Monitoring DPM Emissions in Underground Mines: an Australian Perspective

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Aim of Presentation

Deliver a summary of
• government oversight
• industry initiatives, and
• technology advances
relating to the management of particulate tailpipe emissions from diesel equipment in Australian underground mines
Comparing Canada and Australia

Many similarities from a mining and demographic perspective

<table>
<thead>
<tr>
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<th>Canada</th>
<th>Australia</th>
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</thead>
<tbody>
<tr>
<td>Population</td>
<td>34,480,000</td>
<td>22,620,000</td>
</tr>
<tr>
<td>Land Area</td>
<td>9,985,000km²</td>
<td>7,741,000km²</td>
</tr>
<tr>
<td>Mining Exports</td>
<td>$102 billion</td>
<td>$139 billion</td>
</tr>
<tr>
<td>Key Resources</td>
<td>Nickel, Gold,</td>
<td>Coal, Iron Ore, Gold, Nickel</td>
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<tr>
<td></td>
<td>Copper, Potash</td>
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Coal Mining - Australia
Mining Regions

Gold Mining - Australia

All Mining – Canada/USA
DPM Reduction Strategies

As delegates will already be aware, key strategies for controlling DPM emissions in underground mines include:

- adequate and effective ventilation
- higher technology (cleaner) engines and exhaust treatment systems, e.g., exhaust filters
- cleaner fuels
- targeted, preferably measured maintenance

This presentation focuses primarily on the last bullet item.

Why Measured Maintenance?

Traditionally, maintenance is performed to a schedule:
- hours of operation, distance travelled, etc

But scheduled maintenance is not always an optimal approach, can result in:
- undetected defects which can cause damage, downtime
- premature replacement, replenishment and refurbishment of fully functional and serviceable components

Result: Avoidable Costs !!

Routine condition monitoring can detect faults early and extend useful life of serviceable components

Result: Optimal Performance and Money Saved !!
Government Oversight (1)

National


• standard is currently being revised and updated
• anticipate that DPM emission testing sections of the standard will be significantly revised to include more effective test procedures and reflect advances in DPM measurement systems.

Government Oversight (2)

State Level

Primary responsibilities for mines safety lie with State governments:

• all have enforceable overarching OHS responsibilities through State-based regulations
• but to present, DPM emission measures have mostly been released as guidelines, rather than regulations
• mandatory 6-monthly testing is already done in one State
• DPM issues not fully harmonized, but progress being made
• mines are being strongly encouraged to adopt / strengthen self-testing as part of their maintenance practices

An increasing number of mining companies have now voluntarily established their own programs
**Government Oversight (3)**

### New South Wales

NSW has been a leader in promoting effective measures for reducing tailpipe DPM and gaseous emissions

- MDG 29 “Guideline for the management of diesel engine pollutants in underground environments” has been the lead document since 2008
- strong risk-management based approach, coupled with the application of techniques developed through large-scale practical research to explore and validate testing methods
- provides for transient, loaded testing of in-use equipment as part of their maintenance regime, wherever practical
- MDG 29 is discussed further later in the presentation

**Government Oversight (4)**

### Queensland

With huge mining activity in the State, QLD is also very actively working to reduce underground DPM emissions

- a very active industry/government/supplier forum meets quarterly
- strong commitment to effective technical and procedural strategies for DPM exposure reduction
- a draft “Code of Practice for the Management of Diesel Engine Exhaust Pollutants in Underground Environments” maintains strong consistency with the NSW Government’s MDG 29 management guidelines
- scheduled for final review and release in the coming months.
DPM Testing Philosophy

- Emphasis is on using DPM testing as an integral component of routine maintenance
  - rather than an independent periodic monitoring tool
- Test equipment must therefore be practical, useable and provide relevant information to maintenance personnel
  - directly useful for condition monitoring and confirmation of maintenance effectiveness
- To achieve this, test equipment must:
  - operate in real-time
  - be easy to use with minimal training
  - integrate smoothly with normal workflow

Testing Frequency

- Prior to inclusion in a routine testing program, each item of diesel underground equipment must be “benchmark” tested to establish a reference DPM performance
  - when machine is new or after major reconditioning
- MDG 29 specifies that pre/post maintenance testing be performed and results recorded at least once a month
- In addition, each item of equipment must be independently tested by an independent certified organization every 6 months
  - if independent testing is performed at 3 month intervals, requirement for self-testing is waived
The two principal DPM measurement procedures remain
the "stall" and "free acceleration" tests (see following slides)
• time for setup, test and result delivery < 3 min

Some non-mandatory testing is also done with instrument
mounted on a vehicle to record DPM levels over a period of
normal equipment operation.
Data can be used by ventilation engineers estimating mass
emission rates

Results are reported as:
– average DPM concentration over complete test (mg/m³)
– average concentration at idle
– average concentration at full power
– minimum concentration
– maximum concentration

Test and reporting requirements mean that real-time DPM measurement is essential
• MDG 29 acknowledges several measurement methods
  ~ opacity (DPM by math conversion)
  ~ laser light-scattering (LLSP)
  ~ photo-acoustic
  • LLSP is now dominant method
Free Acceleration Test

This test is used only for plant with no torque converter

Target Emission Limits

- State governments are progressively lowering the target emission test result number (mg/m³)
  - currently only advisory but industry is responding well
  - some consideration being given to introducing mandatory limits.
Typical DPM Reduction from “Measured Maintenance”

Using a short test to evaluate engine condition, and measuring again post-maintenance improves the efficiency and effectiveness of work performed. Some mines have reported fleet-wide average DPM reductions of up to 60%, over an 18 month period.

Testing Issues Under Review

Possible changes to several aspects of DPM testing are currently being discussed:

1. Can the current Stall Test be improved?
2. Should we continue to report DPM as elemental carbon (EC) or change to total particulate concentration?
3. Where exhaust waters scrubbers are used, should measurement be pre- or post-scrubber?
Possible Revised Stall Test

Would reduce heat build-up on torque converter and more closely reflect in-use engine load patterns

Retain 60 second total test duration, but include three short acceleration/full power modes

Report DPM as Elemental Carbon (EC) or Total PM?

Current approach is to report Elemental Carbon
- Consistent with NIOSH 5040 reporting, but:
  - many non-EC particles are also dangerous and should not be ignored
  - this issue being raised by at least two Australian State governments

In reality may not be a major issue
- Australian and US researchers very closely agree on mass conversion factors:
  - total carbon = total particulate x 0.8
  - elemental carbon = total particulate x 0.5
DPM Measurement Location – Priority?

In mines where exhaust water scrubber is used (e.g., coal), should DPM be measured pre- or post-scrubber? (Current Australian practice is post-scrubber)

Ventilation engineers use post-scrubber DPM as one input to setting ventilation flows.

Engine maintenance personnel need to accurately monitor engine-out (pre-scrubber) DPM to track engine condition and validate repair effectiveness.

(scrubber extracts 20–30% of DPM from “dry” exhaust)

Which location should have priority?

Pre-or Post-Scrubber??

DPM test results (mg/m3) measured before scrubber allow direct tracking of engine condition

Linkage between stall test DPM concentration and ventilation rate is much less direct
– due to high variability in engine load/speed during normal operation
– post-scrubber measurements are valuable for ventilation purposes, but accuracy less critical.

Consensus now leaning towards pre-scrubber measurement

(there are also several additional indirect benefits)
Summary

- Minimizing emissions of Diesel Particulate Matter (DPM) is a very high OH&S priority
  - designated a Class 1 carcinogen by the World Health Organization.
- Targeted "measured maintenance" can deliver very significant reductions in tailpipe DPM emission levels, as well as
  - early defect identification reduces secondary impacts
  - extended operational life using “on condition” replacement.
- Testing to identify high polluters and confirm maintenance effectiveness is now a quick, simple, routine task.
- Australian developments in testing methods and simplified measuring tools allow mine operators and underground personnel alike to benefit from cleaner, safer working environment, lower costs and improved equipment reliability.