Effects of Exhaust Aftertreatment Technologies on Concentrations of Diesel Particulate Matter and Gases in Underground Mines

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Diesel Emissions from Underground Mining Equipment

- Diesel particulate matter (DPM) and elemental carbon (EC)
- CO
- NO and NO₂
- CO₂
- hydrocarbons
Aftertreatment Technologies in Underground Mines

- CO and hydrocarbons:
  - Diesel oxidation catalytic converters (DOC)

- Diesel particulate matter (DPM) and elemental carbon (EC):
  - Diesel particulate filter (DPF) systems;
  - Filtration systems (FS) with disposable filter elements (DPEs);
  - Flow through filters

- NO and NO₂
  - Lean NOₓ catalyst,
  - Selective catalytic reduction (SCR) systems

- Integrated aftertreatment systems
Aftertreatment Technologies in Underground Mines

- **CO and hydrocarbons:**
  - Diesel oxidation catalytic converters (DOC)

- **Diesel particulate matter (DPM) and elemental carbon (EC):**
  - **Diesel particulate filter (DPF) systems:**
  - **Filtration systems (FS) with disposable filter elements (DPEs):**
  - Flow through filters

- **NO and NO₂**
  - Lean NOₓ catalyst,
  - Selective catalytic reduction (SCR) systems

- Integrated aftertreatment systems
DPF Systems

Elements

Media
- Wall flow monoliths
- Cordierite
- Silicon carbide (SiC)
- Deep bed filters
- Ceramic fiber
- Sintered metal fiber

Catalyst
- Non-catalyzed DPF systems
- Catalyzed DPF systems:
  - Wash coat catalyst
  - Fuel borne catalyst
DPF Systems
Regeneration

DPF Regeneration – burning off carbon collected on the filter media

- Regarding the regeneration concept, contemporary DPF systems available to mining industry can generally be classified into two groups:
  - **Passive**
    Exhaust gas temperatures are favorable and a DPF is regenerated during a duty cycle without operator’s involvement and need for external sources of heat.
  - **Active**
    DPF is sized to accumulate DPM between two active regenerations. Accumulated DPM is removed using an external source of energy:
    - electrical heaters;
    - fuel combustion.
Approximate minimum exhaust temperatures required to initiate regeneration process:
- Non-catalyzed DPF – over 600 °C;
- Base metal catalyst – over 390 °C;
- Nobel metal catalyst – over 325 °C;
- Continuously Regenerating Technology (CRT) - over 260 °C…

25-30% or more of a duty cycle on vehicle/engine should be operated at loads generating exhaust temperatures exceeding minimum regeneration temperatures.

Frequency and duration of the favorable temperature occurrences are playing important role in initiating and supporting regeneration process.
Regeneration of DPF Systems
Exhaust Temperature Histogram
Regeneration of DPF Systems
Exhaust Temperature Histogram
DPF Systems
Active Regeneration

- Electrical Heating
  - On-board heaters
    - Air/exhaust gas heating
    - Substrate heating (sintered metal)
  - Off-board heaters
    - Air heating

- Fuel combustion
  - Flame combustion
    - Automated full flow fuel burner system
    - Stationary partial flow fuel burner system
  - Catalytic combustion
Passive DPF systems:
- relatively simple
- low operational requirements;
- low maintenance requirements;
- lower initial cost;
- regeneration depend on exhaust heat!!!
- In some cases potential for increase in NO$_2$ and sulfates emissions.
DPF Systems
Passive vs. Active Regeneration Concept

- Active DPF systems:
  - regeneration does not depend on exhaust heat;
  - no long-term effects on secondary emissions;
  - might require changes in way vehicles are operated;
  - higher initial cost;
  - relatively complex;
  - higher maintenance requirements;
  - require change in operator’s attitude;
Underground mining stigma:
- Passive=transparent=“business as usual”
- Active systems=downtime=“trouble”

Advanced DPF regeneration strategies are constantly emerging:
- Integration of DPF systems into engine management system

DPF systems evaluated by MSHA are posted at http://www.msha.gov/01-995/Coal/DPM-FilterEfflist.pdf
Filtration Systems (FS) with Disposable Filter Elements (DFE)

- Systems designed to control diesel emissions from permissible underground coal mining equipment:
  - Surface temperature requirements (30 CFR § 7.98):
    - $< 302°F (150°C)$
  - Exhaust temperature requirements (30 CFR § 7.102)
    - Wet exhaust conditioner: $< 170°F (76°C)$;
    - Dry exhaust conditioner: $< 302°F (150°C)$. 
Filtration Systems (FS) with High Temperature Disposable Filter Elements (DFE)

- Systems designed to control diesel emissions from non-permissible underground coal mining and other equipment:
  - No surface temperature requirements
  - Exhaust temperature requirements:
    - DFE efficiency;
    - Potential for spontaneous combustion of accumulated soot.
Equivalent Disposable Filter Elements (DFE)

- List of the DFE evaluated by MSHA is available in Table 1 at [http://www.msha.gov/01-995/Coal/DPM-FilterEfflist.pdf](http://www.msha.gov/01-995/Coal/DPM-FilterEfflist.pdf)
- Equivalency with respect to efficiency recognized only if DFE is used below manufacture specified exhaust temperature limits (185, 302, 650 °F)
The elements should be replaced when engine backpressure exceeds engine manufacture recommended limit:
- DDEC Series 60 - 41 in H₂O
- Caterpillar 3306 PCNA - 34 in H₂O

Low emissions extend life of the DFE
- Emissions assisted engine maintenance directly benefits DFE life.
Useful References on DPF and DFE Systems

- DieselNet Technology Guide.
  http://www.dieselnet.com/tg.html#other

  http://www.cdc.gov/niosh/mining/pubs/programareapubs8.htm

- Mine Safety and Health Administration (MSHA) Diesel Particulate pages:
  http://www.msha.gov/01-995/dieselpart.HTM
DPF and DFE Systems in Underground Mines

Achieving substantial reductions in the exposure to DPM depends on the ability of the industry to widely implement advanced diesel emissions control technologies primarily DPF systems.

Design, selection, and implementation of DPF systems for underground mining presents unique challenges:

- Wide variety of application with specific operational, engineering and maintenance issues.
- MSHA regulations
  - Confined space:
  - \((\text{NO}_2 + \text{NO}) \text{ vs. } \text{NO}_x\)
- Retrofit systems vs. OEM.
- Harsh environment.
- “Business as usual” philosophy vs. reality
  - Human factor;
  - High expectations.
Selection of DPF Systems for Underground Mining Applications

Considerations:

- Effects on DPM/EC and gaseous emissions
  - Reductions in
    - total diesel particulate matter (DPM)
    - elemental carbon
  - Secondary emissions
  - Laboratory vs. in-use emissions

- Regeneration strategy

- Implementation issues

- Cost.
Effects of DPF systems and DFEs of DPM emissions

  - Cordierite DPF elements – 85%
  - Silicon carbide DPF elements – 87%
  - DFE – equivalency criteria
Effects of DPF Systems on Gaseous Emissions

- NO to NO₂ conversion
- Ventilation rate requirements might be higher for the engines equipped with certain types of DPF systems

### Dilution Ratios

<table>
<thead>
<tr>
<th>MODE</th>
<th>Engine-out Emissions</th>
<th>DPF-out Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO₂</td>
<td>CO</td>
</tr>
<tr>
<td>1</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>2</td>
<td>16.3</td>
<td>0.9</td>
</tr>
<tr>
<td>3</td>
<td>14.3</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>11.5</td>
<td>1.3</td>
</tr>
<tr>
<td>5</td>
<td>5.7</td>
<td>4.0</td>
</tr>
<tr>
<td>6</td>
<td>20.5</td>
<td>1.8</td>
</tr>
<tr>
<td>7</td>
<td>18.7</td>
<td>1.5</td>
</tr>
<tr>
<td>8</td>
<td>15.9</td>
<td>1.6</td>
</tr>
<tr>
<td>9</td>
<td>2.3</td>
<td>2.1</td>
</tr>
</tbody>
</table>

PM = particulate matter, NO₂ = nitrous oxide, NO = nitric oxide, CO₂ = carbon dioxide, CO = carbon monoxide, NO₂ = nitric oxide
Effects of DPF Systems and DFEs on Concentrations of DPM in Mine Air

™ Isolated Zone Studies at Stillwater Nye Mine
™ May/June 2003, and 2003
™ August/September 2004. 2004

™ To measure the effects of selected diesel emissions control technologies on the concentrations and properties of aerosols and gases in mine air:
™ DPF systems;
™ DFEs;
™ DOCs and;
™ Reformulated fuels.
Rationale Behind Isolated Zone Testing

- Direct in-situ assessment of the effects of control technologies on quality of ambient air in occupational environment.
- Vehicles operated over a simulated transient production cycle.
- Interaction between vehicle, engine, and control technology.
- Complements results of laboratory evaluations.
LHDs in Isolated Zone

Upstream Sampling Station

Upstream Load/Dump Point

Vehicle Sampling Station

Fueling Station

Muck Pile

Downstream Load/Dump Point

Downstream Sampling Station

~1750’

~300’

~1000’

~450’

Ventilation Doors

Downstream load/dump point

Upstream load/dump point
Haulage Trucks in Isolated Zone

- **Upstream Sampling Station**
- **Upstream Dump Point**
- **Vehicle Sampling Station**
- **Fueling Station**
- **Downstream Load Point**
- **Downstream Sampling Station**

- Upstream dump point:
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6

- Downstream load point:
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9

Dimensions:
- ~530 m (1739 ft)
- ~90 m (295 ft)
- ~300 m (984 ft)
- ~140 m (459 ft)
Sampling Strategy Used in IsoZone Tests

- Three sampling locations:
  - Upstream sampling station, ~300 ft (91 m) upstream of the upstream load/dump point.
  - Downstream sampling station, ~450 ft (137 m) downstream of the upstream load/dump point.
  - On-vehicle, ~6 ft (1.8 m) from the operator.

- Contribution from the vehicles obtained by subtracting upstream from downstream concentrations.
Instrumentation at Downstream Sampling Station
Instrumentation at Upstream Sampling Station
### Aftertretment Systems Tested in 2003

<table>
<thead>
<tr>
<th>Aftertretment System</th>
<th>DPF Media</th>
<th>DPF Catalyst</th>
<th>DOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engelhard DPX DPF</td>
<td>Ceramic, Cordierite</td>
<td>platinum washcoat</td>
<td>N/A</td>
</tr>
<tr>
<td>DCL MineX 5C57 11 DPF</td>
<td>Ceramic, Cordierite</td>
<td>platinum washcoat</td>
<td>N/A</td>
</tr>
<tr>
<td>Engelhard PTX DOC</td>
<td>N/A</td>
<td>N/A</td>
<td>Ceramic substrate with platinum based catalyst</td>
</tr>
</tbody>
</table>
## Aftertretment Systems Tested in 2004

<table>
<thead>
<tr>
<th>Filtration System</th>
<th>DPF Media</th>
<th>DPF Catalyst</th>
<th>DOC Media and Catalyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>ArvinMeritor (AM) DPF with Pt DOC</td>
<td>Ceramic, Cordierite</td>
<td>N/A</td>
<td>Metal substrate with platinum based catalyst</td>
</tr>
<tr>
<td>ArvinMeritor (AM) DPF with Pd DOC</td>
<td>Ceramic, Cordierite</td>
<td>N/A</td>
<td>Metal substrate with palladium based catalyst</td>
</tr>
<tr>
<td>Donaldson P604516 DFE</td>
<td>High Temperature Disposable Filter Element</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Filter Service DFE</td>
<td>High Temperature Disposable Filter Element</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Selected Results of Isolated Zone Studies

- Effects of selected DPF systems, FS with DFEs and DOC on:
  - mass concentrations of elemental carbon particles under 800 nm
  - number concentrations and size distribution of aerosols between 10 and 392 nm
The Effects of DPFs and DOC on Mass Concentrations of Elemental Carbon (EC)

The graph shows the concentrations of EC and DPM before and after treatment for three different products: Engelhard DPX, DCL MineX, and DOC. The concentrations are measured in µg/m³.

- **Engelhard DPX**
  - Baseline: 1182 µg/m³
  - Aftertreatment: 1344 µg/m³
  - Concentration Reduction: 162 µg/m³

- **DCL MineX**
  - Baseline: 1112 µg/m³
  - Aftertreatment: 1434 µg/m³
  - Concentration Reduction: 322 µg/m³

- **DOC**
  - Baseline: 1228 µg/m³
  - Aftertreatment: 1632 µg/m³
  - Concentration Reduction: 404 µg/m³

The graph indicates a significant reduction in the concentrations of EC and DPM after treatment, particularly for DOC, where the reduction is the most noticeable at 404 µg/m³.
The Effects of DPFs and DOC on Mass Concentrations of Elemental Carbon (EC)

<table>
<thead>
<tr>
<th></th>
<th>Concentrations [µg/m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Engelhard DPX</td>
<td>96</td>
</tr>
<tr>
<td>DCL MineX</td>
<td>87</td>
</tr>
<tr>
<td>DOC</td>
<td>-3</td>
</tr>
<tr>
<td>EC</td>
<td>75</td>
</tr>
<tr>
<td>DPM</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>-15</td>
</tr>
</tbody>
</table>
The Effects of DPFs and DFEs on Mass Concentrations of Elemental Carbon (EC)

![Bar chart showing concentrations of Elemental Carbon (EC) in ug/m^3 for different systems: Muffler, AM Pd DOC, Donaldson, and Filter Services. The chart compares values for EC HV, TPM Gravimetric, and TPM TEOM.](image-url)
The Effects of DPFs and DFEs on Mass Concentrations of Elemental Carbon (EC)

<table>
<thead>
<tr>
<th></th>
<th>AM Pd DOC</th>
<th>Donaldson</th>
<th>Filter Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC HV</td>
<td>92</td>
<td>92</td>
<td>70</td>
</tr>
<tr>
<td>TPM GRAV</td>
<td>69</td>
<td>85</td>
<td>62</td>
</tr>
<tr>
<td>TPM TEOM</td>
<td>72</td>
<td>76</td>
<td>65</td>
</tr>
</tbody>
</table>
The Effects of DPFs and DOC on Concentrations of Aerosols with Electrical Mobility Diameter Between 10 and 392 nm in Mine Air

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Average Geometric Mean [nm]</th>
<th>Average Total Particle Conc. @ MSHA VR [#/cm³]</th>
<th>Increase in Total Particle Conc. [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>#92128 Haul Truck, MSHA VR = 5.66 m³/s (12000 ft³/min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>67.28</td>
<td>4.49E+06</td>
<td>--</td>
</tr>
<tr>
<td>Engelhard DPX DPF</td>
<td>43.74</td>
<td>8.07E+06</td>
<td>79.6</td>
</tr>
<tr>
<td>#99942 LHD, MSHA VR = 7.08 m³/s (15000 ft³/min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>75.42</td>
<td>1.63E+07</td>
<td>--</td>
</tr>
<tr>
<td>DCL MineX DPF</td>
<td>38.06</td>
<td>2.61E+07</td>
<td>60.6</td>
</tr>
<tr>
<td>#92526 LHD, MSHA VR = 4.72 m³/s (10000 ft³/min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>85.74</td>
<td>8.56E+06</td>
<td>--</td>
</tr>
<tr>
<td>Engelhard PTX DOC</td>
<td>72.4</td>
<td>1.01E+07</td>
<td>18.2</td>
</tr>
</tbody>
</table>

- Tested DPFs greatly increased the aerosol number concentrations.
- Tested DPFs reduced $D_{50}$ of the aerosols.
- Tested DOC slightly increased aerosol number concentrations.
- Tested DOC slightly reduced $D_{50}$ of the aerosols.
Size distribution of aerosols in mine air
Truck with Engelhard DPX DPF vs. Muffler

2003
Size distribution of aerosols in mine air
LHD with DCL MineX vs. Muffler

2003
Size distribution of aerosols in mine air
LHD with DOC/Muffler vs. Muffler

LHD with DOC/Muffler vs. Muffler

DOC/Muffler #1
DOC/Muffler #2
Muffler #1
Muffler #2
The Effects of DPFs and DFEs on Concentrations of Aerosols with Electrical Mobility Diameter Between 10 and 392 nm in Mine Air

The diagram shows the distribution of aerosol concentrations with electrical mobility diameter (\(dN/d\log(D_p)\)) in mine air. The graph plots \(dN/d\log(D_p)\) (number of particles per cm\(^3\)) against \(D_p\) (electrical mobility diameter) on a logarithmic scale. The data is categorized by different brands, including Muffler, AM Pd DOC, Donaldson, Filter Services, and AM Pd DOC. The concentrations are presented in a log scale ranging from 10 to 1000 nm.
The Effects of DPFs and DFEs on Concentrations of Aerosols with Electrical Mobility Diameter Between 10 and 392 nm in Mine Air

<table>
<thead>
<tr>
<th>Exhaust Configuration</th>
<th>Downstream</th>
<th>Upstream</th>
<th>Net Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average GMD 1</td>
<td>Average GMD 2</td>
<td>Norm. Average Number</td>
</tr>
<tr>
<td></td>
<td>nm</td>
<td>nm</td>
<td>$10^7$ #/cm$^3$</td>
</tr>
<tr>
<td>Muffler</td>
<td>34.2</td>
<td>86.0</td>
<td>2.2098</td>
</tr>
<tr>
<td>AM DPF with Pd DOC</td>
<td>42.5</td>
<td>68.3</td>
<td>1.6952</td>
</tr>
<tr>
<td>Donaldson</td>
<td>24.2</td>
<td>73.6</td>
<td>1.0360</td>
</tr>
<tr>
<td>Filter Services</td>
<td>35.8</td>
<td>73.6</td>
<td>1.0360</td>
</tr>
</tbody>
</table>
The Effects of DPFs and DOC on Concentrations of Nitrogen Dioxide (NO$_2$)

<table>
<thead>
<tr>
<th>Test Vehicle and Test Type</th>
<th>Average NO$_2$ concentration at MSHA Ventilation Rate</th>
<th>Increase in NO$_2$ concentrations by control technology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ppm</td>
<td>%</td>
</tr>
<tr>
<td>#92128 Haul Truck, MSHA vent 5.66 m$^3$/min (12000 ft$^3$/min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muffler</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Engelhard DPX DPF</td>
<td>2.1</td>
<td>269</td>
</tr>
<tr>
<td>#99942 LHD, MSHA vent rate 7.08 m$^3$/min (15000 ft$^3$/min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muffler</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>DCL MineX DPF</td>
<td>1.5</td>
<td>180</td>
</tr>
<tr>
<td>#92526 LHD, MSHA vent rate 4.96 m$^3$/min (10500 ft$^3$/min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muffler</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Engelhard PTX DOC</td>
<td>1.1</td>
<td>26</td>
</tr>
</tbody>
</table>

- The ambient concentrations of NO$_2$ increased when vehicles with platinum coated DPFs were tested.
- Tested DOC did not significantly affect ambient concentrations of NO$_2$.  

2003
Ventilation-normalized NO$_2$ concentrations at downstream sampling station observed during the tests with LHD retrofitted with DCL MineX DPF.
### The Effects of DPFs with DOC and DFEs on Concentrations of Nitrogen Dioxide (NO₂)

<table>
<thead>
<tr>
<th>Test Vehicle and Test Type</th>
<th>Average NO₂ concentration at MSHA Ventilation Rate</th>
<th>Increase in NO₂ by control technology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ppm</td>
<td>%</td>
</tr>
<tr>
<td>Muffler</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>AM Pt DOC</td>
<td>0.69</td>
<td>180</td>
</tr>
<tr>
<td>AM Pd DOC</td>
<td>0.24</td>
<td>-2</td>
</tr>
<tr>
<td>Donaldson</td>
<td>0.14</td>
<td>-44</td>
</tr>
<tr>
<td>Filter Services</td>
<td>0.03</td>
<td>-87</td>
</tr>
</tbody>
</table>

- The average ambient concentrations of NO₂ increased when vehicle with DPF and platinum coated DOC was tested.
- The average ambient concentrations of NO₂ did not increase when vehicle with DPF and palladium coated DOC was tested.
- Tested DFE reduced ambient concentrations of NO₂.
Ventilation-normalized NO$_2$ concentrations at downstream sampling station
References to Stillwater Reports


Issues with Implementation of DPF Systems

- Selection
- Installation
- Secondary emissions
- Maintenance
- Engine backpressure monitoring
- Ash accumulation
- Education
Selection and Optimization of DPF System for Underground Mining Application

- Successes of DPF installations were found to be warranted only in the case of careful and educated DPF system selection for the particular application.
  - The objectives of DPF system installation should be clearly defined;
  - The technical limitations should be identified.

- Selection of DPF for the application is a delicate task and requires a relatively high level of expertise.

- Mine operators should coordinate efforts to upgrade new vehicles and retrofit existing vehicles with filtration systems with vehicle, engine, and aftertreatment technology manufacturers.
Selection and Optimization of a DPF System for Application

- The DPF is an integral part of the vehicle/engine/DPF system.
- Design of the system should be based on long-term exhaust temperature profiling.
- The DPF system should be sized using realistic in-use emissions for the particular piece of equipment.
- DPF system should be installed and used only on the vehicles/engines application that it was designed for.
The installation of DPF system should be proceeded and supported with thorough emissions-based maintenance:
- In-use emissions should be measured at system inlet and outlet.

DPF system can not replace engine maintenance

Integrity of exhaust and DPF system should be maintained:
- External leaks;
- Internal leaks:
  - mechanical damage;
  - uncontrolled regeneration problems.
Engine Backpressure

- Engine backpressure limitations
  - Engine manufacture vs. DPF system manufacturer recommendations.

![Pie chart showing engine backpressure levels](image)

- >200 mbar: 40.0%
- >150 mbar: 32.4%
- <150 mbar: 27.7%

- >200 mbar: 84.2%
- >150 mbar: 7.6%
- <150 mbar: 8.2%

*Courtesy Josef Stachulak, Inco Ltd.*
Engine Backpressure Monitoring

- Sizing of the system is critical:
  - Engine backpressure – engine limitations:
    - Caterpillar 3306 PCNA - 34 in H₂O;
    - DDEC Series 60 – 42 in H₂O.

- Reliable backpressure monitoring and logging capabilities are essential for filtration system performance.

- Pressure gage and alarm should be included in the filtration system.

- Operator training and education.
Ash Accumulation

- Ash originates from fuel, lubricating oil, engine wear and/or fuel additives:
  - up to 1% of DPM.

- Ash cannot be regenerated as carbon. Accumulation of ash in the filter results in a continuous increase in base backpressure.

- Periodic cleaning of the filter is required.
The strategies and technologies to achieve targeted mine air quality standards should be carefully planned and selected.

In significant number of cases achieving substantial reductions in the miners exposure to DPM strongly depends on the ability of the operators to widely implement advanced diesel emissions control technologies.

DPF systems and FS with DFEs offer dramatic reductions in DPM/EC emissions, but careful planning, selection and optimization is needed to overcome potential implementation issues.

The introduction of those systems should be supported with emissions assisted maintenance and filtration system support program.

The maintenance and production crews should be adequately trained to support operation of the systems.
The findings and conclusion of this publication have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be constituted to represent any agency determination or policy. Mention of any company or product does not constitute endorsement by NIOSH.

Thank you for your attention!

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