Diesel Particulate Matter (DPM) Reduction

Practical Limits for Reducing Ambient DPM Exposure with Airflow Dilution

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Introduction

- Controlling DPM is a growing area of focus for modern, mechanized underground mines around the world
- Ventilation is a critical component in controlling ambient DPM Exposure
- No panacea exists for reducing DPM at all levels/in all cases with ventilation
- When choosing an effective DPM reduction strategy, it is important to understand the limitations of each component/technology

Airflow Dilution

- Dilution, by definition involves the addition of "fresh" uncontaminated air being added to contaminated air, thereby reducing the percentage of the contaminant component
  - Contaminant limits are generally given in percentage (%), or concentrations ppm, or µg /m^3
  - Calculation of required airflow is quite simple for gaseous contaminants…

Equation 1:

$$Q = 100Eg / Cg$$

where:

Q	=	Required airflow (m^3/s)
Eg	=	Gas emission rate (m^3/s)
Cg	=	Concentration limit (%)

Airflow Dilution cont.

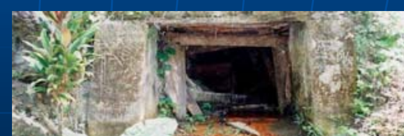
- Equation 1 was derived specifically for gaseous contaminants, and assumes turbulent flow, total mixing, etc.
- This represents the maximum theoretical efficiency for dilution
- DPM will behave differently than true gases since it is not entirely gaseous
- Entities such as MSHA, CANMET have developed other relationships to define the airflow required for the dilution of DPM

Practical Limits for Applying Airflow Dilution

- The utility/application of airflow dilution is affected by a variety of factors:
  - Climate/geography
  - Mine infrastructure
  - Mine plan/budget
  - Environmental Conditions
  - Others

Climate/Geography

- Climate may influence the degree to which ventilation may be increased at a particular operation
- For mines with climatic concerns, increasing the ventilation may require increases in the capacity of costly air heating or refrigeration systems



Existing Mine Infrastructure

- Existing Mine entries and ventilation infrastructure can limit potential increases in ventilation
- Large mine openings (such as those found in many underground rock quarries) require impractical airflow quantities to achieve minimal velocities
- Small/undersized openings restrict ventilation capacity via upper velocity limits
- In both cases, ventilation costs may skyrocket rapidly

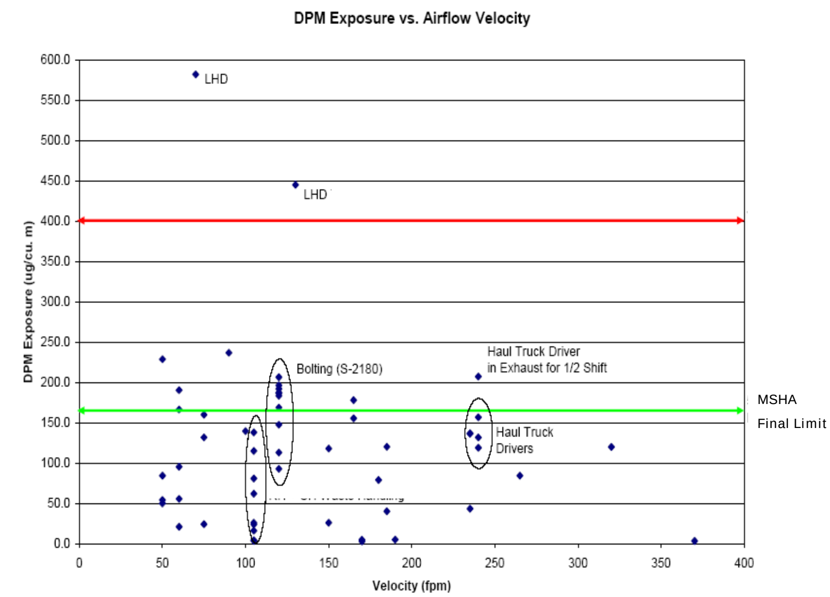
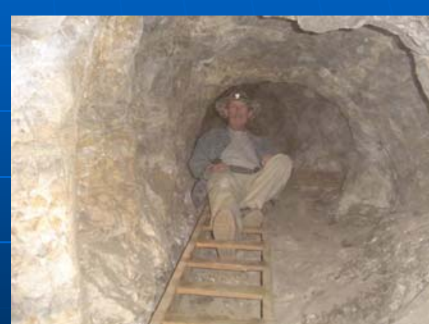


Figure 12: DPM Exposure vs. Airflow Velocity

Upper Velocity Limits

- ~ 20 m/s (4,000 fpm) for dedicated ventilation drifts/raises
- May be less if other environmental conditions exist (i.e. water blanketing)
- Upper velocity limits are significantly lower in entries used for personnel travel and/or haulage routes (where DPM exposure is a concern)
- Increases in airflow may require the expansion of mine infrastructure at significant cost



Mine Plan/Budget

Fan Laws

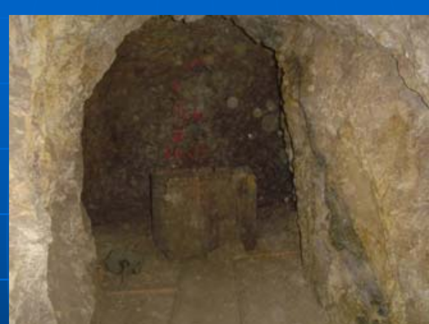
$$CFM_2 = \frac{RPM_2}{RPM_1} \times CFM_1$$

$$SP_2 = \left(\frac{RPM_2}{RPM_1}\right)^2 \times SP_1$$

$$BHP_2 = \left(\frac{RPM_2}{RPM_1}\right)^3 \times BHP_1$$

- Fan Static Pressure has a squared relationship to increases in volume
- The relationship between Fan Power ($) and volume is cubic
- Doubling your airflow increases ventilation cost(s) by 8 times for only a 50% reduction in contaminants… (Eq. 1)
- Operating cost(s) of ventilation systems must be weighed against capital cost(s) of new development

Environmental Conditions



- Significantly increasing the airflow underground may introduce or exacerbate other negative health-related conditions
- Environmental hazards include dust and fogging
- These impacts may preclude the use of increased airflow to dilute DPM

Incorporating Ventilation into your Compliance Strategy

- Overall approach must tailor specific solutions to specific concerns and incorporate a wide-range of options for DPM reduction while considering all possible ramifications of any changes to the airflow underground
- It is important to understand the root cause(s) of high DPM exposure at specific sites
- The potential for high exposures from contact with even small or infrequently used Diesel equipment is possible in areas of low/no ventilation
- Conversely, in isolated cases in order to achieve the same reduction in exposure from a DPF with a 95% efficiency it would take an increase in airflow of 20x !!

Matching Solutions to Problems

Potential Issue(s):

- Consistently high, Mine-wide exposures
- High exposures in isolated stope(s)
- Problematic LHD or haul truck
- Spotty exposure levels throughout the mine

Potential Solution(s):

- Engine Replacement
- Fuel Change
- Boost Localized Ventilation
- **Boost Mine Ventilation System**
- Exhaust After-treatment
- Maintenance Program Audit
- New Equipment Purchase

Regulatory Limits

- The applicable standards for enforcement, coupled with the existing mine conditions can significantly effect the usefulness of ventilation as a DPM reduction technology
- Proposed U.S. standard of DPM (160 µg /m^3) is unlikely to be met via ventilation dilution alone
- At present, many other countries have either significantly higher limits or NO REGULATIONS concerning DPM exposure levels in underground mines

Conclusions

- Adequate ventilation is a required component of ANY DPM reduction strategy
- The design and operation of the mine ventilation system should be optimized BEFORE examining alternatives or additional measures
- It is important to know where you stand in regards to any applicable laws or regulations (how far you need to go)
- No one technology/application exists for every DPM-related issue, and ALL available solutions should be considered when developing a reduction/compliance strategy

Questions?

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