U.S. Department of Labor MSHA Mine Safety and Health Administration

Diesel Particulate Matter Control Strategies

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Outline

- 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 $1{,}000_{DPM}$ $\mu g/m^3$
  - PI → $1{,}000_{DPM}$ $\mu g/m^3$ = 800_{TC} $\mu g/m^3$
  - 2x PI → 500_{DPM} $\mu g/m^3$ = 400_{TC} $\mu g/m^3$
  - 5x PI → 200_{DPM} $\mu g/m^3$ = 160_{TC} $\mu g/m^3$
- PI's for MSHA Approved engines listed on MSHA's Internet website

https://lakegovprod2.msha.gov/ReportView.aspx?ReportCategory=EngineAppNumbers

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

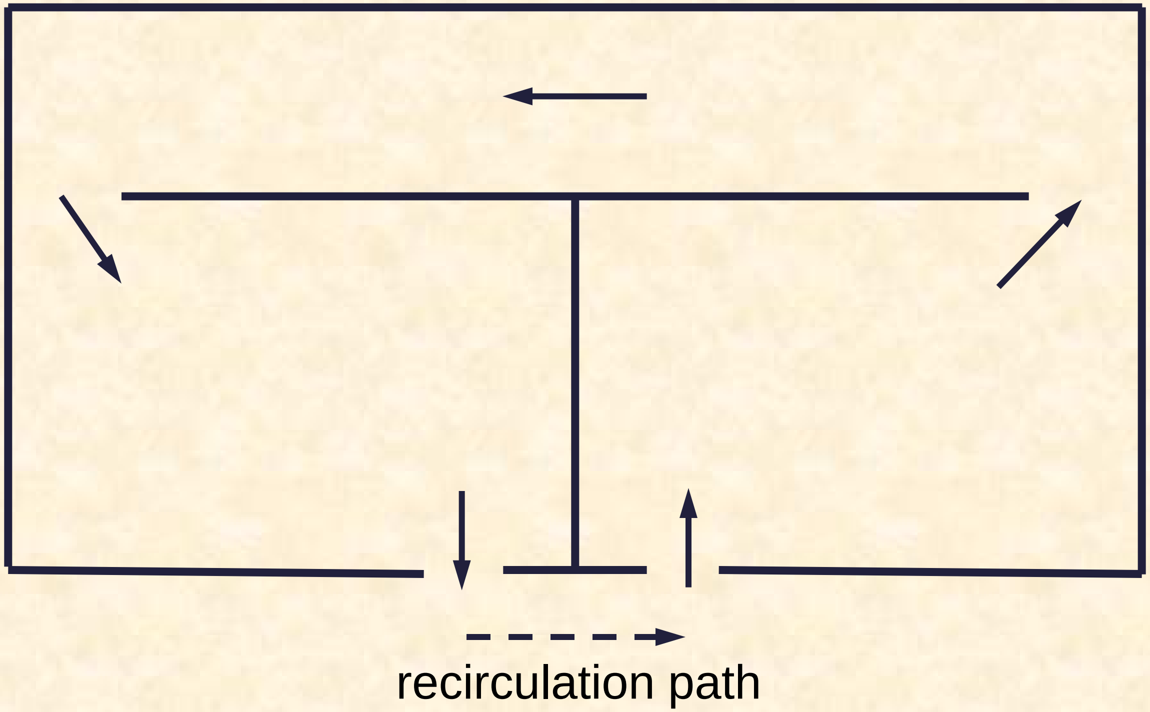
Remember: 2 x cfm = 8 x hp = 8 x $

- 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

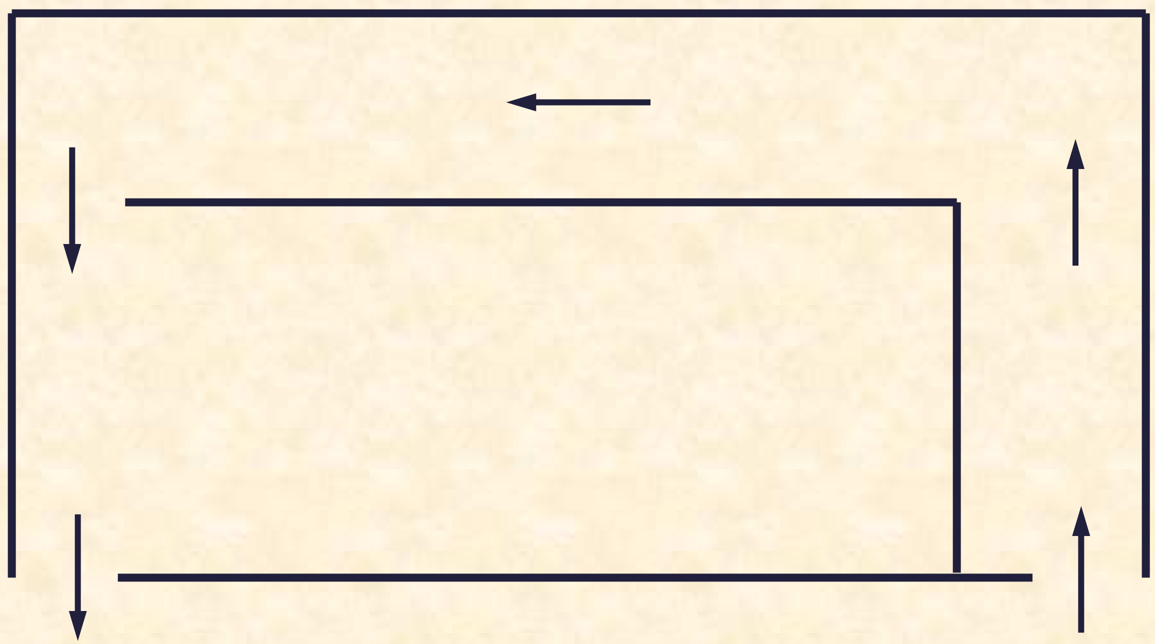
Ventilation System Layouts

- 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

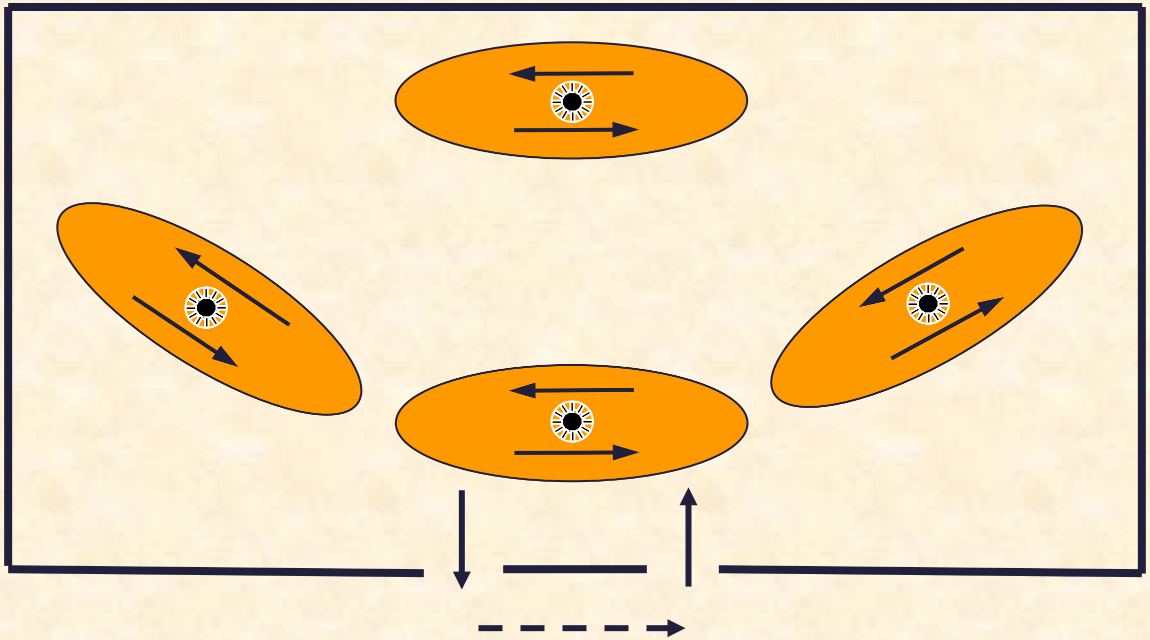


Separated Intake and Exhaust

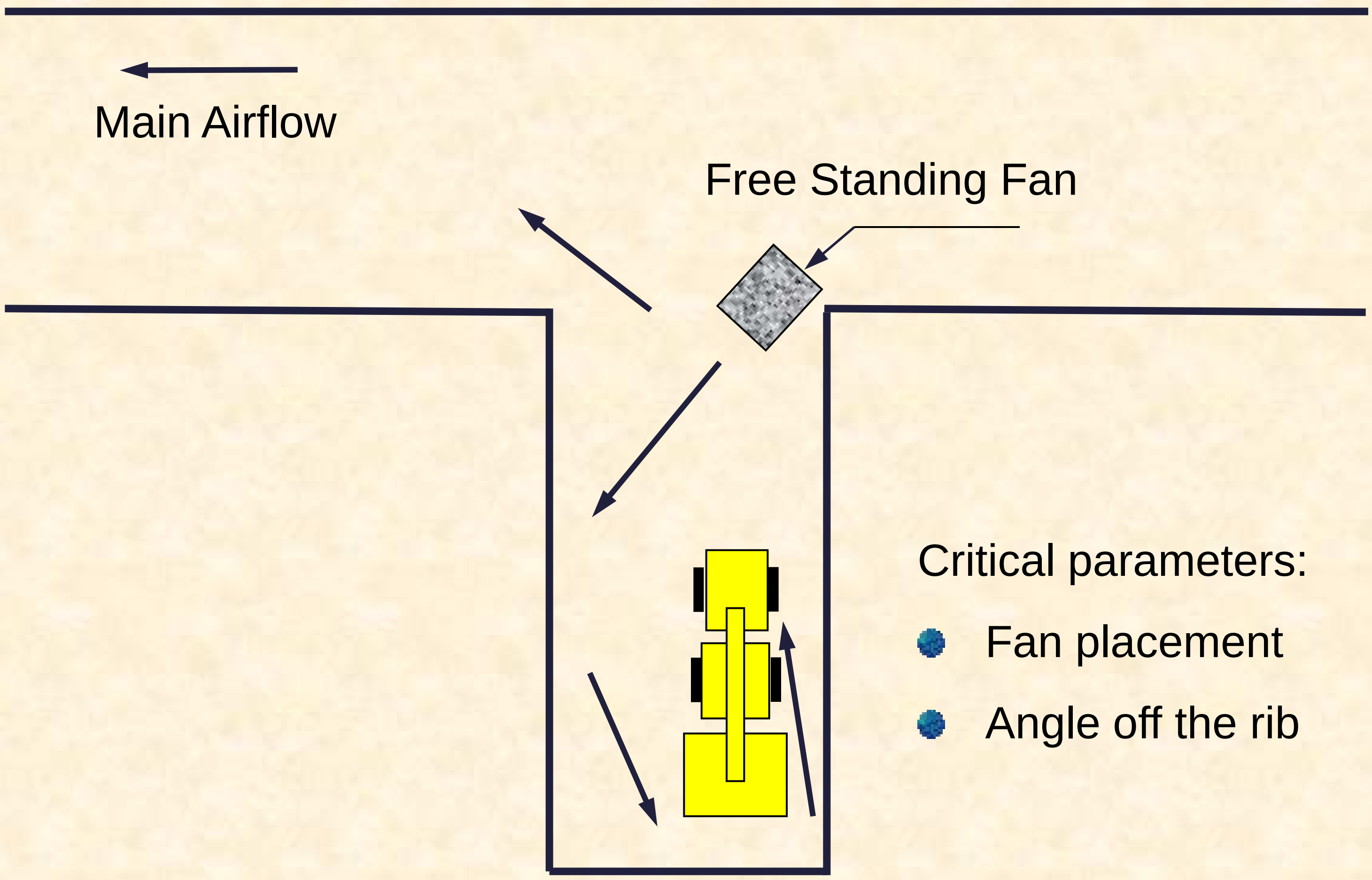


Recirculation

Free-standing booster fans with no ventilation control structures (stoppings, air walls, doors, etc.) cause recirculation.



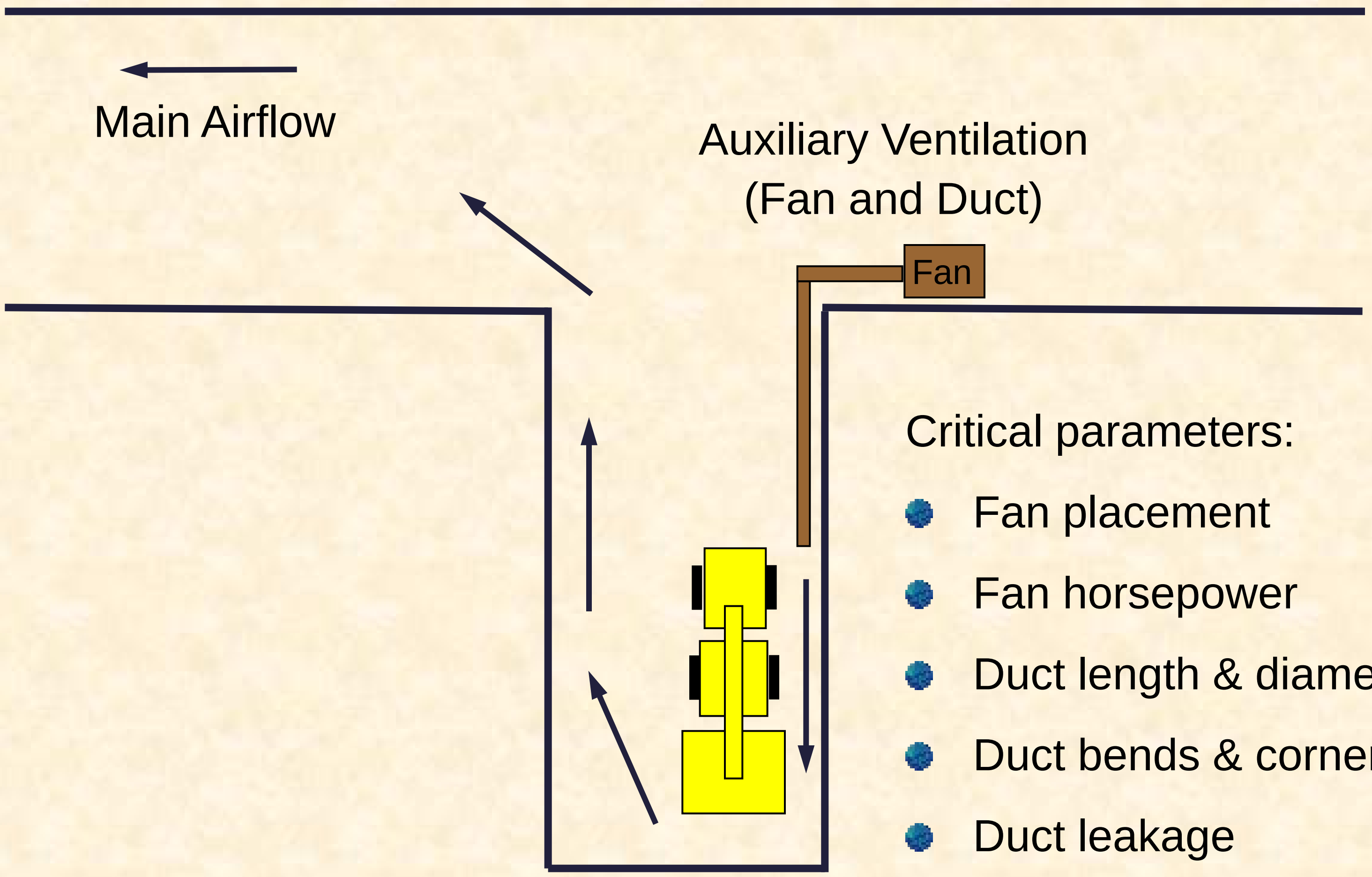
Dead Ends – Free-Standing Fans



Critical parameters:

- Fan placement
- Angle off the rib

Dead Ends – Auxiliary Fan



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-inch wg per 100 feet per 10°F

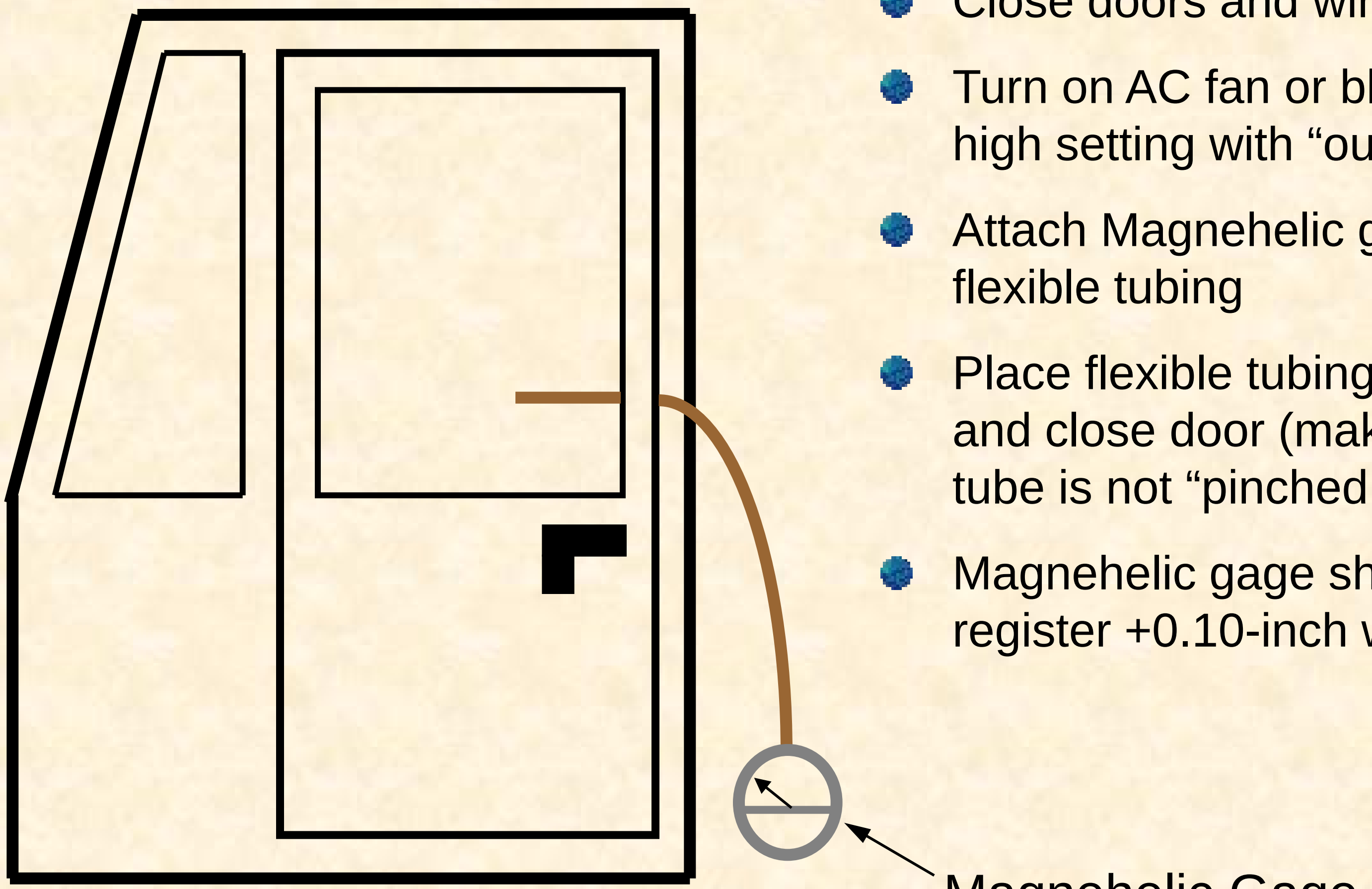
    100-foot shaft and 40°F change (15°F to 95°F)

    NVP = 0.03 x 100/100 x 40/10 = 0.12-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 ($100\ ft^3$ 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

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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
  - http://www.msha.gov/01-995/Coal/DPM-FilterEfflist.pdf

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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

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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)

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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

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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

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DPM Emissions Testing of Biodiesel Fuel Blends

Testing demonstrated

- DOC for all fuels
  - Nearly eliminated CO emissions
  - Increased NO_2 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

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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

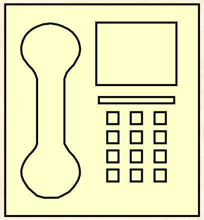
Part II Diesel Particulate Final Rules

Single Source Page

Metal/Nonmetal Mines

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

Contact Information



Feel free to contact me with any questions.

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