

Improving the Health of Underground Personnel

BHP Billiton Cannington

The Problem

Diesel particulate matter (DPM) has been identified as a level one carcinogen by the World Health Organisation.

DPM refers to the fine carbon particles or "soot" in diesel exhaust that can penetrate deep into the lungs and pose serious health risks, not dissimilar to those caused by asbestos. It is particularly relevant for workers operating diesel-powered equipment in confined spaces, and poses health risks like irritation and respiratory and cardiovascular problems. Evidence is growing about a causal link between DPM and lung cancer.

At BHP Billiton's Cannington mine in North West Queensland, DPM is a known occupational hazard due to the operation of diesel equipment in the underground environment.

Concerned about employee exposure to DPM, Cannington resolved to take positive steps to clean up the air for its operators.

The Solution

While all underground operations routinely monitor DPM levels, Cannington made the decision to actively reduce exposure to DPM and **proactively** address health and safety concerns.

In 2010, as part of its exposure control program, Cannington reviewed available mechanical retro-fitting options, searching for existing technology to reduce DPM.

Whilst Caterpillar – a leading manufacturer of heavy vehicle and mining equipment and major supplier to Cannington – offers a DPM filter as an "off the shelf" option for its equipment, the technology is not applicable for underground environments. With no suitable answer, Cannington began searching for a solution, with the goal of a step-change in DPM control, looking to **fix the source** of the problem rather than protecting against it.

Cannington previously utilised the traditional personal protective equipment and monitoring response model to continuously measure DPM. This project is the first of its kind in that it researched and developed an engineering control (higher rating in the hierarchy of controls) to actively reduce DPM.

In 2011, as part of targeted DPM surveillance, Cannington assessed which heavy vehicles in its underground truck and loader fleet were not meeting DPM targets.

Cannington identified which vehicles would be the most effective to target, with the most favoured approach being engineering controls on machines with the highest DPM emissions—the R2900G and R1700G loader engines.

Cannington's maintenance and engineering departments approached project partners OEM Caterpillar and dealer Hastings Deering with a proposal on how the parties could work together to develop a solution.

Discussions commenced between party representatives to determine DPM reduction targets and how these could be achieved. A project team was assembled, and ran various scenarios using:

- Cannington's heavy vehicle equipment;
- future equipment needs;
- available technologies and their effectiveness; and
- Cannington expectations.

It was determined that an all-encompassing engine design-based solution was required, comprising of:

1. Engine redesign and factory testing;
2. On-site verification and testing; and
3. Cannington fleet upgrade.

Step 1. Caterpillar engine redesign

The Caterpillar engine redesign comprised of two stages:

- **Stage 1** – redesign of engines and development of new high performance, fuel efficient, emissions controlled components.
- **Stage 2** – the design, development and installation of a customised, underground, diesel particulate 'flow through filter'.

Current engine design



Existing underground loader engine



Stage one



Engine redesign and component replacement



Stage two

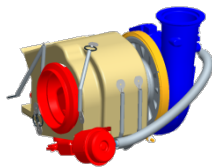


The development and inclusion of a Diesel Particulate Flow Through Filter

Stage 1

R2900G loader engine redesign included new, high efficiency electronic injectors, high flow insulated exhaust manifold, insulated heat harnessing turbo charger and new computer software and programming to provide ultimate performance and fuel efficiency throughout the power curve.

The R1700G loader engine was customised to include an insulated heat harnessing turbo charger, high flow insulated exhaust manifold, computer software and programming and a new camshaft with variable valve actuation to ensure adequate air, fuel and emissions management.



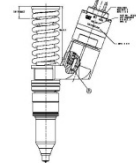
Insulated heat harnessing turbo charger



Variable valve actuation camshaft



High flow, insulated exhaust manifold



High efficiency fuel injectors

Three months were spent by Cannington engineers and Caterpillar on engineering component design, and developing and manufacturing the components and testing. Factory testing for exhaust emissions was conducted at Caterpillar's engine test facility in the United States.

Stage 2

Stage 2 involved the design, development and installation of a new diesel particulate flow through filter.

Exhaust flow through filters are not new; however, a filter was not available for R1700G and R2900G engines. Alternatively, Cannington, Caterpillar and Hastings Deering provided criteria for a new filter that had the ability to reduce carbon and DPM, would not inhibit engine performance, and kept backpressure from the exhaust system within the limits of current engine specifications.

The prototype developed by Caterpillar and Cannington engineers delivered a further 50% DPM reduction and the criteria set by Cannington was achieved—this was in addition to reductions from the Stage 1 engine redesign.

Together, the redesigns also allowed the engines to operate on both ultra-low-sulfur diesel (ULSD) and low ash engine oil, providing further emission improvements.

With the laboratory development completed, field verification and testing of the Stage 1 and Stage 2 redesigns was required.



Figure 1. Intake of the diesel particulate flow through filter developed for the R1700G and R2900G engines.

Step 2. On-site verification and testing

Cannington received the Stage 1 parts in June 2012. It took two shifts to install the new parts on one test R1700G engine and one test R2900G engine on underground loaders.

The results were immediate. Stall testing of the engines showed no reduction in performance. Conversely, both loaders showed an increase in performance and a reduction in fuel consumption.

In October 2012, Cannington received four of the Stage 2 newly developed diesel particulate flow through filters. Before trialling on heavy vehicles, the filters were tested using a purpose-built Cannington designed and manufactured heated shake table, whereby the filters could be assembled and tested under trial situations to replicate operating conditions, including heat and vibration and test durability.



Figure 2. Cannington's heated shake table.

Once the filter's strength and performance was verified on the heated shake table, the filters were trialled on several underground heavy vehicles, including the test R1700G and R2900G loaders and two AD55B underground haul trucks.



Figure 3. Test machine R1700G loader at Cannington.



Figure 4. Test machine R2900G loader at Cannington.



Figure 5. Test machine AD55B haul truck at Cannington.

Step 3. Cannington fleet upgrade

Based on the initial results, Cannington has now transitioned four underground heavy vehicles to the Carbon Reduction Project system.

The remaining truck and loader fleet is scheduled to be 100% compliant with the Carbon Reduction Project by the end of the 2013 calendar year.

Benefits/ Effects

The project's achieved outcomes have driven Caterpillar to offer the modifications as optional extras on all underground haulage and loader equipment (not previously available to purchasers).

The final test results with the Stage 1 parts fitted showed an unprecedented ventilation reduction of 26% on the redesigned R1700G engine and 42% on the redesigned R2900G engine.

Engine	Original ventilation rate (cubic feet per minute)	Stage 1 ventilation rate (cubic feet per minute)	Ventilation reduction	Fuel consumption improvement
R1700G	21,300	15,700	26%	7%
R2900G	35,700	20,700	42%	4%

Stage 1 also provided:

- Increased fuel efficiency;
- Improved performance above 2,000 metres sea level for R1700G loader;
- The equivalent of a 3% increase in dual stall rimpull for R2900G loader;
- Ability to run on low sulphur fuel and low ash engine oil, further reducing carbon emissions.

Stage 2 delivered the following outcomes:

- Lower ventilation rate for underground machines (effective reduction in diesel particles);
- Reduction in exhaust/engine noise for underground machines;
- No impact on performance;
- No additional maintenance requirements.

This project has improved working conditions and introduced better maintenance practices, with more attention to engine maintenance and a greater focus on exhaust leaks. This ensures the Carbon Reduction Project is working to the optimal level.

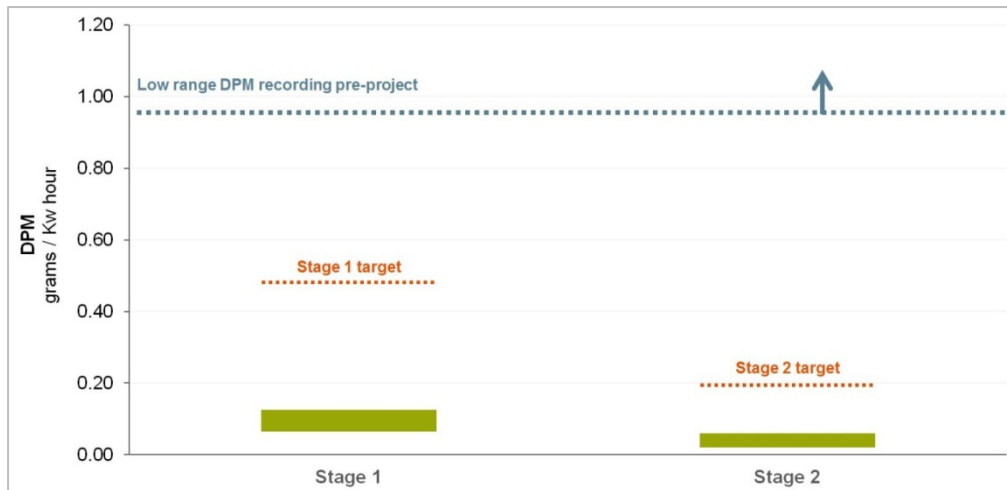


Figure 6. The range of results achieved with the implementation of the Carbon Reduction Project on test machines R1700G, R2900G and AD55B.

The above results were drawn from Cannington’s underground exhaust gas analysis regime.

Results clearly show both Stage 1 and Stage 2 have had a significant impact in reducing DPM and have performed better than project targets established by Cannington.

The project is an excellent example of a workforce health initiative that delivers clear, positive results and better workplace outcomes for employees, without any impact on safety or production.

Transferability

This project, instigated by Cannington and developed jointly by Cannington, Caterpillar and Hastings Deering, provides a DPM solution that extends beyond the Cannington operation.

It can be applied to any underground mining operation where industry standard Caterpillar R2900G and Caterpillar R1700G loaders are in operation.

The project’s technology is now available as an optional extra on all new Caterpillar underground heavy vehicles, meaning all mine sites can take advantage of the project’s outcomes.

Due to this industry-wide application, the project has the potential to be recognised as best practice and industry leading technology by peers.

Innovation

This initiative is an advanced solution. By partnering with Caterpillar and Caterpillar dealer Hastings Deering to develop an effective, sustainable solution, the

Cannington project has provided an OEM 'optional extra' for the mining market and is changing the way the mining industry regards and controls DPM.

From inception in 2011 to implementation in 2012, the project has provided a measurable and effective response to DPM in underground environments.

This project displays Cannington's overriding commitment to health and safety by going **above and beyond** statutory requirements. Rather than merely recording and monitoring DPM levels, Cannington is actively **reducing** the problem with the aim of eliminating the hazard.

The project's ability to address carbon and DPM emissions is evidenced by:

- Reduction in DPM and carbon from underground heavy vehicle exhausts, below targeted levels;
- Increased fuel efficiency of underground heavy vehicles;
- Reduction in exhaust and engine noise;
- Ability for underground heavy vehicles to run on fuel and oil with greater environmental credentials;
- Reduction in component heat and risks associated with heat transfer and fire;
- Increase in workforce awareness of technology to abate occupational exposures; and
- Industry-wide access to the technology due to manufacturer/ dealer support and commercial markets.

Rather than creating a complex and expensive response to DPM control, the project capitalises on the experience of its workforce; existing business relationships; the expertise of the manufacturer; and advances in technology to target DPM at its source.