Real-Time DPM Measurement as a Maintenance Tool

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Presentation:
Peter Anyon  PM-Tech / MAHA
Developing a DPM Management Strategy

Research / Evaluation

Government Responses

Pre-Program DPM Emission Profiles

Test Equipment

Implementation

Program Effectiveness

Summary & Conclusions
Research

• An intensive testing and evaluation study undertaken by The Australian Coal Industry’s Research Program (ACARP) and coordinated by the New South Wales Department of Primary Industry’s Mines Technical Services Division
  - in conjunction with SIMTARS, NIOSH
  - supported by external consultants and industry
  - over the period 2000~2002

• Aim: “…to find one or more methods for measuring diesel particulate matter (DPM) in the raw exhaust of diesel-powered mining equipment at underground coal mines”.
Test Program Structure

Dynamometer Testing

- of candidate instrument performance and comparison
- Evaluation of suitability for DPM testing under closely controlled conditions
- 3 engines (Cat 3306, Kia 4100, Cat 3126)
- 4 instruments (three laser light-scattering, one pressure drop)
- tested over 8 steady state and two transient modes
- results correlated with traditional gravimetric filter method
Test Program Structure

Field Testing

- five New South Wales mines selected as test sites
- where feasible, multiple instruments were operated in parallel
- mixture of steady-state and transient tests used
- tests included free acceleration, idle and acceleration/power modes with torque converter engaged
Key Project Outcomes

• **Stall Test**
  – 60-second idle/full power/idle test with drive engaged, using the torque converter as a dynamometer.

![Australian Mining DPM Stall Test](chart)
Key Project Outcomes

- **Free Acceleration Test**
  - for plant with no torque converter, three full-throttle accelerations (gear in neutral) to governed speed, spaced over 60 seconds
Initial Government Response (Summary)

Primary Guidelines

- ambient DPM exposure limit 0.1mg/m³ elemental carbon (EC). EC to be calculated as equivalent to 0.5 x total suspended diesel particle mass

- all new engines to have “signature” test before entering service

- all existing engines to be maintained to “best” emissions level then have “signature” test

- periodic (max 4 week intervals) testing to monitor condition and trigger rectification if DPM exceeds limit (initially 30% > than signature, soon to be 20%)

- records to be maintained of all test results for individual vehicles/plant
Preliminary fleet testing was performed at several mines to characterize the emission profiles of vehicles.

Results of this testing showed considerable similarities

- most engines had low - moderate emissions, with a few very high emitters peaking the curve
DPM Emission Distribution: Initial Survey (Example 1)

Ranked Stall Test PM Emissions for 26 Diesel Engines (mg/m3)

PM Emission Level (mg/m3)

Ranking (Best to Worst)
DPM Emission Distribution: Initial Survey (Example 2)

Stall Test PM Results
23 Vehicles Highest to Lowest

- PM Concentration (mg/m³)
- Ranking

4 Vehicles Produce 43% of PM Emissions

- REPAIR
- MONITOR
- OK

4 Vehicles Produce
43% of PM Emissions
Correlations, Test Cycle vs On-Task Operation
On-Vehicle Testing
On-Board Real Time Recording

Custom software (available with instrument) stores and charts continuous DPM Concentration vs Time for analysis and correlation studies.
### Correlation, Example 1

<table>
<thead>
<tr>
<th>Static Test</th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.7</td>
<td>194</td>
<td>58.1</td>
<td></td>
</tr>
</tbody>
</table>

Engine hours: 6758
Last 1000 service: 0

Average = 58.16394
## Correlation, Example 2

### Table

<table>
<thead>
<tr>
<th>Static Test</th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20.5</td>
<td>66</td>
<td>36.5</td>
</tr>
</tbody>
</table>

### Graph

![Graph showing data over time](image)

- **Engine hours:** 7822
- **Average:** 34.34803
- **Last 1000 service:** 676
Correlation, Example 3

<table>
<thead>
<tr>
<th>Static Test</th>
<th>Min</th>
<th>Max</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.6</td>
<td>416</td>
<td>48.8</td>
</tr>
</tbody>
</table>

Average = 38.0728
Implementation
Test Equipment

• Third generation laser light scattering (LLSP) is now the measuring method of choice in Australia
• Incorporates several years of experience and industry feedback
• Simple one-button operation
• Auto-zero before every test
• NiMH Battery, >2hrs testing
• Remote control for single person testing
• On-screen and flashing LED operator prompts
• Automatic test result generation
• Simple field calibration and service
MPM-4M (4th Generation)
Stall Test DPM Results (Typical)

Test Result Screen (Example)

Second-by-second test data can also be exported directly to PC via RS232/USB
Testing Program

• Every vehicle and item of plant operating underground is tested (minimum) monthly. Most mines test every 2 weeks or weekly.

• DPM result >20% above “signature” level for that vehicle mandates maintenance/repair before returning underground.

• Absolute DPM limits are also applied (next slide)

• A standardized diagnostic tree is generally used to identify and rectify high emissions, based on cost/frequency analysis (eg, start with air filter and work down from there)
DPM Limit Progression (Stall Test)

Limit DPM Concentration (mg/m³) by Year

- 2004: 150 mg/m³
- 2008: 75 mg/m³
- 2011: 50 mg/m³
Program Effectiveness (Example)

Average DPM Reduction = 60%
Benefits (Health & Economic)

• Program minimizes DPM exposure risk to underground personnel

• Measured Maintenance also optimizes fuel consumption and has potential to improve engine reliability.

• By maintaining “On-Condition”, wastage costs due to unnecessary maintenance are avoided.

• Assigning specific cubic flow requirements to individual vehicles allows optimization of equipment deployment and ventilation flows, without exceeding DPM exposure levels
Summary

• DPM measurement is now broadly accepted as a necessary and integral part of mine equipment and ventilation management.

• Test cycles and test equipment have proved to be practical and effective

• Continuing dialogue and cooperation between and within industry and government has been essential for effective program implementation
Measured Maintenance

“IF YOU CAN’T MEASURE IT YOU CAN’T FIX IT”