



Peter Anyon, MDEC, Oct 2012

- 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

Peter Anyon, MDEC, Oct 2012

**PM**  
Tech

## Comparing Canada and Australia



Many similarities from a mining and demographic perspective

	<u>Canada</u>	<u>Australia</u>
Population:	34,480,000	22,620,000
Land Area:	9,985,000km <sup>2</sup>	7,741,000km <sup>2</sup>
Mining Exports:	\$102 billion	\$139 billion
Key Resources:	Nickel Gold Copper Potash	Coal Iron Ore Gold Nickel

Peter Anyon, MDEC, Oct 2012

**PM**  
Tech

## Mining Regions



### Coal Mining - Australia



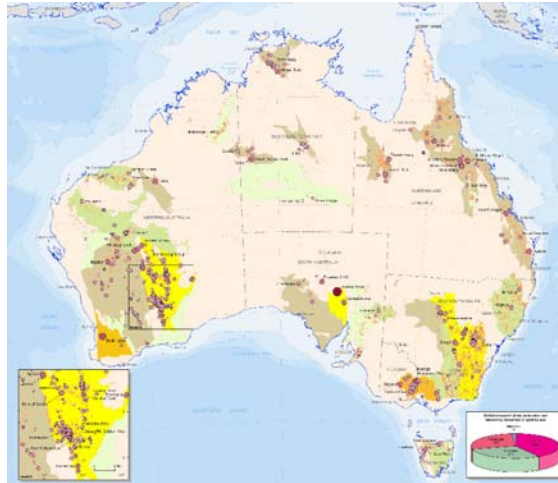
Peter Anyon, MDEC, Oct 2012

PM  
Tech

## Mining Regions



### Gold Mining - Australia



Peter Anyon, MDEC, Oct 2012

PM  
Tech

## Mining Regions



### All Mining – Canada/USA




Peter Anyon, MDEC, Oct 2012

PM  
Tech

## 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, eg exhaust filters
- cleaner fuels
- targeted, preferably *measured* maintenance

This presentation focuses primarily on the last bullet item.


---

Peter Anyon, MDEC, Oct 2012

PM  
Tech

## 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 !!**


---

Peter Anyon, MDEC, Oct 2012

PM  
Tech

## Government Oversight (1)

---



### National

Australian Standard AS/NZS 3584:2008 – “Diesel Engine Systems for Underground Coal Mines” includes performance requirements for a range of safety and emissions–related operating parameters

- 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.


---

*Peter Anyon, MDEC, Oct 2012*

PM  
Tech

## 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**


---

*Peter Anyon, MDEC, Oct 2012*

PM  
Tech

## 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


---

*Peter Anyon, MDEC, Oct 2012*

PM  
Tech

## 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.


---

*Peter Anyon, MDEC, Oct 2012*

PM  
Tech

## 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


---

Peter Anyon, MDEC, Oct 2012

PM  
Tech

## 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**

---

Peter Anyon, MDEC, Oct 2012

**PM**  
Tech

## Test Routines



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

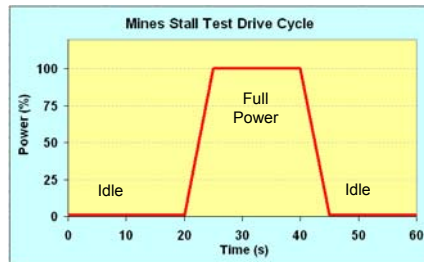
Some non-mandatory testing is also done with instrument mounted on a vehicle to record DPM levels over a period of normal equipment operation. Data can be used by ventilation engineers estimating mass emission rates



Peter Anyon, MDEC, Oct 2012

**PM**  
Tech

## Current Stall Test

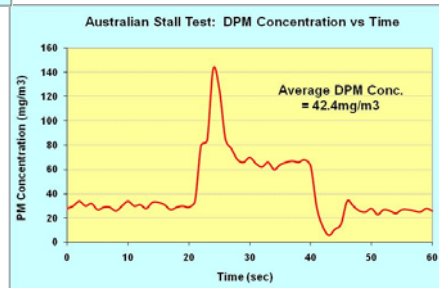


Results are reported as:

- average DPM concentration over complete test ( $\text{mg}/\text{m}^3$ )
- 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




Peter Anyon, MDEC, Oct 2012



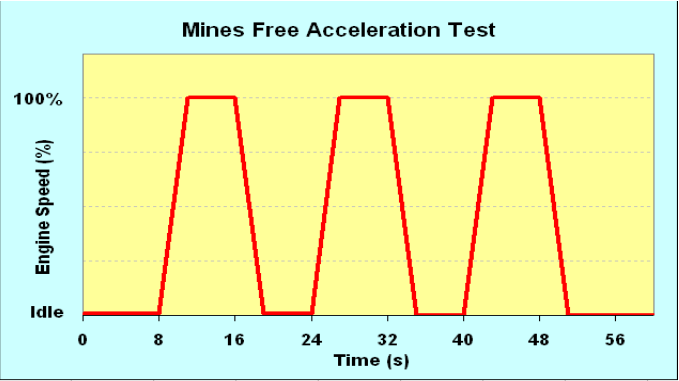
**PM**  
Tech

## Free Acceleration Test



---

This test is used only for plant with no torque converter



**Mines Free Acceleration Test**


Time (s)	Engine Speed (%)
0	Idle
8	Idle
12	100%
16	100%
20	Idle
24	Idle
28	100%
32	100%
36	Idle
40	Idle
44	100%
48	100%
52	Idle
56	Idle

---

Peter Anyon, MDEC, Oct 2012

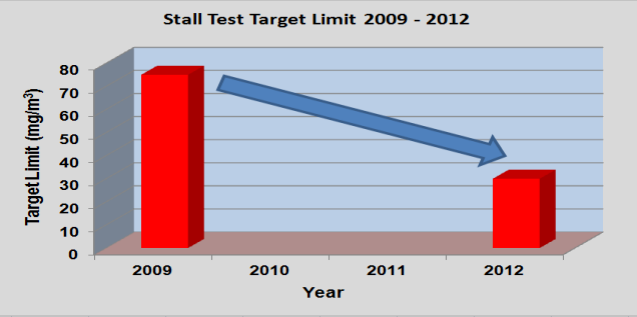
**PM**  
Tech

## Target Emission Limits



---

- State governments are progressively lowering the target emission test result number (mg/m<sup>3</sup>)
  - currently only advisory but industry is responding well
  - some consideration being given to introducing mandatory limits.



**Stall Test Target Limit 2009 - 2012**


Year	Target Limit (mg/m <sup>3</sup> )
2009	80
2010	70
2011	60
2012	35

---

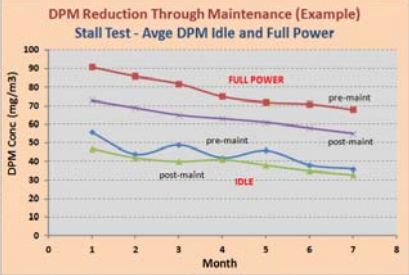
Peter Anyon, MDEC, Oct 2012

**PM**  
Tech

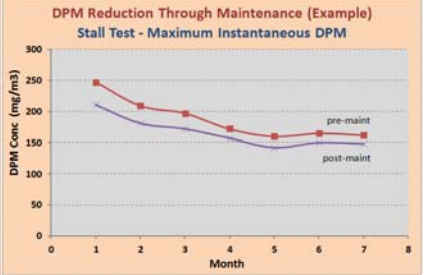
## Typical DPM Reduction from “Measured Maintenance”



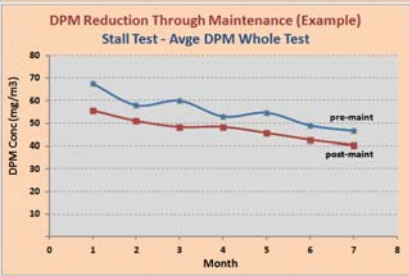
**DPM Reduction Through Maintenance (Example)**  
Stall Test - Avg DPM Idle and Full Power



**DPM Reduction Through Maintenance (Example)**  
Stall Test - Maximum Instantaneous DPM



**DPM Reduction Through Maintenance (Example)**  
Stall Test - Avg DPM Whole Test




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

Peter Anyon, MDEC, Oct 2012

**PM**  
Tech

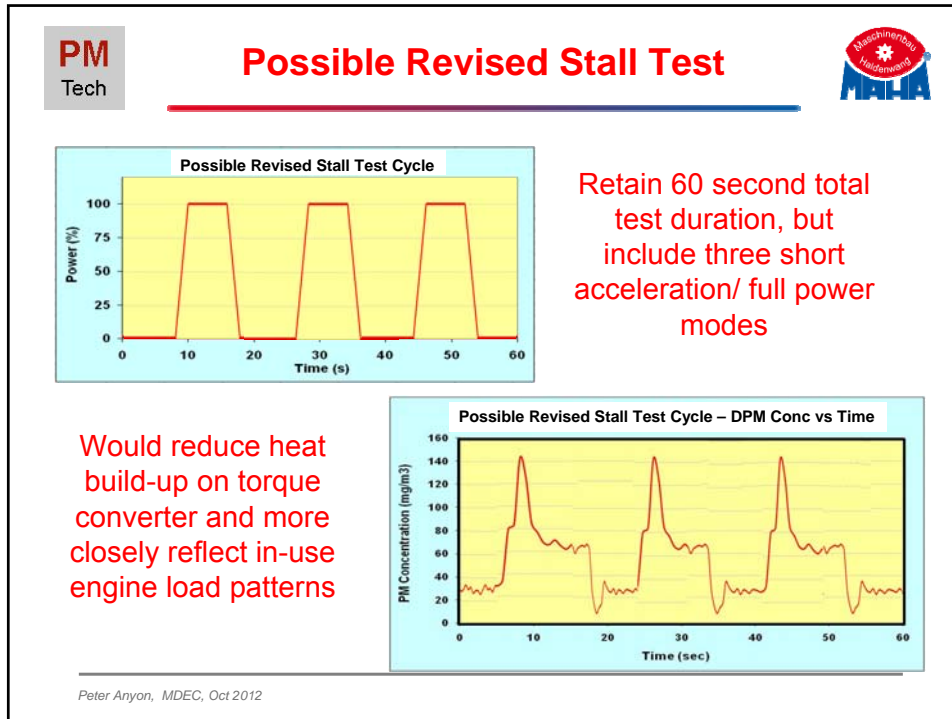
## Testing Issues Under Review



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?**

Peter Anyon, MDEC, Oct 2012



**PM**  
Tech

## 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

Peter Anyon, MDEC, Oct 2012

**PM**  
Tech

## **DPM Measurement Location – Priority?**



**In mines where exhaust water scrubber is used (eg 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 ??**

Peter Anyon, MDEC, Oct 2012

**PM**  
Tech

## **Pre-or Post-Scrubber ??**



**DPM test results (mg/m<sup>3</sup>) 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)**

Peter Anyon, MDEC, Oct 2012

**PM**  
Tech

## 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

Peter Anyon, MDEC, Oct 2012