Diesel Particulate Matter Control Strategies

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Control Strategies

Effectiveness of DPM Exposure Controls
  - Ventilation
  - Environmental Cabs
  - Administrative Controls

Emission Reductions

DPM Emissions Testing of Biodiesel Fuel Blends

Conclusions
Control Strategies

DPM reduction depends on:
- Exposure controls
  - Ventilation
  - Environmental cabs
  - Administrative controls
- Emission reduction
  - Diesel engines
  - Engine maintenance
  - Biodiesel fuel
  - Aftertreatments

Almost all mines will require a combination of the controls to attain compliance.
Effectiveness of DPM Exposure Controls

Ventilation
- DPM reduction depends on nature of upgrade
- Improvement roughly proportional to airflow increase

Environmental cabs up to 80% reduction
- 800 $\mu$g/m$^3$ reduced to 160 $\mu$g/m$^3$ in cab
- Some workers cannot work inside a cab

Administrative Controls
Ventilation

- Widely used method for DPM control
- DPM reduction proportional to airflow
  - Doubling airflow ≈ 50% DPM reduction
- Increasing ventilation can be difficult and costly
  - Major upgrades
    - Example:
      16-foot diameter shaft = $1,000/foot
- Power
  - Example:
    250,000 cfm at 1-inch wg = 40 hp
    40 hp x 100 hours/week @ 10¢/kw-hour = $15,000/year
    1.25x airflow = 2x hp = 2x electricity cost
    2x airflow = 8x hp = 8x electricity cost
How Much Air is Enough?

Particulate Index (PI) = airflow quantity needed to dilute DPM emissions to \(1,000_{\text{DPM}} \mu g/m^3\)

- \(\text{PI} \rightarrow 1,000_{\text{DPM}} \mu g/m^3 = 800_{\text{TC}} \mu g/m^3\)
- \(2 \times \text{PI} \rightarrow 500_{\text{DPM}} \mu g/m^3 = 400_{\text{TC}} \mu g/m^3\)
- \(5 \times \text{PI} \rightarrow 200_{\text{DPM}} \mu g/m^3 = 160_{\text{TC}} \mu g/m^3\)

PI’s for MSHA Approved engines listed on MSHA’s Internet website

How Much Air is Enough?

Examples of engine PI’s

- **Cat 3306 PCNA (150 hp)**
  - PI = 27,000 cfm
  - 5 x PI = 135,000 cfm

- **Deutz BF4M2012 (150 hp)**
  - PI = 3,000 cfm
  - 5 x PI = 15,000 cfm

*Remember:* 2 x cfm = 8 x hp = 8 x $

Boosting airflow is a good start, but also need to direct air where needed (walls, stoppings, doors)

- Eliminate short circuits and recirculation paths
- Ensure air reaches all working areas and faces
Ventilation System Layouts

Avoid

- Adjacent intake and exhaust openings
- Small diameter shafts/slopes < 10-foot diameter
  - Very high resistance (high power costs)

Distributing air underground

- Long unmined blocks
- Brattice lines
- Auxiliary fan and duct (rigid and flexible) for developments ends
  - Inlet needs to be in fresh air
  - Maintain duct
Adjacent Intake and Exhaust

recirculation path
Separated Intake and Exhaust
Free-standing booster fans with no ventilation control structures (stoppings, air walls, doors, etc.) cause recirculation.
Dead Ends – Free-Standing Fans

Critical parameters:
- Fan placement
- Angle off the rib
Dead Ends – Auxiliary Fan

Main Airflow

Auxiliary Ventilation
(Fan and Duct)

Critical parameters:
- Fan placement
- Fan horsepower
- Duct length & diameter
- Duct bends & corners
- Duct leakage
Natural Ventilation

Temperature difference causes pressure difference.

Example:

\[ NVP = 0.03 \text{-inch wg per 100 feet per } 10^\circ F \]

100-foot shaft and 40°F change (15°F to 95°F)

\[ NVP = 0.03 \times \frac{100}{100} \times \frac{40}{10} = 0.12 \text{-inch wg} \]

0.12-inch wg → 20,000 to 50,000 cfm is typical

0.12-inch wg is maximum value & usually less

Not sufficient for DPM dilution

Reverses from summer to winter

Very low in spring and fall (sometimes zero)
Environmental Cabs

Environmental cabs can reduce:
- TC exposure
- Noise exposure
- Silica and other dust exposure

Cabs should be:
- Tightly-sealed with no openings
- Repaired when windows are broken
- Pressurized with filtered breathing air
  (follow regular filter change-out schedule of 250 hours)
- Designed for 1 air change per minute
  (100 ft³ cab requires 100 cfm fan)
- Operated with doors & windows closed
  (may need air conditioning)
- Maintained in good condition
Testing Cab for Positive Pressurization

- Close doors and windows
- Turn on AC fan or blower to high setting with “outside air”
- Attach Magnehelic gage to flexible tubing
- Place flexible tubing into cab and close door (make sure tube is not “pinched off”)
- Magnehelic gage should register +0.10-inch wg or more
Administrative Controls

- Control DPM exposures through operating procedures, work practices, etc.

- Job rotation prohibited as DPM administrative control
  [§57.5060(e)]

  - Job rotation
    - Means assigning a job to more than one worker so that each worker does the assigned job for only part of a shift
    - Spreads exposure to more workers
    - Good industrial hygiene practice prohibits job rotation for control of exposures
Administrative Controls

Examples:

- Minimize engine idling and lugging
- Keep fuel and lube oil clean
- Utilize traffic control and production scheduling
  - Keep heavy traffic downstream from miners who work outside of cabs (e.g. powder crew)
  - Route haul trucks in return air, especially when ascending ramps loaded
- Limit horsepower based on available cfm’s
- Schedule blasters on non-load/haul shifts
- Keep cab doors and windows closed
Emission Reductions

Methods to reduce diesel particulate matter emissions:

- New engines produce lower DPM emissions
- Diesel particulate filters remove DPM
- Alternative fuels reduce DPM emissions
- Maintenance program insures methods working properly
Diesel Particulate Filters

- Passive regenerated ceramic filters
  - self regenerate based on duty cycle

- Active regenerated ceramic filters
  - need regeneration station

- Fuel burner with ceramic filter
  - creates temperature as in passive type system

- Sintered metal fiber filters
  - electrical heating for onboard regeneration

- Paper filters
  - cooled exhaust

- High temperature disposable filter
  - filter lift based on duty cycle and operating time

- MSHA Filter Listing
DPM Emissions Testing of Biodiesel Fuel Blends

Biodiesel
- Registered fuel & fuel additive with EPA
- Ultra-low sulfur diesel fuel
- Derived from vegetable oils or animal fats
- Blended with standard petroleum-based diesel fuel
- Significantly lowers EC emissions

MSHA’s compliance sampling indicated
- Significant reductions using high biodiesel content fuel blend
  - EC exposures (2003 & 2004 EC-based limit)
  - TC exposures (2007 TC-based limit)
- Further analyzed data to separate EC & OC emissions
  - EC significantly lower using biodiesel
  - Biodiesel could cause OC emissions to increase
- Concern – reduction in EC offset by increase in OC emissions
DPM Emissions Testing of Biodiesel Fuel Blends

MSHA’s Approval & Certification Center diesel laboratory

- Conducted diesel emission testing using Isuzu 4JG1T engine to measure
  - TC, EC, & OC
  - Various exhaust gases (CO, CO\(_2\), NO, NO\(_2\))

**Tested**

**Fuels**

- 3 petroleum diesels
  - [certified low sulfur diesel & ultra-low sulfur diesel (ULSD), highway ULSD]
- 3 B100 biodiesels
  - (2 pure soy-based biodiesel, blend of soy-based & animal fat-based biodiesels)
- B50 blend of soy biodiesel & ULSD
- 100% Fischer-Tropsch synthetic

- With & without diesel oxidation catalyst (DOC)
DPM Emissions Testing of Biodiesel Fuel Blends

Testing demonstrated

- Biodiesel produced
  - Modest reduction in TC emissions without DOC
  - Significant reduction in TC emissions with DOC compared to petroleum diesel
- Significant TC reductions when using B50 & B100
- Highest TC reductions using 100% biodiesel with DOC
DPM Emissions Testing of Biodiesel Fuel Blends

Explanation for resulting TC emissions

Biodiesel
- Significant reductions in EC emissions
- Increased OC emissions compared to petroleum diesel without DOC
  - Partially offset EC reduction
  - Net TC did not increase

Using DOC for all fuels
- No net effect on EC emissions
- Significant reduction in OC emissions

Significant TC reduction using biodiesel with DOC
- EC reduction produced by biodiesel
- DOC eliminated significant portion of OC emissions
(continued)

DPM Emissions Testing of Biodiesel Fuel Blends

Testing demonstrated

- DOC for all fuels
  - Nearly eliminated CO emissions
  - Increased NO₂ emissions (control by adequate mine ventilation)

- Engine duty cycle influence TC reduction from biodiesel without DOC
  - OC increased
    - Heavy duty cycle when biodiesel use at minimum
    - Lighter load conditions as percentage of TC & absolute value
  - Biodiesel most effective in reducing TC when engine works hard
    - Effective at reducing EC significantly at all load conditions
    - Produces most OC increases at light loads

- TC emissions at heavy & light engine load conditions
  - Reduced using biodiesel with DOC
  - Compared to petroleum-based diesel with/without DOC
DPM Emissions Testing of Biodiesel Fuel Blends

- Isuzu 4JG1T engine compared to most makes & models of Tier 2 or later off-road engines
  - Biodiesel expected to produce similar results
  - Similar upward & downward trends in various emissions expected

- Transition from standard petroleum diesel to high biodiesel content fuel blend
  (cost, fuel quality & availability, low temperature properties, solvent effects, microbial growth, long term storage stability, energy content, oil change intervals)
Conclusions

Most mines should work to attain compliance with a combination of control strategies:

- 3 exposure controls
- 4 emission reduction
DPM Information

Part II Diesel Particulate Final Rules
Single Source Page

Metal/Nonmetal Mines

www.msha.gov/01-995/Dieselpartmnm.htm
Contact Information

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