The Development of a New Maintenance Tool for Raw DPM Measurement

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MKNIZD | Factors

October 2014

Overview

- Background
- Design of Diesel ChekMate®
- Calibration of ChekMate® vs NIOSH 5040
- In field comparisons
- Potential applications
- Limitations

Background

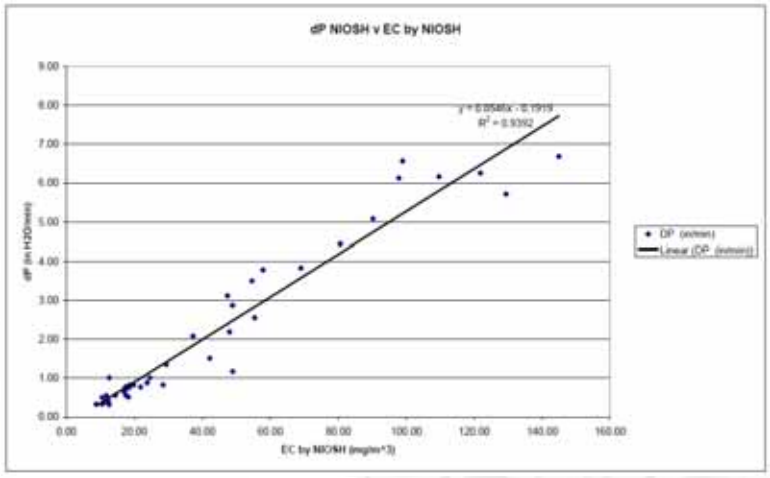
- 2000 – NIOSH demonstrate relationship between differential pressure vs workplace respirable dust levels
- 2004 – extension of this principle developed by NIOSH & SKC Inc to measure DPM under field conditions
- Device given operating name “Diesel Detective” and trialled in USA, Australia, Canada & South Africa

Background (cont)

- Australia study showed device had good potential as a survey type quality measurement instrument
- Device never commercialised due to sampling & filter issues
- Original patent lapsed in Australia on 7th July 2013

"Diesel Detective"

Diesel Detective Calibration (Australian Field Samples)



Source: NSW DPI 2004

LLS vs Backpressue

- Research in Australia by NSW DPI (2004) and Davies (2013) suggested the use of a single conversion factor from TSP to EC by LLS devices is not valid for all engine types
- NSW DPI (2004) research indicated the use of Δp not influenced by engine type. Recent EC/Δp calibration using 8 different engine types supports this conclusion

Design of Diesel ChekMate®

- Research by Davies (2013) showed
  - Sampling from the tailpipe of a vehicle subject to probe insertion distance issues
  - EC could be sampled on a quartz filter in the raw exhaust at temperatures up to at least 115^{o}C
  - Sampling post a water filled scrubber tank not practicable if using filters to collect DPM (EC)
  - Sampling from manifold gave a better overview of engine parameters

Design of Diesel ChekMate®

- Developed ERP exhaust mixing & cooling system
- Enabled sampling direct from exhaust manifold and cooled exhaust to <50^{o}C
- Overcame water on filter issues & gave better picture of key engine parameters
- Developed filter holder so a workplace dust sampling pump & a basic backpressure meter could be used

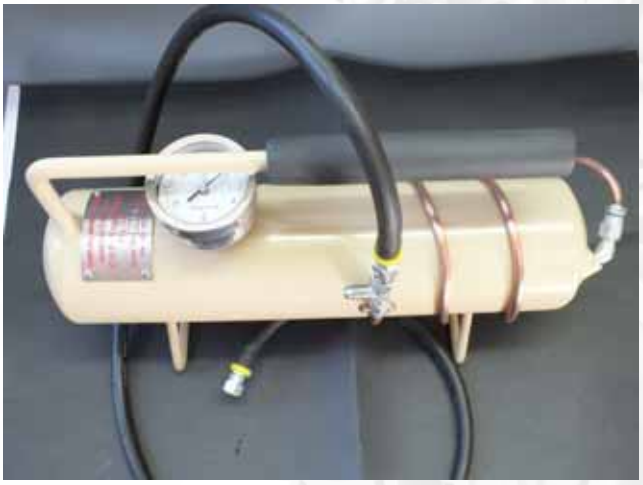
Design of Diesel ChekMate®

- Focus on simplicity & robust design for use in workshops by diesel mechanics
- Calibrated against NIOSH 5040 using 71 in field engine samples from both coal & metaliferrous mining industry
- Operating range 25 – 80 mg/m^3 EC in raw exhaust
- Low range EC (<25mg/m^3) & TC calibrations in progress

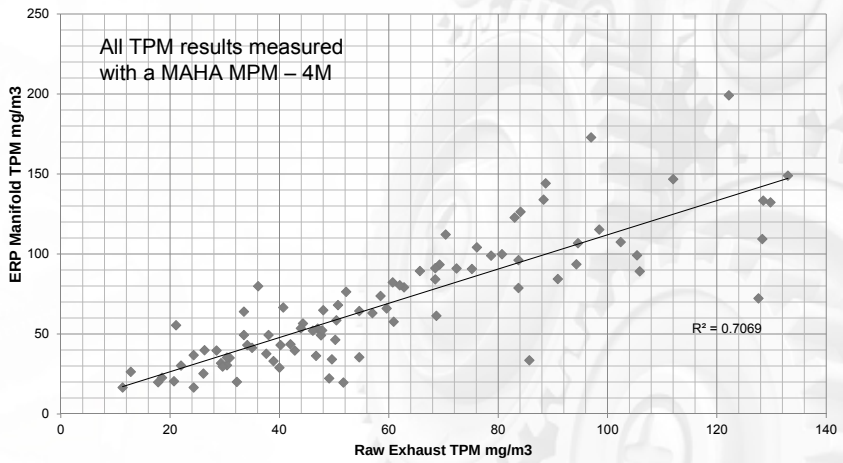
Design of Diesel ChekMate®

- Following feedback from operations ChekMate® has been fitted with flow control solenoid, linked timer & pendant for single person operation
- Patents pending in Australia, Canada & South Africa

ERP Mixing & Cooling System



Manifold vs Tailpipe Comparison Australian Coal Industry



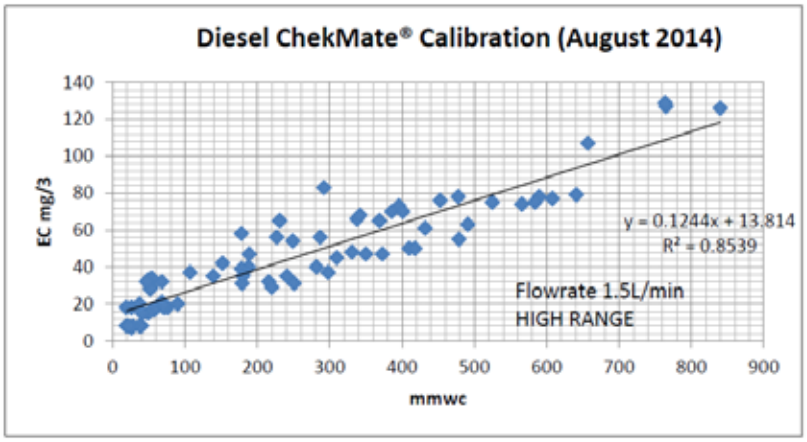
ChekMate® Probe & Filter Holder

Loading Filter into Probe

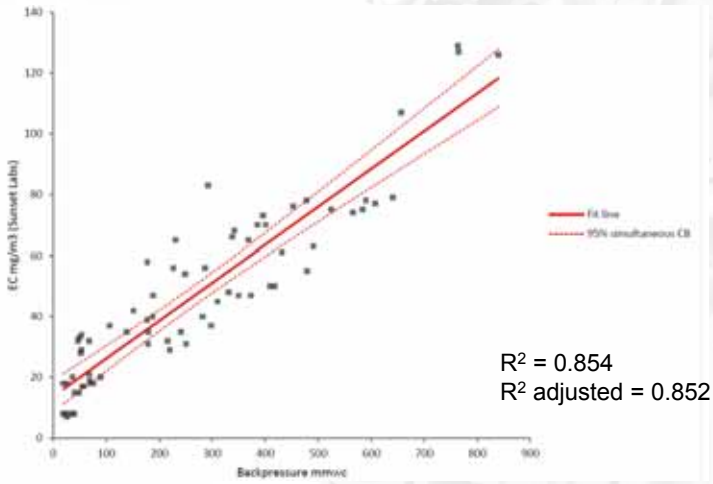
Sampling System & Probe Connected to Raw Exhaust System

ChekMate® & ERP Mixing System During Sample Collection

ChekMate® Calibration Curve 71 Samples from In Service Engines

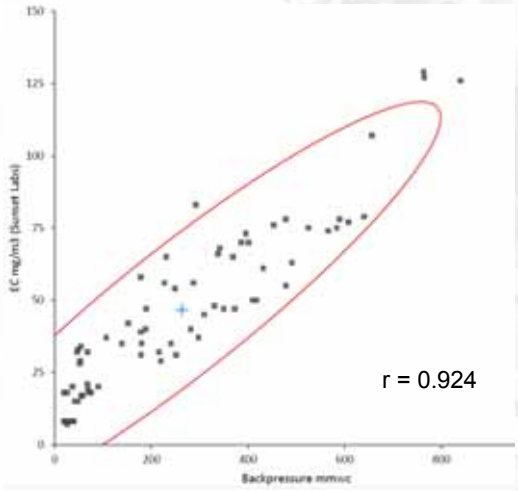


Linear Regression with 95% Confidence Bands



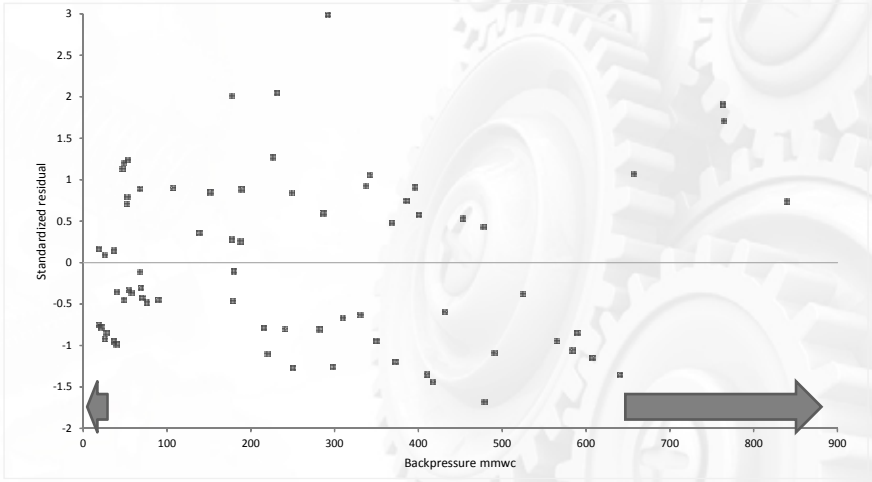
$R^2 = 0.854$
R^2 adjusted = 0.852

Pearson Correlation with 95% Confidence Bands



r = 0.924

Residuals



In Field Comparisons

Workshop Location	Engine	ChekMate® EC mg/m3 (+/- 20% unc)	Sunset Lab. EC mg/m3 (+/- 15% unc)
Cobar	Cat 15	38 (30-46)	35 (30-40)
Cobar	Cat 15	47 (38-56)	31(26-36)
Cobar	Cat 15	50 (40-60)	40 (34-46)
Cobar	Cat 15	61 (49-73)	47 (40-54)
Cobar	Cat 15	45 (36-54)	35 (30-40)
Cobar	Cat 15	52 (42-62)	37 (31-43)
Cobar	Cat 15	<25	6
Cobar	Cat 15	29 (23-35)	37 (31-43)

In Field Comparisons (cont)

Workshop Location	Engine	ChekMate® EC mg/m3 (+/- 20% unc)	Sunset Lab. EC mg/m3 (+/- 15% unc)
Cobar	Cat 15	33 (26-40)	35 (30-40)
Cobar	Cat 15	43 (34-52)	29 (24-34)
Cobar	Cat 15	56 (45-67)	48 (41-55)
Newcastle	Cat 3306	>80	126 (107-145)
Newcastle	Cat 3306	<25	1
Wollongong	Cat 3306	>80	129 (110-148)
Wollongong	Cat 3306	<25	<1
Wollongong	Cat 3306	<25	2

In Field Comparisons (cont)

Workshop Location	Engine	ChekMate® EC mg/m3 (+/- 20% unc)	Sunset Lab. EC mg/m3 (+/- 15% unc)
Wollongong	Cat 3306	<25	1
Wollongong	Cat 3306	<25	2
Perth	Cat 15	53 (42-64)	45 (38-52)
Perth	Cat 15	<25	<1
Perth	Cat 15	58 (46-70)	47 (40-54)
Perth	Cat 15	74 (59-89)	55 (47-63)
Perth	Cat 15	<25	1

Potential Applications

- In mine workshops as a tool (linked with an ECOM EN2-F gas analyser & DEEM6S software interface) for mine mechanics operating an emissions based maintenance program
- To test the in-service efficiency of DPFs
- Estimation of raw exhaust EC levels for ventilation calculations

Limitations

- Engine exhausts with very high organics (grossly over fuelled) can give high results due to blockage of filter causing increased back pressure. Identified by ECOM Gas analysis
- Uncertainly of results +/- 20% which is adequate for a screening device (NIOSH 5040 analysis +/-12% on ChekMate® samples and +/- 15% including volume)

Summary

- A new simple low cost tool for site mechanics to screen dirty engines for maintenance
- When linked with an ECOM EN-2F gas analyser & DEEM6S software interface gives a powerful low cost diagnostic system that can be used at sites by site personnel

References

- Volkwein JC, Schoeman AL & Page SJ (2000), Laboratory evaluation of pressure differential based respirable dust detector tube. Appl Occup Environ Hyg; 15: 158-64
- Volkwein JC, Mischler SE, Davies B & Ellis C (2008), Field measurement of diesel particulate emissions. Annals of Occup Hyg; 52 (2): 99-105
- Davies B (2013), Calibration of portable raw exhaust diesel particulate analysers. Coal Services Health & Safety Trust Research Project
- NSW DPI (2004), Methods for measuring diesel particulate matter from underground mining equipment , Report 04/0884, November 2004