborne?
c) 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 the observed limits for Amorphous Silica exceeded the 1.5 mg/m3 limit in the worker area.

In addition to concerns over silica dust exposure, Work Safe BC also states 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[iii].

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 calculate the amount of air needed for each piece of diesel equipment. The calculation should also take into account the recommended amount of air so to provide clean air at the face. It should be noted that the diesel equipment requirements are determined by the size of each piece, taking into account empirical standards on how much air flow is needed to clear away the exhaust fumes from each piece as shown in Table 2 below. 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 the static pressure of the system is calculated. This is done using standard principles from the Industrial Ventilation Handbook. The handbook combines the actual duct length with corresponding duct length factors such as exit losses and coupling losses. This will provide an effective duct length as shown in Table 3.

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 6 the inlet ducting is visible to the right side of the picture. This ducting carries the dirty air from the tunnel into the De-Duster inlet. The integrated impeller, Figure 7, mixes the dust and water through a very rapid pressure differential brought about by its dynamic action. This integrated impeller is shown in Figure 7.

Figure 6 De-Duster Ducting

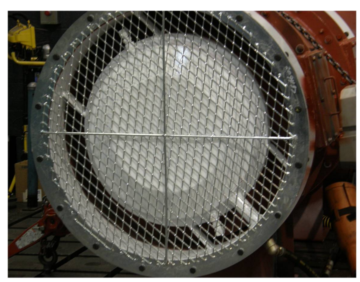


Figure 7 Integrated impeller

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 operating in clean air as illustrated in Figure 8. After leaving this bifurcated section it is again sprayed with water using an internal water spray system as shown in Figure 9. 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.

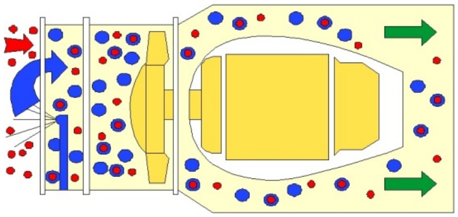


Figure 8 Dust Capture Principles

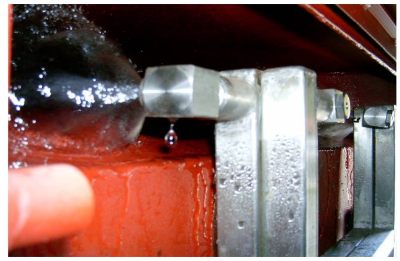


Figure 9 Internal Water Sprays

4.3 *Utility needs*

Utility need requirements must be evaluated and considered for each project. In this particular case the amount of horsepower (kw). To power the De-dusting unit's 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 De-duster has an integrated impeller with a characteristic fan curve that relates air volume to static pressure of the system as illustrated in Figure 10. The curve also estimates power consumption based on the air volume against its relative static pressure which is shown on the red line in Figure 10 as well. Frequently, in order to achieve and maintain the total static pressure of the tunnel as it advances, a booster fan is placed in series with the De-duster, as 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.

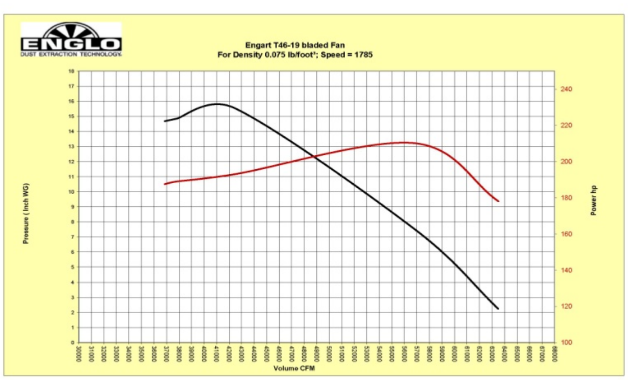


Figure 10 Fan curve illustration

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 De-duster 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 very successful for total dust control. Dust level readings were taken at various locations throughout the tunnel to determine if the system met the regulators' approval. 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.

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

6. CONCLUSIONS

In effect, the wet extraction system met or exceeded all of the safety and regulatory requirements for dust levels and airflow. Subsequently tunneling operations were allowed to proceed, allowing construction to continue and thus saving the project. Furthermore, the system was approved for use on a permanent basis and for all future tunneling projects.

7. REFERENCES

Occupational Health and Safety Regulations, Part 22, Underground Workings, 2003 Oct 29. Vancouver, B.C., Work Safe BC; [accessed 2018 Sep 1] https://www.worksafebc.com/.

Occupational Health and Safety Regulations, Policies Part 05, Controlling Exposure, 2010 Sep 15. Vancouver, B.C. Work Safe BC; [accessed 2018 Sep 1] https://www.worksafebc.com/.

Occupational Exposure Limits – Chemical and Biological Substances, Discussion Paper, 2004. Vancouver, B.C., Work Safe BC; [accessed 2018 Sep 1] https://www.worksafebc.com/.

8 ENDNOTES

---

[i] (Work Safe BC, Controlling Exposure Policy and Procedure, 2015)

[ii] (Work Safe BC, Underground Workings Policy and Procedure, 2003)

[iii] (Work Safe BC, Occupational Exposure Limits – Chemical and Biological Substances, 2004)