ACARP
Wall-Flow DPF Project

Overview for 21st ETH Conference

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June 2017

Project Milestones – Completed C25073

	Project Activity	
Phase 1	Part 1 - Onsite Duty Cycle Analysis and development of custom test cycles	✓
	Part 2 - Engine Setup/Baseline and Correlation to Real World	✓
	Part 3a - Hot System DOC+Filter	✓
Phase 2	Part 3b - Preliminary (Aboveground) Site Trial (hot system)	✓
	Part 4 - P1 Design Engineering - Cold exo-surface DOC/Filter System	✓
	Part 5 - P1 Cold System PoC/Development	✓

P1 is first level prototype; where proof-of-concept is demonstrated.

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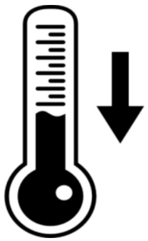
Australian Coal Industry Challenges

Underground coal mining has largely electrified many operations, but diesel engines are still used for multipurpose load-haul-dump (LHD) vehicles and man transporters.

Diesel engines operating in underground coal mining need to comply with additional flame and explosion protection measures due to the presence of elevated ambient methane and highly combustible coal dust.

The health of underground workers is at risk without appropriate exhaust emission controls for particulates and gaseous pollutants.

Compounding this situation, the low operational duty cycle of the diesel LHD engine results in a very low average EGT which works against the performance of conventional DPF solutions.



<150ºC

- Tailpipe exhaust
- All surfaces

Ambient CH_4

- Comply at elevated levels
- Shutdown at excessive levels

Explosion Proof

- Certification

Pollutants

- Particulate
- Gaseous

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What is ACARP?

A$0.05 per tonne collected from all black coal produced in Australia

ACARP

Access to R&D taxation rebates and generated research

Nominal ACR budget ~$18m/year; 100% industry funded

- Fundamental research projects
- Applied research projects
- Commissioned projects

UNDERGROUND
Health and safety, productivity and environment initiatives.

OPEN CUT
Safety, productivity and the right to operate are priorities for open cut mine research.

COAL PREPARATION
Maximising throughput and yield while minimising costs and emissions.

TECHNICAL MARKET SUPPORT
Market acceptance and emphasising the advantages of Australian coals.

MINE SITE GREENHOUSE MITIGATION
Mitigating greenhouse gas emissions from the production of coal.

MINING AND THE COMMUNITY
The relationship between mines and the local community.

NERDDC
National Energy Research, Development & Demonstration Council (NERDDC) reports - pre 1992.

ACARP – Australian Coal Industry's Research Program;
formerly *Australian Coal Association Research Program*

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Project Outline

ACARP project C25073 was proposed by industry stakeholders seeking an exhaust aftertreatment solution that:

- Enhances worker health through improved underground air quality; and
- Reduces operational costs associated with currently implemented diesel particulate emissions systems.

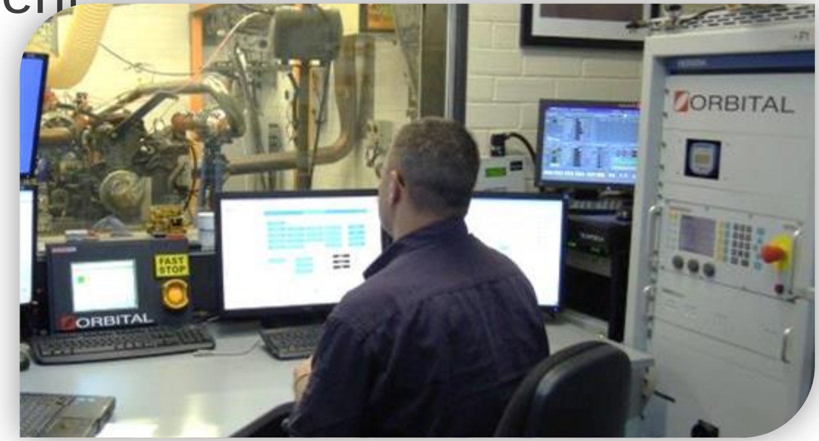
2017 will see the industrialisation of the system for commercial trials.

Approach to Development

Given explosion risks for product innovation in a working coal mine an alternate approach to development was adopted.

Characterisation of LHD operations in a working mine were used to develop a series of real world engine cycles for use during development.

Development was then undertaken off-line using a state-of-the-art engine test facility, with hardware transferred to the mine for confirmation testing of results.



▲ **Orbital's Heavy Duty, transient capable, certification grade facility**

Orbital's Heavy Duty Engine Facility

Exhaust Extaction

Exhaust Flow by Horiba PTFM

Data acquisition (temp and press)

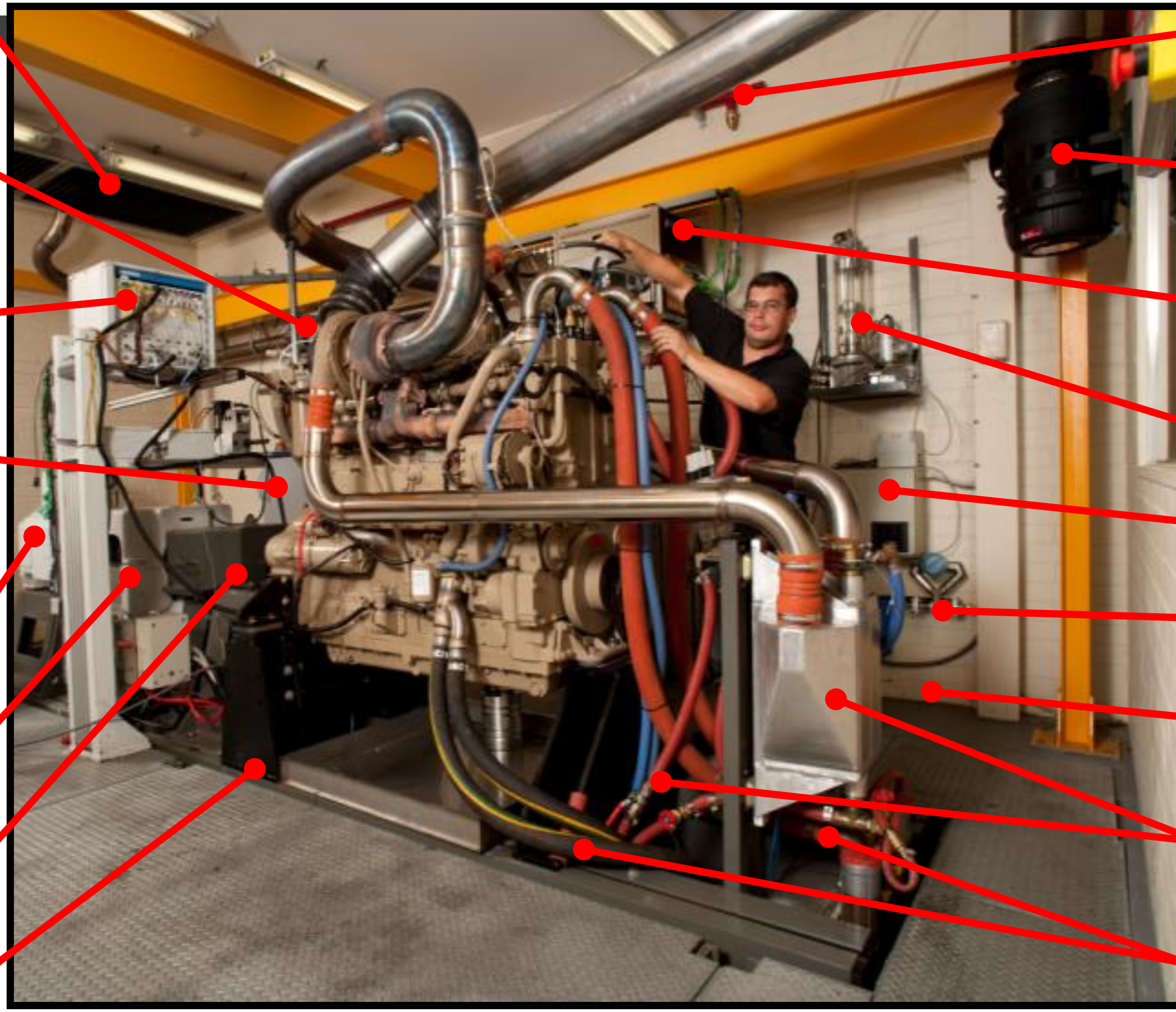
Gravimetric PM, Partial Dilution 4x Samples

AC Dyno for Transients

Water Brake Dyno for Steady State

Precision Torque Flange

Floating testing bed for vibration dampening



Fire Suppression System

Intake Air, with optional LFE

Data acquisition (custom and high-speed)

Onosokki Fuel Flow Meter

Fuel Conditioning

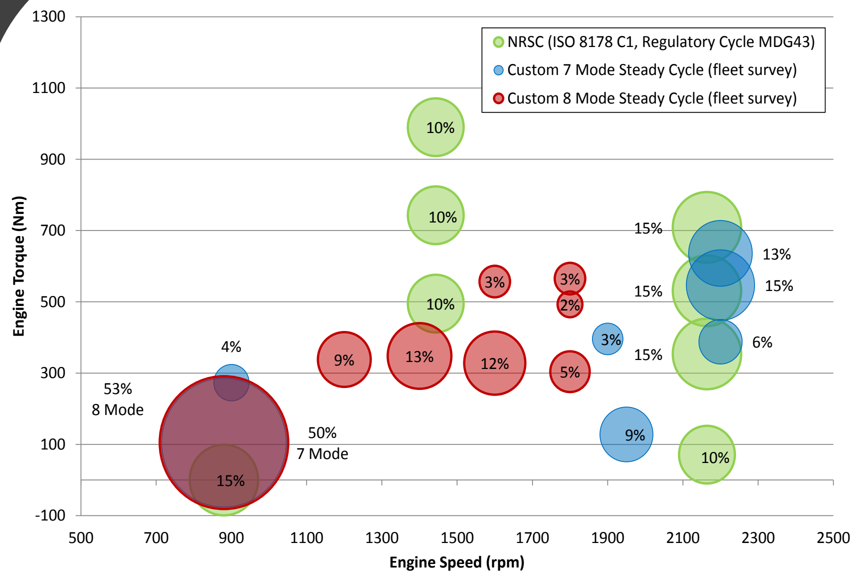
LNG Flow Meter

Horiba gaseous emissions (next room)

Intake intercooling (also underfloor)

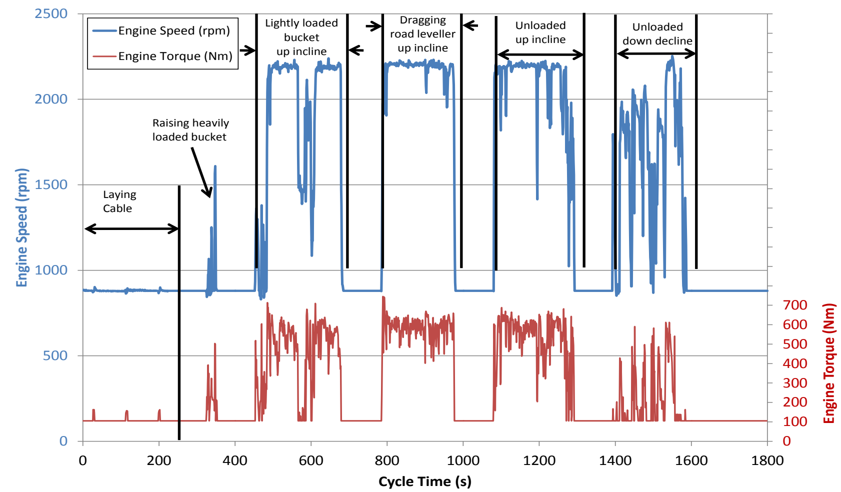
Underfloor coolant control

Developed Test Cycles



▲ Comparison of Regulatory and Fleet Based profile of LHD engine operation (Steady State engine testing points)

▼ Transient cycle representing a variety of LHD operations in underground coal mining composited into a single cycle



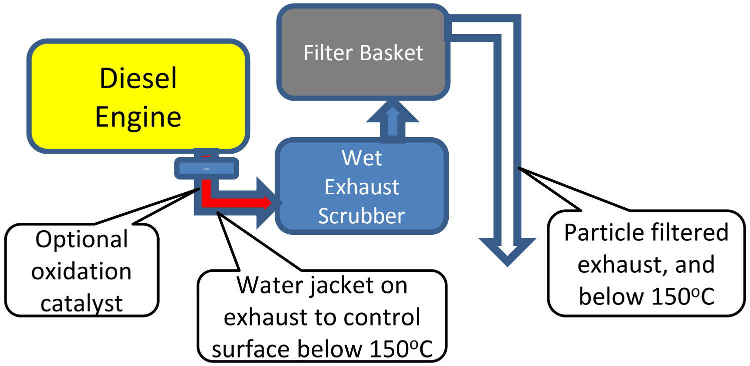
High resolution time based data was acquisitioned from a working machine, aligned with long-term fleet average data from a number of similar model machines and converted to both steady state and transient development cycles.

System Changes

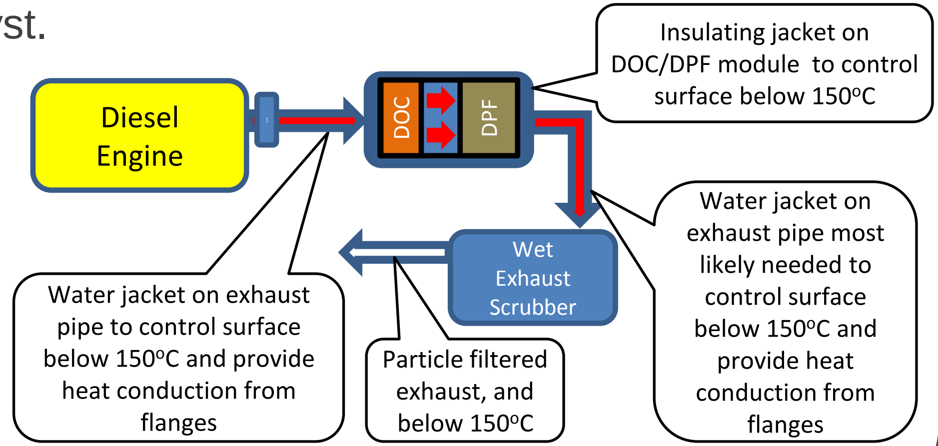
The coal industry has to date mostly used wet exhaust scrubbers and disposable filters to address tailpipe emission and temperature requirements.

▲ **Typical Load-Haul-Dump (LHD) vehicle used in underground coal operations**

The revised system uses a specially packaged wall-flow diesel particulate filter (DPF) with a platinum based pre-catalyst.



▲ **Conventional wet scrubber and disposable filter system**



▲ **Proposed layout of the wall-flow filter system meeting underground coal regulations**

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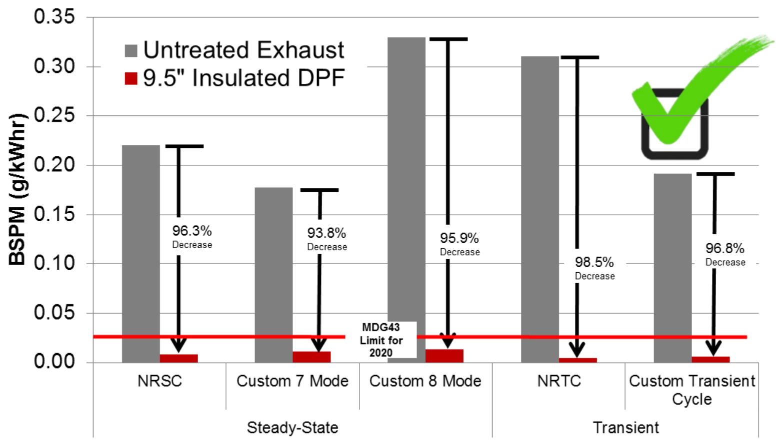
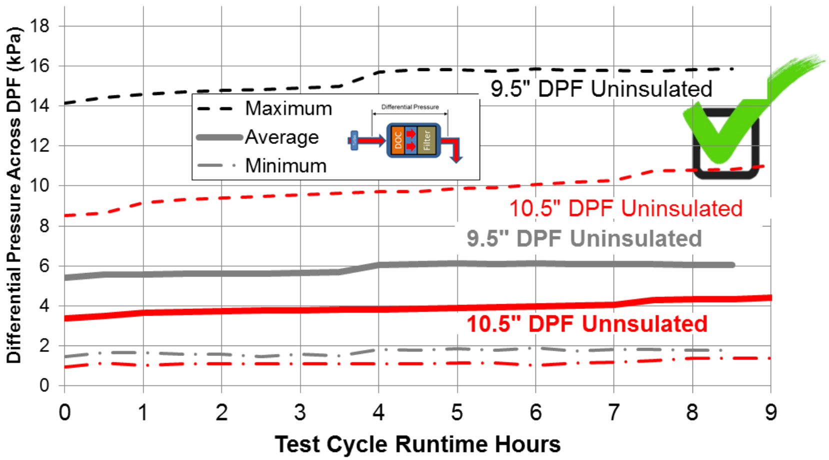
Proof-of-Concept Results

The rapid development project delivered PM reductions in excess of 95% over both regulator and real world cycles with the selected DPF.

Operation over continually repeated real world cycles showed that exhaust back pressure was stabilised confirming satisfactory regeneration was possible despite low exhaust gas temperatures.



▲ Comparison of Total PM results over different test cycles regulated and custom (steady state and transient)

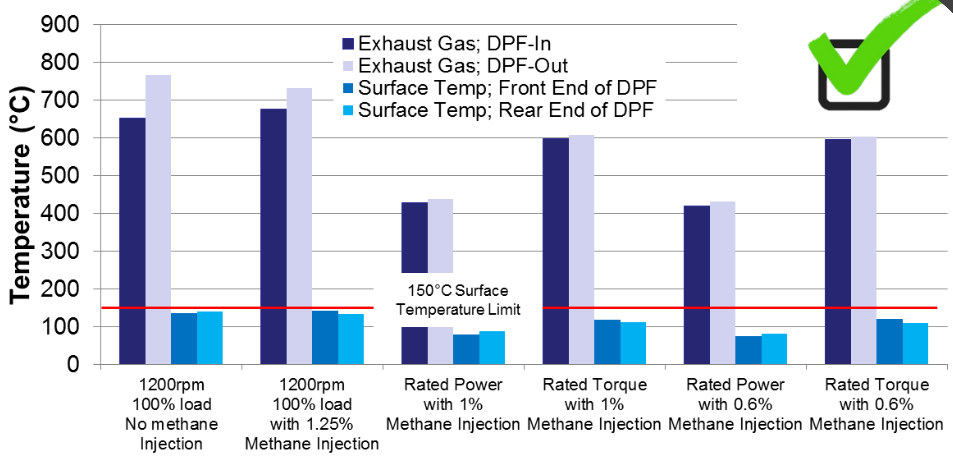


▲ Comparison of DPF differential pressure and stabilisation over the industry developed transient test (10.5" system is lower/better)

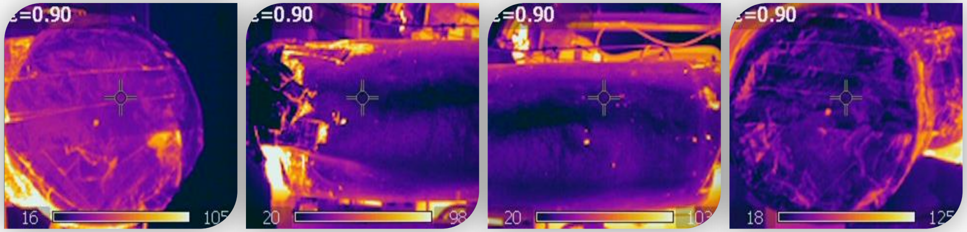
System Surface Temperature

Despite exhaust gas temperatures in excess of 600ºC, external surface temperatures were measured to be controlled to less than 150ºC through the use of an insulated DPF.

The industrialised system will use a combination of an insulated DPF and water-cooling.



▲ **Comparison of Proof-of-Concept Insulated CCRT Surface Temperatures**



▲ **FLIR thermal images for 9.5" Insulated DPF at 1200rpm Full-Load (the highest EGT point; images shown from Entry (right) to Exit (left)**

Next Project Milestones – C26070

	Project Activity	
Phase 1	Part 6a - Industrialisation Design - DPF, pipework and basic monitoring	
	Part 6b - On-Engine Validation and Durability Testing of P2* system	
	Part 6c - Field Trial of P2* system incl. Support and Monitoring System Software Refinement	
Phase 2	Part 7a - Emissions Certification Testing	
	Part 7b - Safety Certification Testing	

System level P2 is second level prototype; which will have the form, function and performance of a production intent design but will not be made off production tooling/fixtures.

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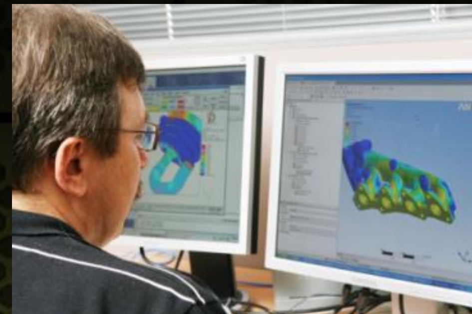
▲ CAD – Design Engineering



▲ CFD / FEA / Analysis

▲ Embedded Electronics

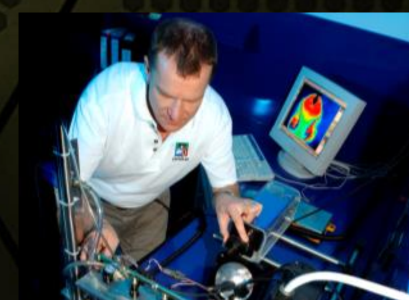
▲ Failure Analysis & Metrology

▲ Vehicle Fitout & Modification

▲ Prototyping and Supply

▲ Engine Test – 3hp to 800hp

▲ Alternative Fuels – NG, Bio



▲ Fuel System Testing

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