CURRENT PROJECTS

This report is a summary of current projects for the months November and December 2018 and January 2019
ACARP CONTACTS

PROGRAM MANAGEMENT
Australian Coal Research Limited
Level 5, Suite 18
Christie Centre
320 Adelaide Street
Brisbane Qld 4000
Phone: 07 3010 9717

Ian Neill
Executive Director
ian@acarp.com.au

Terry Reilly
Levy Administrator
terryr@acarp.com.au

PROJECT ADMINISTRATION
Australian Research Administration Pty Ltd
Level 12, 167 Eagle Street Brisbane Qld 4000
PO Box 7148 Riverside Centre Qld 4001
Phone: 07 3225 3600

Anne Mabardi
anne@acarp.com.au

Patrick Tyrrell
patrick@acarp.com.au

Nicole Youngman
nicole@acarp.com.au

RESEARCH COORDINATORS
Peter Bergin
Underground NSW
peter.bergin@optusnet.com.au

Cam Davidson
Open Cut – Mining
cam@cwrd.com.au

Ashley Conroy
Technical Market Support
ashley@ashleyconroy.com.au

Nerrida Scott
Coal Preparation
nscott@neluca.com

www.acarp.com.au

DISCLAIMER
No person, corporation or other organisation (“person”) should rely on the contents of this report and each should obtain independent advice from a qualified person with respect to the information contained in this report. Australian Coal Research Limited, its directors, servants and agents (collectively “ACR”) is not responsible for the consequences of any action taken by any person in reliance upon the information set out in this report, for the accuracy or veracity of any information contained in this report or for any error or omission in this report. ACR expressly disclaims any and all liability and responsibility to any person in respect of anything done or omitted to be done in respect of the information set out in this report, any inaccuracy in this report or the consequences of any action by any person in reliance, whether wholly or partly, upon the whole or any part of the contents of this report.
C25004
Review of Australian and International Coal Burst Experience and Control Technologies: Scoping Study and Stage 1

University of New South Wales
Ismet Canbulat

Value: $404,000
Report Expected: February 2019
Industry Monitor/s: Coal Burst Task Group
ACARP Contact: Patrick Tyrrell

A draft report is with the industry monitor(s) for review.

C26006
Coal Burst Monitoring Technology Using Microseismicity

CSIRO
Xun Luo

Value: $230,500
Report Expected: March 2019
Industry Monitor/s: Coal Burst Task Group
ACARP Contact: Peter Bergin

The aim of this project is to investigate possible correlations between microseismicity and coal burst events for monitoring and prediction. This first stage of the research involves in three work programs:

- Installation of CSIRO microseismic monitoring systems at three mines;
- Documentation of the microseismic data sets and mining process data and make it available for scientific use for coal burst research; and
- To perform preliminary data processing and evaluation.

The microseismic data from Mine A that was collected in 2010 by CSIRO has been reprocessed, after approval gained from the Coal Burst Task Group to use this mine as the non-coal burst prone mine for microseismic signal research. The final report of the project is being written and it is expected to be finished in one month. This report will cover microseismic monitoring research programs at three coal mines. The raw and processed microseismic data have been archived.

C26053
Predict Stress State and Geotechnical Conditions Near Major Geological Structures Using Microseismic Technology and Distinct Element Modelling

CSIRO
Baotang Shen
Ismet Canbulat

Value: $275,520
Report Expected: February 2019
Industry Monitor/s: Coal Burst Task Group
ACARP Contact: Peter Bergin

Stress state and geotechnical conditions often change significantly near major geological structures (e.g., faults, shear zones, dykes) which is the cause of most major mine instabilities and/or safety hazards including coal burst, roof falls, water inrush, gas outburst etc. This project aims to develop an integrated method of mapping the stress state and strain energy during mining near the major geological structures. After knowing the strain energy and the related stress state, the risk of coal burst in a roadway can then be quantified for risk control purposes.

The research conducted in this project included:

- A comprehensive field monitoring program in the vicinity of a major geological structure in a selected mine site where the risk of coal burst may be elevated;
- Detailed analysis of monitoring data to identify the stress anomalies near the geological structure and evaluate the possibility of using the monitoring tools for coal burst forecasting; and
- Three-dimensional numerical modelling to investigate the stress distribution and the strain energy concentrations for the purpose of risk mapping of coal burst.

For the integrated field monitoring, ‘Mine Site 1’ was selected as the monitoring site where pressure bumps had been experienced in roadways due to the existence of a strong conglomerate unit in the overburden strata. The monitoring system was located at a gateroad of Longwall 107 near a major dyke where the mining conditions had been observed to change significantly in previous panels. The monitoring program included installing four microseismic geophones, four stressmeters and four extensometers in the roadway roofs and coal pillars, aiming to obtain seismic and stress change data during mining. These instruments were distributed symmetrically on two sides of the dyke to investigate the effects of the dyke. The monitoring system was installed in November 2017 when the longwall face was about 400m from the monitoring location. The longwall panel was completed at the end of July 2018 when the longwall face passed the monitoring location by 634m. The monitoring program was finished on the 27th August 2018. Overall, the monitoring program had been successful and it recorded valuable stress, displacement and seismic data during mining. The monitoring data had been systematically analysed in this study.
Two numerical modelling studies had been carried out in this project. The first was a systematic three-dimensional numerical modelling for Mine Site 1 using 3DEC, to compare with the monitored results. This modelling study investigated the stress distribution and strain energy concentration in the vicinity of the dyke during longwall mining, and analysed the mechanisms of the dyke influencing the risk of coal burst. This study also quantified and evaluated the strain energy accumulation particularly in the vicinity of the roadway and the dyke. A comprehensive parametric study was conducted to investigate the effects of various geological and geotechnical factors and the results are compared with the calibrated 'base case model'. Additionally, a simple, preliminary coal burst risk classification method was suggested, and the results obtained from the parametric study were used to assess its validity.

The second numerical study focussed on a reverse fault and its effects on the stress concentration and the risk of coal burst, using a specific geology from another Australian mine. Stress distribution in the vicinity of the reverse fault was analysed considering the geological history of the fault formation where high horizontal stresses led to the initiation and propagation of the reverse faulting. Various in situ stresses and mechanical parameters of the fault, including the ratio of horizontal stress to vertical stress, were used to analyse the state of fault.

All the planned tasks have been completed, a draft report is with the industry monitor(s) for review.

C26054
Modelling of Dynamic Fracture Mechanisms
University of Wollongong
Gaetano Venticinque
Jan Nemcik

Value: $197,500
Report Expected: March 2019
Industry Monitor/s: Coal Burst Task Group
ACARP Contact: Peter Bergin

A draft report is with the industry monitor(s) for review.

C26060
Mechanics of Gas Related Coalbursts in Mining
SCT Operations
Winton Gale

Value: $273,750
Report Expected: April 2019
Industry Monitor/s: Coal Burst Task Group
ACARP Contact: Peter Bergin

The aim of this project is to identify the role gas pressure in coal bursts. The project seeks to identify the mechanics of the process and provide a better understanding of risks, prediction and prevention of such coal burst events.

Work undertaken has been:
- Laboratory studies of gas diffusion rate of coal samples under burst conditions;
- Review of literature regarding gas induced bursts and outbursts;
- Computer modelling of the gas induced burst process;
- Discussion with key industry personnel regarding the burst fundamentals and organisation of a collaborative approach to the problem.

Work was undertaken to understand the role of micro fabric in the burst process. Results to date indicate that the energy available form gas within the coal fabric is available to induce a coal burst under a range of conditions. The amount is dependent on the time frame and the nature of micro and macro fractures in the coal fabric.

Study of the energy required to cause a gas related burst has been undertaken and the results have been presented at the Ground Control Conference in Morgantown 2018.

A review of possible rapid gas desorption via networking of micro fabric has been undertaken. It is considered that the nature of the micro fabric within the coal is an important factor in the desorption rate under appropriate conditions.

The project is in preparation for reporting.

C26062
New Outburst Risk Determination Measures Along With Data Gathering and Analysis for Coalburst Assessment
Sigra
Jeff Wood

Value: $612,200
Report Expected: March 2019
Industry Monitor/s: Coal Burst Task Group
ACARP Contact: Peter Bergin

The primary objective of this project is to implement in parallel with current outburst management processes the findings of project C23014, Outburst Risk Determination and Associated Factors, completed in 2015. The second objective is to determine what common factors also affect coal bursts. A lot of good work has been completed but the project has stalled in implementation because of complications at host mines. Because of this and because of a current surge in external work Sigra has sought to delay the presentation of the project report beyond February 2019.
The aim of this project is to identify the energy related to a number of mechanisms attributed to possible coal burst occurrences. This covers the range of seismic energy, strain energy and gas expansion energy. The project seeks to identify the mechanics of the process and provide a better understanding of risks, prediction and prevention of such coal burst events.

Work undertaken has been:

- Review of energy from strain energy along geological surfaces such as bedding planes and faults;
- Review of rock testing data to identify the energy within the rock mass during rock fracture events;
- Review of energy available from gas within the coal material;
- Review of energy from seismic sources and the effect of distance from a roadway; and
- Review of energy available from mine geometries.

Study of energy from stored strain has been reviewed in more detail with computer models of potential sources about longwall panels.

Alleviation methods for coal bursts has been studied and reviewed. A review of destress drilling has been undertaken to determine the conditions under which it may be applicable.

Using 3D models (namely 3DEC and Flac3D) the following assessments are being carried out:

- Definition and quantification of energy required to cause a coal burst under a range of coal geological domains;
- Quantification of the magnitude of energy available from the strain, gas expansion, seismic energies.
- Energy release in different jointing/cleating environments;
- The effect of mine design and support on the risk of a coal burst; and
- Risk of a coal burst within various geological and mining domains.

A comparison of energy-based mechanisms with ‘traditional quantitative’ approaches has been made and the results are consistent with experience.

The coupled model developed in this project used for gas expansion and strain energies using input from FLAC3D numerical modelling. The results revealed that the energy available for conversion to kinetic energy is most significant for a burst within coal where plastic strains are greatest. This model appeared to be producing results that are in line with the experience.

The effects of discontinuities on the strength and energy release characteristics of coal mass samples under uniaxial compression were also investigated. UDEC was used to model pillar-scale coal mass samples that were represented by an assembly of triangular deformable blocks and pre-existing discontinuities such as bedding planes and cleats were also added into the models. It was found that cleat spacing can have a significant impact on compressive strength and energy release, with both strength and energy release (magnitude and rate) reducing as the number of cleats were increased. This work is one of the first attempts to numerically model and quantify the energy release which occurs during the failure of pillar-scale coal mass samples with varying cleat densities.

Fault-slip induced by longwall mining is a significant cause of indirect coal burst. FLAC3D was used to model a longwall face that approaches a fault with different fault angles of 45°, 60°, 75° and 90°. The results from this study indicated that numerical results showed that cover depth, friction angle of the fault plane and fault angle have significant influences on shear stress drop, shear slip and the magnitude of seismic energy. In terms of fault behaviour during longwall extraction, shear stress on the fault plane above the coal seam first increased and then decreased when the longwall face was approaching the fault. The maximum magnitude of seismic events occurred when the longwall face was 15 m to 40 m away from the fault. Most seismic slip occurred on the fault plane above the coal seam with minimal movement below the coal seam.
A literature review has been conducted on the subject of coal burst and coal testing methodologies focusing on the snapback behaviour to calculate excess stored strain energy in coal. This will allow us to identify the propensity of coal for coal bursts. A detailed literature review was submitted in December 2018.

We have finally received the first batch of block coal samples on 23rd January. The second batch of the coal samples will arrive in the mid-February. Currently, coal samples are being tested to identify the best option for core recovery. For this purpose, we use a radial drill and water jet cut for sample preparation. By the end of February, we will be able to finish first tests for snap-back behaviour to calculate excess stored energy. We will also prepare rectangular coal prism specimens for advanced rock burst tests in China. The planned China visit we expect to happen in June.

**C27039**

**True Triaxial Strength of Coal Measure Rocks and its Impact on Stability of the Roadways and Coal Burst Assessment**

**SCT Operations**
Mahdi Zoorabadi
Winton Gale

**Value:** $187,000

**Report Expected:** October 2019

**Industry Monitor/s:** Coal Burst Task Group

**ACARP Contact:** Peter Bergin

No report received.

**C27041**

**Ground Support Requirements in Coal Burst Prone Mines**

**University of New South Wales**
Ismet Canbulat

**Value:** $150,000

**Report Expected:** July 2019

**Industry Monitor/s:** Coal Burst Task Group

**ACARP Contact:** Peter Bergin

The objectives of this project are:

- Review the international best-practice ground control systems in burst prone mines;
- Evaluate and characterise ground support principles and considerations;
- Assess yielding support technologies and determine the energy absorption requirements for the ground support systems for coal burst control;
- Identify engineering principals and failure mechanisms of yielding support; and
- Establish functional requirements of appropriate and effective ground support technologies for coal burst control that are in line with the Australian experience, regulations, mine design and operational practices.

Work undertaken has been:

- An extensive review of the ground support systems that are used in rock and coal burst conditions;
- Gathering of data from dynamic tests on support elements;
- Gathering of data from static testing to calibrate the numerical models; and
- Preliminary modelling of the cable behaviour under laboratory conditions.

The structural behaviour of cable bolts under both static and dynamic loading was assessed using ABAQUS/Explicit. The models were initially calibrated against the laboratory results obtained from static loading of cable bolts as part of an ACARP project. Following the calibration of the models, the structural behaviour of cable bolts under dynamic loading was studied. Since preparing the laboratory experiments to simulate the behaviour of cable bolts under dynamic loading is demanding, a validated and novel numerical simulation was developed. To simulate the behaviour of the cable bolts under impact loading, a 110 kg mass at velocity of 0.2 m/s was dropped on top of the concrete blocks. The results indicated that the high strain rates as a result of the impulsive loading can change the capacity and the behaviour of cable bolts. This change can be explained based on the influence of the dynamic amplitude factor, which can be highly critical in design of ground support systems in burst-prone conditions.

A preliminary analytical model based on the plastic hinge concept was also developed. The results indicated that numerical and analytical models can be used to assess cable bolt behaviour under dynamic loading to design ground support in burst-prone conditions.

**C27048**

**Monitoring Stability of Roadway and the Longwall Face for Coal Burst Risk Management Using Distributed Fibre Optic Sensing Techniques**

**CSIRO**
Xun Luo

**Value:** $195,000

**Report Expected:** April 2020

**Industry Monitor/s:** Coal Burst Task Group

**ACARP Contact:** Peter Bergin

The project objective is to investigate a distributed fibre optic sensing technique for coal burst monitoring in Australian underground coal mines. The investigation will involve a comparison of seismic characteristics obtained from fibre optic cables and geophones, in a laboratory and possibly at a planned mine site or in a tunnel. The ultimate goal of this project is to develop a new and economic tool for Australian coal mines for coal burst risk management.

A laboratory experiment on distributed fibre optic sensing was conducted from January 15-17 at CSIRO Geophysics Laboratory, using a single mode military fibre (400 m long)
and a multi-mode NBN fibre (1,200 m long). The Silixa instrument made in UK was selected to record the fiber vibrations. The objective of this experiment is to investigate whether the travel-time differences can be detected along the distributed fibers, in response to active and passive seismic sources. Four geophones were also installed at different locations beside the fibers in order to compare the seismic characteristics between the fibers and geophones. The preliminary results of this experiment have shown that the time differences along the fibers can be reliably detected. This encouraging result has suggested the usefulness of distributed fiber optic sensing for microseismic monitoring at coal mines for monitoring coal burst and longwall caving processes. Further data processing and analysis on the collected data are in progress and more results will be obtained in the following months.

C27060
Damage and Risk from Seismic Events

SCT Operations
Richard Lynch
Winton Gale

| Value: | $435,000 |
| Report Expected: | May 2020 |
| Industry Monitor/s: | Coal Burst Task Group |
| ACARP Contact: | Peter Bergin |

The aims of this project are to:
• Develop and significantly improve the velocity models within the coal mine strata at three geological sites;
• Review seismic activity at sites. This would be based on seismic monitoring data within a specific geological environment or computer modelling of caving and fracture modes about longwalls or roadways;
• Assess the wave propagation modes and pathway in stratified rocks from seismic events which occurs at various locations about a longwall or roadway;
• Simulate the effect of a range of events on potential damage about working areas. The range of events would relate to location, type of event (shear rupture /tensile fracture etc) and magnitude of the event; and
• Review the damage and risks for longwalls and roadways for seismic events in coal mines.

Work has been undertaken to scope up a monitoring network at Mine 1. Site work has been initiated and the monitoring array is in the process of being installed and monitored.

Study of source mechanisms effects on wave patterns has been undertaken. The effect of different velocity models is currently being undertaken.

Work on the nature of seismic waveforms from different fracture surfaces has been undertaken to assess the effects of wave form on damage to a ribsides. The effect of such waveforms on roadway stability is also planned for the next quarter in particular the effect of a seismic energy source close to a roadway.

Environment - Subsidence and Mine Water

C20038
Standardised Subsidence Information Management System

NSW Department of Industry
NSW Department of Planning & Environment
Gang Li

| Value: | $655,000 |
| Report Expected: | April 2019 |
| Industry Monitor/s: | Dan Payne, Phil Enright |
| ACARP Contact: | Peter Bergin |

The objective of the extension project is to develop online facilities enabling the industry stakeholders in NSW and Queensland to gain access to the subsidence information resource that has been established as a result of the parent phase of the project.

All project activities have now been completed except the following:
• Completion of the report, which is currently in progress. It is expected that the report will be completed at the end of February/early March;
• Completion of the user’s manual, which is to commence following the completion of the above-mentioned report; and
• Final review of the subsidence query facilities (ie presentation styles and necessary explanations on web pages) before putting them on the internet.

The researcher sought an extension from the Industry Monitors to complete the project at the end of April. This was approved.

C24013
Managing and Conserving Native Plant Species in the Mining Environment

Royal Botanic Gardens and Domains Trust, Sydney
Cathy Offord

| Value: | $441,300 |
| Report Expected: | May 2019 |
| Industry Monitor/s: | Bernie Kirsch, Gary Brassington |
| ACARP Contact: | Patrick Tyrrell |

This project specifically focuses on two threatened Persoonia species – P. hirsuta and P. hindii – that occur on mining lease land. The outcomes of this project are:
• To determine the techniques required to optimise survival of Persoonia in the revegetation context;
• To determine the environmental conditions required to improve plant propagation success and plant survival.
Planting sites for the first translocation of both plant species have been finalised, following results from respective soil analyses. Work is ongoing to prepare suitable sites for planting, such as water access and fencing. Growth and survival of plants for the upcoming translocations continues to be monitored in the nursery. A literature review on managing Persoonia in the landscape has been published in a peer-reviewed journal with direct relevance to the current project.

The very poor flowering and fruiting season in 2018 has led a greater focus on further refinement of propagation from vegetative cuttings in 2019.

C25056
Change Detection in Complex Vegetation Communities

Biosis
Andrew Fletcher
Richard Mather
Tony Cable

Value: $274,700
Report Expected: April 2019
Industry Monitor/s: Bernie Kirsch
Gary Brassington
ACARP Contact: Patrick Tyrrell

Development and formalisation of classification workflows has continued during the quarter. A method for boundary delineation from UAV imagery is nearing completion and includes an assessment of uncertainty in boundary delineation. Solar azimuth and elevation, spectral properties of the camera are the major factors in repeatability of UAV products. Repeatability of canopy models is essential for effective monitoring. In the coming month imagery will be collected at both sponsor sites to test and validate the workflows that have been developed. This work will demonstrate monitoring capability over 18 months and transferability of methods to new communities. This work is continuing in parallel with preparation of the final report and scientific manuscripts. During first quarter 2019 final field works to delineate swamp boundaries of the original test communities by experienced field ecologist on ground assessment. This will provide both validation of UAV product and spatial uncertainty in boundary. Comparing expert field ecological observation with explicit plant level models will greatly increase understanding of the sources of uncertainty in boundary determination and provide statistical limits for detection of change.

C27052
FO-RO Site Trial at Newstan Colliery

CSIRO
Ramesh Thiruvenkatachari

Value: $393,270
Report Expected: January 2020
Industry Monitor/s: Claire Cote
David Randall
Paul O'Grady
ACARP Contact: Cam Davidson

This project aims to conduct a site trial demonstration of an integrated forward and reverse osmosis (FO-RO) process for the treatment of coal mine impacted water. The site trial demonstration is the next step in the development of this technology and builds on the outcomes from the previous projects (C23031 and C21043). This trial will evaluate the stability and performance of the FO-RO system with and without conventional pre-treatment for mine water. The maximum reduction in brine volume and the quality of the treated water in meeting the discharge and reuse water quality criteria will be evaluated under varying feed water characteristics.

Mechanical work in assembling the FO-RO prototype test unit is currently being undertaken. Draft electrical design drawings have been prepared and are under review. Instrumentation control and monitoring system is being prepared. Electrical work for the test unit will commence on completion of mechanical work. On-site infrastructure preparation is also being carried out. The test unit construction is expected to be completed by April.

C27059
Swamp Hydrology Modelling for Advancing Rehabilitation Planning and Management

University of Queensland
Mandana Shaygan
Neil McIntyre
Thomas Baumgartl

Value: $197,800
Report Expected: March 2020
Industry Monitor/s: Bernie Kirsch
Gary Brassington
Peter Corbett
ACARP Contact: Patrick Tyrrell

The objective of this project is to assess the resilience and sustainability of vulnerable Temperate Highland Peat Swamps on Sandstone in response to variations in soil moisture content induced by underground mining activities and climate variability.

This project also aims to develop a hydrological model that can predict soil moisture variability in a range of swamp conditions and support projections of possible vegetation responses.
The research adopted a stepped approach for the monitoring and simulation of variations in the soil moisture content of swamps. A visit to mine site 1 and 2 at the beginning of the project was performed to identify preferred monitoring locations.

A literature review was also performed to collect and evaluate the existing data and knowledge of the sites. 20 soil moisture sensors have been purchased to monitor the soil moisture condition of the selected locations within mine site 1. The soil moisture sensors will be installed at four locations, at which five moisture sensors will be installed up to a soil depth of approximately 200 cm per monitoring location. While the permission process for installing the sensors at mine site 1 is underway, an uncalibrated soil hydrology model of the swamps has been developed based on the existing data of the swamps. The HYDRUS model has been employed for this. Soil samples have been collected from mine site 2 and in upcoming work will be used to estimate soil hydraulic parameters using standard laboratory procedures. Following this, calibration and testing of the HYDRUS model can proceed using in-situ soil moisture data from swamp soils, including both mine-affected and control site soils.

### Exploration

**C25067**  
**Seismic Diffraction Imaging for Improved Structural Detection in Complex Geological Environments**

**CSIRO**  
Binzhong Zhou

<table>
<thead>
<tr>
<th>Value:</th>
<th>$374,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report Expected:</td>
<td>March 2020</td>
</tr>
<tr>
<td>Industry Monitor/s:</td>
<td>Heather Schijns, Paul O'Grady</td>
</tr>
<tr>
<td>ACARP Contact:</td>
<td>Patrick Tyrrell</td>
</tr>
</tbody>
</table>

This is the second stage of the project which builds on the completed stage one project. Stage one focused on an evaluation of the algorithms developed in earlier project C22016 for the detection of small faults. It demonstrated that about half of the small faults (< 1m) mapped from mining that were not detected by reflection seismic data analysis, could be associated with extracted diffractions. This clearly illustrates that diffraction imaging adds value to the reflections and warrants the further development of the diffraction imaging technique to make it applicable to a complex geological environment. This extension project aims to improve the current algorithms to work with dipping or gently folded coal seams; to expand the algorithms to work with 3D seismic surveys; and to develop validated interpretation workflows that add confidence to the interpretation of small structures and avoid false positive fault interpretations.

In this quarter, following the successful test of the dip estimation method based on the seismic plane wave gradients, the project team has incorporated the dip estimation algorithm with the previously developed diffraction imaging method using the moving average error filter (MAEF) for more complex geological environments. Figure 1(a) is an original final seismic post-stack section containing many sub-parallel dipping reflections. In particular, there is a thrust fault with relatively weak diffractions present in the red rectangular area. We applied the MAFE filter in three different ways to the seismic data in Figure 1(a) to extract diffractions: applying the filter directly to the stack section without event flattening (Figure 1(b)); the MAFE filter is applied to the flattened stack section with the picked reflection followed with restoring the flattening process (Figure 1(c)); and the MAFE filter was applied in the local dip direction estimated by the dip estimation algorithm (Figure 1(d)). Besides many residual reflections such as marked by the green arrows in Figure 1(b), the direct application of the MAFE filter to the stack section does not extract the desired diffractions effectively. If the stack section is flattened before the application of the MAFE filter, there are still some residual reflections remaining, as marked by the green arrows in Figure 1(c), the extracted diffractions are much more evident compared with the result in Figure 1(b). This illustrates the importance of the event flattening in diffraction extraction. However, if the MAFE filter is applied in the local dip direction estimated by equation (3), as shown by Figure 1(d), it produces not only more evident diffractions associated with the thrust fault, but also reduces the residual reflections significantly compared to the results in Figure 1(b) and (c). This clearly demonstrates that applying the MAFE in the seismic dipping direction is an effective way to extract diffractions from seismic reflection data without the need of flattening the target event. Further testing and refinement of the new algorithms are underway to make them more robust.

![Figure 1](image-url)  
**Figure 1** Diffraction extractions by with a 21-trace MAEF filter: (a) Original seismic stack section overlaid with a picked reflection in red curve; (b) extracted by a direct application of the MAFE filter to the section in (a); (c) created by applying the MAFE filter to the flattened section of (a) with the picked reflection followed with restoring the flattening process; (d) obtained by applying the MAFE filter in the local dip direction estimated by the dip estimation algorithm.
C27027
Advances in Acoustic Logs to Predict the Stress Redistribution in Coal Strata as a Result of Degassing-Dewatering

University of New South Wales
Hamid Roshan
Hossein Masoumi

Value: $105,860
Report Expected: May 2020
Industry Monitor/s: John Terrill, Roger Byrnes
ACARP Contact: Peter Bergin

The main objective of the project is to use acoustic logging to extract the poroelastic response of the coal seam at in situ condition and predict stress re-distribution as a result of degassing/dewatering.

Over that last quarter, The Biot coefficient measurement and analysis were completed. A set of thermodynamic equations was developed to model the Pseudo-Biot coefficient with sorbing gases. It was shown that Biot Coefficient might not be applicable to rock with sorbing capacities and modification to the whole definition is required. The model was then simplified using Percolation theory for field applications where acoustic together with density measurements can be used to predict the Biot and Pseudo-Biot coefficient. Extra measurements of Biot coefficient of several other coal samples are in progress to refine the model and obtain better accuracy. The measurement of anisotropic mechanical-physical properties is being currently conducted. These anisotropic analyses include major cleat orientation and stress anisotropy from acoustic measurements for the non-sorbing and sorbing gases. The shear wave splitting for sorbing rocks is under investigation for the first time. It is sought to obtain information about the orientation of major cleats and stress anisotropy in presence of sorbing gases from acoustic waves (Compressional and Polarised shear wave).

*Anisotropy in mechanical properties from acoustic measurements in coal sample (Compressional and Polarised shear wave).

C27057
Automated Structural Mapping using a Mobile Laser Scanner

University of New South Wales
Simit Raval

Value: $108,146
Report Expected: January 2020
Industry Monitor/s: Brian Vorster, Paul Buddery, Roger Byrnes
ACARP Contact: Patrick Tyrrell

The main objective of this project is to evaluate a mobile laser scanner for routine mapping of underground mine environments and embedded structural features.

This quarter, previously collected LiDAR data from a mine site has been evaluated in terms of point density and point spacing through data triangulation. Data collected in handheld mode had higher point density showing some of the underground features such as roof bolts. A workflow is currently under development for automated identification and extraction of the roof bolts from the laser scanning data. The developed methodology will ultimately lead to automated change detection of bolting conditions. The data captured by the laser on a vehicle-mounted mode exhibited positioning errors. It was observed that the length of the loop closure and changes in the scanning environment (such as opening and closing of ventilation doors) influence the mapping accuracy. The error in mapping was proportional to scan length. Further, change in the environment during active scanning led to incorrect feature matching in the SLAM algorithm which resulted in erroneous points. A chain of processing algorithms was developed and implemented (such as range-based filtering and connected component filtering) to remove range-induced noises. Data upsampling and point re-projection were implemented to increase point density of the vehicle-mounted data. The upsampling had a prominent effect in improving the vehicle-mounted data making it suitable for some of the feature’s extraction. Additionally, several laboratory-based experiments were also conducted during this quarter to develop innovative solutions for quick registration and georeferencing.

Few structures, such as roof bolts, are visible in the laser scan data.


Health and Safety

C24009
Establish 'At Risk' Distance from Hydraulics

University of New South Wales
David Wainwright
Gary Nauer

Value: $26,908
Report Expected: April 2019
Industry Monitor/s: Paul Gill
ACARP Contact: Patrick Tyrrell

Awaiting lab work to be undertaken at UNSW.

C26047
Real Time Dust Monitor

University of New South Wales
Charles Harb
Duncan Chalmers

Value: $184,300
Report Expected: March 2019
Industry Monitor/s: Bharath Belle, Brad Lucke
ACARP Contact: Peter Bergin

Discussions on suitable laser chips are ongoing and the samples from Albuquerque have been collected. These were analysed and results highlighted a variance in samples collected from two adjacent tubes with almost twice the amount of dust being collected from one tube.

Modifications to the collection method are being undertaken and then the tests should be repeated. This needs to be done so that both instruments sample the same point in the apparatus. Also, each sample collected contained a large amount of dust so that all samples were overloaded with dust.

C26048
Improving Respirable Coal Dust Exposure Monitoring and Control

University of Queensland
David Cliff
Mark Shepherd
Nikky La Branche

Value: $250,000
Report Expected: March 2019
Industry Monitor/s: Bharath Belle, Peter Smith
ACARP Contact: Patrick Tyrrell

The project objective is to improve the industry’s capacity to prevent and manage respirable coal dust exposure of workers through:

• Creation of an up to date information resource on coal dust exposure and control technologies and their effectiveness for both open cut and underground mines, including evaluating their effectiveness;
• Evaluate the currently available real time respirable dust monitors and barriers to their use;
• Dissemination of this information to all ACARP contributing coal mines;
• Updating RISKGATE to include a specific respirable dust topic;
• Promotion of the resources through suitable conferences and industry seminars.

Work to date has continued on:

• Collection and collation of literature relating to dust control technology;
• Collection and collation of literature relating to the science behind the setting of exposure standards for respirable dust;
• Collection and collation of literature relating to respirable dust monitoring techniques;
• Respirable dust samples to the University of Virginia for particle sizing and chemical analysis, as they already have a large database from US mines.

In the next quarter:

• The literature review will be completed;
• Analysis of the exposure data collected from DNRM and Coal Services will be completed;
• Results from prototype particle size and chemical analysis will be completed; and
• The final report will be drafted and submitted.

There has been a delay in part due to the extension of the field work to include the cooperation with Virginia Tech and UNSW and also in processing all the data received from Coal Services and DNRM. It was agreed by the Industry Monitors that the report needed to be comprehensive and a slight delay was in order if this could be achieved. In addition there has been an additional workshop scheduled in November in conjunction with DNRM to discuss the future research needs. Contact: David Cliff: d.cliff@mishc.uq.edu.au

C26065
Dustless Longwall and Development Face

University of Wollongong
Peter Wypych

Value: $339,700
Report Expected: March 2019
Industry Monitor/s: Peter Davidson
ACARP Contact: Peter Bergin

The objective of this project is the development of 'dustless' mining operations in key areas of the longwall and development face. The project is split into two phases, with the first phase focussing on the longwall and the second phase looking at the development face. For both phases of the project the objective of developing dustless operations would be achieved through:
• Identification of key areas of dust generation and the events contributing to these;
• Analysis of mechanisms contributing to significant dust events;
• Evaluation of current dust control techniques;
• CFD analysis: Firstly, of air and dust flow and then with dust suppression sprays included to understand the flow interactions and develop optimised solutions;
• Implementation of new high-energy micro-mist sprays based on solutions developed using CFD analysis and experimental testing;
• Measurement of dust concentrations after the implementation of the new systems and comparison with previous dust levels.

Work in the past quarter has included:
• Trial dust suppression system on longwall at mine site 1 (for roof support movements and canopy sprays for shearer);
• Evaluated effectiveness of installed systems through observations and dust monitoring—
  o dust monitoring indicated reductions in respirable dust concentration of >80% for dust generated by the movement of roof supports and >55% for dust generated by the shearer,
• Continuation of 3D-CAD/CFD modelling of Development Phase of project.

In the next quarter it is aimed to:
• Install proposed system on a suitable continuous miner (with help from OEM and/or another mine site);
• Conduct dust monitoring of installed system and evaluate the performance; and
• Finalise the project including a report summarising the work completed and evaluation of results.

C27007
Assessment of Pyritic Coal Dust Induced Pneumoconiosis
B3 Mining Services
Basil Beamish
Graeme Zosky

Value: $93,000
Report Expected: May 2019
Industry Monitor/s: Bharath Belle, Brad Lucke, Sharif Burra

ACARP Contact: Patrick Tyrrell

The main objective of this project is to assess whether the findings of recent US studies on pyrite in coal as a contributing factor in Coal Worker’s Pneumoconiosis can be translated to Australian coals. The project will answer two key questions:
1. Does Australian pyritic coal dust pose a health hazard (produce bioavailable iron)? And
2. What is the severity of the physiological response (degree of toxicity)?

Results from all epidemiological testing are being finalised and a meeting has been arranged with the Industry Monitors this month to discuss the outcomes. Preparation of the final report is planned throughout February and will include feedback from the Industry Monitors. A draft report is scheduled to be submitted for review by the end of March.

C27010
A Clinical, Occupational and Radiological Review of Lung Disease
Uniting Care Medical Imaging
Bob Edwards
Katrina Newbigin
Rhiannon McBean

Value: $119,600
Report Expected: February 2019
Industry Monitor/s: Bharath Belle, Brad Lucke, Sharif Burra

ACARP Contact: Patrick Tyrrell

This project aims to review positive cases of CMDLD within Queensland, doing so via close examination of radiological images, lung function, medical charts, and occupational histories.

Stages 1, 2 and 3 (case identification, medical and radiological retrospective review, and prospective questionnaire) - A total of 142 potential cases were identified during the study. Due to refinements of the inclusion criteria to ensure that all cases had sufficient evidence of lung disease due to work in Queensland coal mines, 79 were included in the study. An invitation to participate was attempted for all of these cases. 24 declined, 13 were unable to be contacted, and 42 consented to participating in the prospective component of the study. The retrospective component of the study included all 79. Of the 42 consenting participants, 36 completed the prospective questionnaire as 6 were unable to do so within the time provided.

Stage 4 (data collation and analysis) - Data analysis is complete with a brief summary of key data given.

The mean age of included cases was 58.9 years (35-90). A portion of workers had spent a period of their mining careers outside of Queensland (19), reporting to have worked interstate or overseas as well as in Queensland. The mean tenure in the coal mining industry was 26.2 years (6-45).

Dissemination of findings - Interim findings were presented at the ‘Dust Forum’ held at UQ in November 2018. This presentation was attended by coal industry leaders, union representatives, medical professionals, and researchers and was well-received. The final report for this project is in the draft phase and is currently being prepared for submission end of February.
Coal Characteristics and Pneumoconiosis

University of New South Wales
David Cliff
David Waite

Value: $348,800
Report Expected: February 2020
Industry Monitor/s: Bharath Belle
Brad Lucke
Sharif Burra
ACARP Contact: Patrick Tyrrell

Coal workers’ pneumoconiosis (CWP) has been related to the presence of reactive iron minerals such as pyrite in US coals but little information on factors contributing to reactive oxygen species (ROS) generation by Australian coal dusts is available. Project key objectives are to:

- Quantify the toxicity of Australian coal dust to human lung epithelial cells and to determine whether any relationship exists between the toxicity and elemental composition;
- Quantify ROS production and determine whether a relationship exists between the oxidant generating capacity and the elemental composition;
- Develop a screening protocol for particles with regard to potential toxicity and recommend management approaches; and to
- Develop guidelines relating to best practice dust management for Australian coals considered particularly problematic with regard to CWP risk.

During the last three months we have focussed on further characterising a selection of 22 coal samples provided by industry monitors as well as performing in vitro oxidant production studies on samples containing a range of iron minerals. X-ray powder diffraction (XRD) studies have confirmed the presence of iron sulfate minerals, siderite and SiO2 in addition to reduced iron sulfide minerals. Preliminary in-vitro experiments using coal dust suspended in synthetic lung fluid reveal a good correlation between citrate-extractable iron and in vitro ROS production capability (FIGURE 1(A)) with this result suggesting that the concentration of citrate-extractable iron may be used as an indicator to estimate the ROS production capability of particular coal dusts. In vitro experiments mimicking lung-cell immune response to the inhaled coal dust reveal an elevated (40-fold) production of ROS in some instances (FIGURE 1(B)). Over the next quarter our major focus will be on in vivo experiments of the toxicity of particular coal dusts to epithelial cells. Of particular interest will be the elucidation of the relationship (if any) between particle composition and size and epithelial cell toxicity.

We have also submitted a proposal (LP180101146) entitled ‘Elemental release and oxidant production from mixed coal mine dusts’ to the ARC Linkage scheme. If successful, support secured through this scheme will provide significant additional funds enabling increased scope and depth of the ACARP project.

Mine Rescue Vehicle Radar Sensing Integration

CSIRO
Gareth Kennedy
Lance Munday

Value: $254,405
Report Expected: August 2019
Industry Monitor/s: Brad Lucke
ACARP Contact: Patrick Tyrrell

The objectives of this project are to:

- Develop an integrated radar sensor and user interface that is applicable to a wide range of fixed and mobile sensing applications in underground coal mines;
- Provide robust ranging and mapping that is tolerant of both airborne and sensor-surface contamination caused by dust, smoke and water vapour; and
- Trial the system in an underground coal mine and evaluate performance.

The goal of the project is to fulfil these objectives in order to deliver a pre-commercial prototype system that can be rapidly brought to market by a commercial partner. Key benefits of the system are:

- Improved health and safety, whereby persons in any part of a mine, who are subject to disorientation or severely impaired visibility, are able to find their way out of the mine; and
- Enhanced productivity for mining machinery, where operation is impaired due to dust, smoke or water vapour.

Integrated testing of the radar, LED display and software was undertaken during this quarter. A hand-cart was fitted with the radar and display hardware, along with a camera for recording the radar’s point-of-view. On the software side, temporal and spatial filtering were implemented, along with an improved user interface. Together, these provide a human-readable graphic of obstacles in the path. Additionally, the software records
all radar and processing data, which can then be played back synchronously with the video.

Experimental trials of the system were undertaken both indoors and outdoors using a variety of walls and obstacles. These included plaster walls, brick walls, metal walls, rock walls, reinforcing mesh, roof bolts, bolt plates and metal bollards. Experimental results were promising; roof bolts/plates could be discriminated and walls showed up clearly. However, further software processing is required to filter out strong radar returns from large metal objects; these returns can swamp other signals and hence mask closer obstacles.

Preliminary testing of a second type of radar unit was undertaken. This unit uses a higher transmission frequency and has (theoretically) better target discrimination than the current unit. The new unit has a major advantage: it is significantly smaller and would fit in CSIRO’s IECEx - approved transparent flameproof enclosure. Further investigation of the new radar unit will be undertaken to determine its viability.

C28001
Fit for Purpose "Self Aware Unmanned Aerial Vehicle (UAV)" for Remote Underground Deployment: Stages 1 and 2
Mines Rescue
Paul Martin
Steve Tonegato

Value: $228,500
Report Expected: June 2019
Industry Monitor/s: Bharath Belle, Brad Lucke
ACARP Contact: Patrick Tyrrell

The objective of this project is the development of a ‘Self Aware Unmanned Aerial Vehicle (UAV)’ for remote underground deployment. This will enable Mines Rescue to readily deploy UAVs in an underground coal mine post a major incident to gather critical data, including atmospheric explosibility and toxicity, and personnel status. This project will:
• Develop a UAV that is capable of self-hovering in a safe location in an underground roadway with bump protection and high-powered LED lighting for navigation, thereby maintaining a safe and pre-programmed position in an underground roadway with varying ventilation currents and obstructions (eg belt conveyor, mining vehicles), and to survive a loss of control signal by maintaining a safe position;
• Develop a simple driver interface that enables simple control of a UAV – in terms of up/down, left/right, forward/back, thereby enabling operation of the UAV by a non-specialist pilot.

The project has commenced with the one activity undertaken being the negotiation of key terms with the supplier of the hardware and software.

Critical aspects of the terms finalised to date are:
• Definition of UAV specifications;
• Contract price; and
• Inclusion of five day specialist training in all aspects of the UAV.

Whilst the supplier has commenced the build of the specialised UAV, key aspects currently being negotiated are:
• Location of product delivery and training (Canada or Australia are being considered); and
• Timing of the delivery.

It is anticipated that the delay caused by this aspect of the project will delay delivery of the project by 8 to 12 weeks.

C28029
Personal real time dust/particulate monitor (direct mass based measurement)
Lear Siegler Australasia
Peter Phaedonos

Value: $500,000
Report Expected: April 2020
Industry Monitor/s: Bharath Belle, Brad Lucke
ACARP Contact: Patrick Tyrrell

The objective of this project is to design and develop a Personal Dust Monitor based on direct mass-based measurement of respirable dust that is suitable and acceptable to the Australian market for use in Underground mines. The monitor will be certified to intrinsic safety ‘IS’ to Australian ANZEx; and IECEx international standards.

This mass-based technology is the only technology of being able to meet the AS2985-2009 Gravimetric sampling on a continuous monitoring basis.

This monitor is aimed to be used as a personal respirable dust compliance monitor, with already good support from industry.

Standards exist for limiting exposure to the respirable fraction of coal dust in most industrial settings. This real time monitor at any point in the shift will display what exposure levels you will have and allow the operator to make decisions and withdraw to a safe area.

The monitor will measure respirable dust on the filter, it will not distinguish the dust type, the project will look at silica but not necessarily finalise an outcome.
Maintenance

C25063
Photocatalytic Destruction of Diesel Particulate Matter
CSIRO
Yonggang Jin

Value: $527,192
Report Expected: July 2020
Industry Monitor/s: Brad Lucke, Greg Briggs
ACARP Contact: Patrick Tyrrell

A draft report for stage one is with the industry monitor(s) for review. Stage two will commence upon completion of stage one.

C26056
Optimisation of Low and High Pressure Longwall Hydraulic Systems
Quantise Consulting Engineers
Russell Smith

Value: $80,000
Report Expected: March 2019
Industry Monitor/s: Jarrod Sampson, Neville Bunn
ACARP Contact: Peter Bergin

The objectives of this project are to optimise a split between high- and low-pressure longwall hydraulic systems. Aims include quantifying potential benefits in terms of safety, productivity, roof security, and component life. Numerical modelling will be the primary analysis and assessment tool.

Analysis and modelling have been delayed. Resource allocations have been set for completion in March.

C26057
Electrically Safe Variable Speed Drive for Underground
University of Newcastle
Galina Mirzaeva, Peter Stepien

Value: $158,202
Report Expected: March 2019
Industry Monitor/s: Barrie Alley, Brad Lucke
ACARP Contact: Peter Bergin

No report received.

C26059
Proof of Concept of the EST Apparatus on Existing Known Power Supplies
University of Queensland
Enver Bajram, Rajiv Shekhar

Value: $114,767
Report Expected: July 2019
Industry Monitor/s: Greg Briggs, Peter Henderson
ACARP Contact: Patrick Tyrrell

The Electronic Spark Tester (EST) is a concept for assessing the spark ignition risk posed by electrical devices which claim explosion protected by intrinsic safety, as per the IEC standard 60079.11. The concept is intended as an alternative to the currently standardised method of assessing this risk, which relies on mechanical spark creation and explosion tests, and has reproducibility issues. The aim of the current project is to assess the performance of the EST on a broader range of commercially available power supply units (PSUs) than previously tested.

Work has continued on improving test logic for the EST software. A strategy for analysing power supply units with smart load detection and shutdown capabilities has been developed and is currently being tested under various conditions. A new OEM partner has agreed to support the project with the provision of sample equipment for testing. Additionally, the final iteration of the EST hardware design for this project has been completed and is currently awaiting manufacture and assembly.

C26070
Industrialisation of Proof of Concept Wall Flow DOC/DPF System
Orbital Australia
Nick Coplin

Value: $1,246,712
Report Expected: March 2019
Industry Monitor/s: Andy Withers, Bharath Belle, Shayne Gillett, Steve Coffee
ACARP Contact: Patrick Tyrrell

The use of conventional wet type disposable filters is a significant cost for the underground coal sector and there are issues with the filters maintaining performance due to a range of operational reasons.

This second stage project seeks to industrialise the proof-of-concept system developed in the earlier project. The industrialisation activities include:
- Design and validation of the thermal and mechanical design suitable for installation as a retrofit upgrade;
• Develop and validate the requisite electronic monitoring and protection systems, including vehicle integration;
• Achieve guidance on certification readiness from the NSW department of Industry (DRE).

This quarter has seen further reviews with regulators and independent verifiers undertaken as part of the process of seeking approval for site assessment of the DPF package. Addition system assessments of the insulated wall flow DPF with older mechanical injection systems have also been undertaken. Milestones include:
• Completed commissioning of a Cat 3126 mechanical injection system (provided in-kind by Sandvik) as part of assessment of the DPF’s transferability to other engine types; and
• Completed emission and sooting performance assessments with a proof-of-concept installation of the industrialised DPF.

The next round of site testing to be supported by site is planned to include out-bye validation and operational duties within the mine workings, but awaits regulator approval.

Installation of Industrialised DPF for emissions testing on the mechanical injection engine (shortest length from turbo).

C27006
Lightweight/Compact IS 12VDC UPS Portable or Fixed Supply

KRS Technologies (KRS Drive Systems)
Kurt Schober

| Value: | $141,800 |
| Report Expected: | August 2019 |
| Industry Monitor/s: | Graeme Relf, Graham Café, Greg Briggs |
| ACARP Contact: | Peter Bergin |

The objective is to produce a Light Weight and Compact I.S. Portable 12VDC UPS with an extended capacity of up, but not limited to 50Ah capacity. The intention is to supply clean 12VDC power to underground field devices such as WAP’s, Cameras, Sensors, Communications routers and LED lighting and personnel tracking systems. The package shall be easy to carry and deploy for both temporary and fixed installations.

Design of UPS:
• Design of battery and electronic hardware is 95% complete;
• Design of software is 50% complete;
• Casing material selection and set up with final material selected is 97% complete;
• Conditions met regarding size, weight and output capacity is 100% complete;
• Test Safe testing (see below) materials and electronics is at 25%.

During the quarter the electronic hardware design was submitted to Test Safe for evaluation and approval. I was notified in December that I needed to make some alterations to the UPS output as they do not recognise active barrier technology to be suitable for Ex ia
applications without additional protection. New drawings were submitted on the 17th January.

The prototype electronics has now been running for five months and is performing well. No more issues with the earlier slow battery charging. On-going testing of the electronics to monitor charging, discharging of the cells as well as function and reliability and safety. Whilst we wait for Test Safe.

Test Safe in Londonderry to test the following:

- Casing Material with technical data for testing, TBA;
- Battery Cells along with all their technical data for testing, TBA;
- Internal Encapsulant Material along with technical data for testing, TBA;
- Electronic drawings, PCB layouts, and parts lists for test safe to analyse and check creepage distances, component suitability, and that general design requirements have been met, TBA; and
- Sample operator interface to be tested in February, delayed due to above.

C27019
Underground Compressed Air Vehicle

AMM Project Development
Michael Christian

Value: $120,000
Report Expected: August 2019
Industry Monitor/s: Greg Briggs, Rick Chugg
ACARP Contact: Patrick Tyrrell

The objective of the project is to:

- Develop a prototype machine for transporting people in an underground coal mine;
- Test the practical application of compressed air engines as a replacement for existing diesel-powered transport;
- Prove this technology can travel an acceptable duration on one charge of compressed air;
- Show that mobile equipment can run intrinsically safe lighting system;
- Provide the underground coal mining industry with a personal transport vehicle that is diesel particulate free;
- Capture adequate results which can expand the practical use of compressed air engines as a direct replacement for all underground diesel engines eg underground loader.

The period from November to January has seen significant progress on the UCRAV prototype build. The recently introduced industry monitor Rick Chugg visited our workshop and test drove the prototype around the facility and providing valuable feedback on its performance. The compressed air containment enclosure has been designed, undergone stress and deformity analysis modelling and is 40% constructed. Drivability testing has been completed with the final drive ratio’s defined. The motor has been tested with the new cam shaft design providing 35% power improvement as indicated by our previously reported calculation.

The braking system design has been finalised and components ordered with expected delivery late February. The intrinsically safe lighting design has been finalised and components ordered with expected delivery also in late February.

The next quarter will see expected completion of the Design Risk Assessment, completed construction of the compressed air containment enclosure, fitment of the braking system and intrinsically safe lighting systems.

C27075
Advanced Pattern Recognition through Machine Learning for DAS Conveyor Condition Monitoring

University of Queensland
Paul Wilson

Value: $271,200
Report Expected: August 2019
Industry Monitor/s: Brad Lucke, Clinton Vanderkruk, David Goodale, Kevin Rowe, Peter Bergin
ACARP Contact:

Distributed acoustic sensing using fibre optics generates a huge amount of data with one frequency plot per 500 mm of conveyor length. In order to reduce the human workload of interpreting the frequency plots an expert system is used to analyse the frequency patterns and to estimate the type and degree of wear in the bearings of each linestand. The intention of the project is to improve the effectiveness and accuracy of the pattern recognition in order to deliver better condition reports and to do this by using the latest methods of machine learning.

Because of the paucity of reliable training data, and because clustering is the only effective approach in those circumstances, the clustering-based machine learning approach was used for the current phase of work. With the vast amount of data acquired from field testing, new information about the conveyor system has been discovered and is statistically repeatable. The new information has already improved the expert system developed for DAS conveyor condition monitoring.

The statistical approach and cluster analysis were further investigated and we have achieved the following points of success:

- Principal components analysis was used to demonstrate that the original five identified failure mode frequency patterns are valid and statistically independent;
- Cluster analysis has revealed that the fast Fourier transform plots produced by the current system include harmonics from the return idlers which can be of a different diameter. Due to this, the processing
algorithms will now account for the fundamental belt harmonic models for both the carry and return idlers. This will improve the accuracy of the expert system;

- The carry and return idler harmonic models can be used as a speed indicator for the conveyor belt, and can potentially be used as a shell wear indicator;
- Cluster analysis has revealed that there are four types of haystack clusters, each having significant features from each other. These characteristics will now be accounted for in the expert system;
- The feature that defines the newly identified “bouncing” bearing wear pattern is classified as one of the four types of haystack clusters; and
- The theoretical natural bearing frequencies (of the bearing components) can be used as an indicator for specific bearing wear types, but will not be indicative of the exact frequency due to the complex physics involved in the wear.

C28003
Lithium Traction Battery for Underground Coal Project: Stage 2 Build, Test and Certify a Heavy Duty Lithium Battery Module Capable of Powering Underground Coal Plant

Energetique Mining Vehicles
Justin Bain
Phil Coop
Richard Eveleigh

Value: $739,750
Report Expected: September 2019
Industry Monitor/s: Brad Lucke, Greg Briggs, Paul Wyatt, Peter Liston, Rick Chugg, Sharif Burra, Patrick Tyrrell

ACARP Contact: Patrick Tyrrell

The objective of the project is to engineer, build and certify a high-performance battery for use in an Electric Vehicle (EV) system that meets Australian compliance requirements. In the previous project (stage 1), EMV conducted a successful design verification of its heavy-duty lithium battery modules design potential to meet IEC60079 standards for operating in an explosive atmosphere within a coal mine. At the end of this project (stage 2), certified heavy-duty lithium battery modules will be powering an underground coal vehicle.

The following key activities have been conducted to date:

- Long lead time component procurement activities for the battery builds;
- First pass standards review (in addition to stage 1 IEC60079 review) with consideration of the battery design and functionality when in underground operation, (ongoing);
- Planning with a mechanical integration partner for the Proof of Concept vehicle, (ongoing);
- Preparation of an electric flameproof motor strategy;
- Custom on-board charger developments, scoping study and report writing, (ongoing);
- Preparations for review and update of the Failure, Modes, Effects and Criticality Analysis (FMECA) conducted in Stage 1; and
- Preparation for Design and operational first pass risk assessments.

Key tasks to be conducted include:

- Complete front-end engineering plan and resourcing;
- Conducting the FMECA, design and operational risk assessments with industry experts;
- Final design and assembly of battery modules to the confirmed specifications;
- Comprehensive workshop bench-testing and field trialing;
- Additional Battery Management System (BMS) developments and programming;
- Certification testing by the test authority;
- Integrating the certified battery modules and complete battery electric vehicle (BEV) system into a Proof of Concept vehicle; and
- Field trialing of the Proof of Concept electric vehicle in an underground coal mine.

Mineral Technology and Production

C20033
Development of a Safer Underground Explosive

University of New South Wales
Andres Castro
Duncan Chalmers

Value: $323,500
Report Expected: February 2019
Industry Monitor/s: Bharath Belle, Brad Elvy, Danny Brouwer, Russell Thomas, Patrick Tyrrell

ACARP Contact: Patrick Tyrrell

An unsuccessful attempt was made to recommission the gallery on 6th September after a test damaged the door/structure, the investigation has been completed, work is expected to resume in the near future.
C25069
Adaptive Protection Techniques in Mining Electrical Systems
ResTech
Clint Bruin

Value: $304,150
Report Expected: May 2019
Industry Monitor/s: Brad Lucke, Greg Briggs
ACARP Contact: Peter Bergin

The key objective is to demonstrate test the value of adaptive protection techniques at one or more mine sites. Our specific objectives can be set out as follows:

- Gather existing data and experience from mines on nuisance tripping and protection settings in order to better evaluate the opportunities for productivity gains;
- Record as much relevant operating data as possible from real mines. For example, obtaining data on variations in pilot earth resistance and measured earth leakage current over long periods will be valuable;
- Examine standards and regulations to identify areas that may restrict the scope of adaptive protection unnecessarily. Proposals for changes would be made, with technical arguments;
- Construct an adaptive protection system and trial it, as best possible, in a mine as well as on a bench top model. The details on how best to implement this may evolve during the project implementation but the system envisaged would take real measurements, via the fiber network, from protection relays in a working mine and implement a protection controller at the mine surface control room. The protection controller would display and record the recommended protection settings, as well as the actual settings, for consideration by the mine personnel;
- Analyse all data obtained and report on the results.

The project start was delayed and, in addition, there has been difficulty in obtaining suitable resources to program the adaptive protection system however these issues have been solved in the last few months.

The software for the trial has now been completed and fully bench tested. It has also been tested communicating with two IPX relays over the network.

A typical screen shot during system configuration is shown below.

At the time of writing, the engineer at the trial site is providing us with contact details for his automation engineer and it is expected that the system will be installed and operating at the trial site within the next two weeks. The aim is to operate for at least two months. Initial data will be analysed as the system continues to operate.

C26052
Low Cost Laser and Video 3D Imaging Equipment
CSIRO
Peter Reid

Value: $196,261
Report Expected: March 2019
Industry Monitor/s: Brad Lucke
ACARP Contact: Patrick Tyrrell

The objective of this project is to design, manufacture and certify a flameproof enclosure that is suitable for mounting 3d laser and video-based sensors underground in an explosive atmosphere. At the completion of this project it is expected that a number of these enclosures will be fully manufactured and certified with a Laser assembly fully installed, ready for use underground.

Certification of the enclosure is now complete; the enclosure and design have now passed all requirements of 60079-0 & 60079-1 and an IECEx Certificate of Conformity has been issued.

The project report is currently being complied, and expected to be finished by end of February.
C27051
Assistive Shuttle Car Guidance System - Stage 2 Implementation
CSIRO
Jonathon Ralston

Value: $227,275
Report Expected: December 2019
Industry Monitor/s: Bruce Davies
Roadway Development Task Group
ACARP Contact: Patrick Tyrrell

This project aims to develop and demonstrate a new guidance capability that will enable a shuttle car to repeatedly tram the path between a continuous miner and the conveyor bootend in an automatically manner. The central motivation for the work is improve personnel safety and development performance.

The project’s objectives are to:
- Develop a retrofittable guidance prototype to enable supervised auto-tramming;
- Demonstrate the tramming system operating in an analogous underground environment;
- Evaluate performance in a non-operational context with relevant control features.

The key project deliverables are a prototype guidance system and a report that describes project development, outcomes and recommendations.

The first stage of planned activity is almost complete. Activities have included a careful review of system functional requirements, formal design meetings to refine proposed assistive guidance architecture, and exploration of ways to accelerate system development and validation. Important interactions with the host mine site have also been ongoing in order to identify practical deployment matters such as shuttle car availability, complexity of system interfacing, staged technical development plans, and timing for underground validation campaigns.

C27055
LASC Automation 10 Years On
CSIRO
Jonathon Ralston

Value: $101,770
Report Expected: March 2019
Industry Monitor/s: Brad Lucke
ACARP Contact: Patrick Tyrrell

This project is a strategic review of current and required longwall automation capability that aims to deliver an updated assessment of longwall automation practice and future drivers. The overall intention is to provide industry with greater insight and confidence to accelerate the deployment of high-value automation to improve longwall operations.

C25058
Self Drilling Bolt Automation Trial
OKA Rock Bolt Technologies
Mark Levey
Paul Charlton

Value: $1,396,000
Report Expected: March 2019
Industry Monitor/s: Paul O’Grady
Roadway Development Task Group
ACARP Contact: Patrick Tyrrell

The project objectives are:
- The OKA Technology is further refined using findings from project C25058 and integrated into the design and development of a hazardous zone compliant retro-fit pack for a continuous miner; and
- A meaningful underground trial of the retro-fit equipment at a production face is conducted. The technology is to be tested for reliability and robustness in a real production environment.
Progress to date includes:

- A review was carried out of the findings from the 500 bolt underground trial held 2016 using an airtrack bolting rig with the retro-fitted prototype to install vertical, inclined and horizontal bolts;
- Design of the production standard prototype chemical pumping and delivery system is complete;
- Procurement and manufacture of all components is complete;
- The host mine released and delivered the continuous miner for modifications to adapt the OKA technology late July;
- Assembly of the chemical injection modules was completed in February;
- The software control system components and associated wiring are now completed;
- Testing and commissioning of the injection modules in the workshop began mid-April 2018. The intrinsically safe control system programming and commissioning has been delayed due to human resource availability from the supplier. Although work is now progressing, it has delayed the project over 12 months;
- Load transfer testing is currently taking place using the Oka system to install bolts into a workshop purpose-built test rig. Once all testing is complete, the injection units will be relocated to the continuous miner site at another workshop for re-programming of the software to allow for simultaneous bolting from three bolting rigs;
- The host site is currently re-evaluating options to facilitate the trial. Hopefully the trial can be conducted during the first half of the year.

C25068
Automated Long Tendon Installation System

Conway Engineering
Des Conway

Value: $184,500
Report Expected: October 2019
Industry Monitor/s: Roadway Development Task Group
ACARP Contact: Patrick Tyrrell

The project objectives are:

- To develop a proof of concept prototype ‘spin & push’ (Tornado) machine that allows the core theories and principles behind the design to be proven prior to development of an underground ready system for subsequent commercialisation; and
- To present a report summarising findings from research into and the subsequent development of concepts for an Automated Long Tendon Installation System (ALTIS) utilising the Tornado.

Initial wet tests with the Tornado have been completed in the workshop, using a horizontal representation of a bore hole (steel tube). Mixed results were achieved, with some concerning evidence regarding the interaction between the long ten don tip and the resin sausage skin coming to light. Two different long tendons have now been trialled—

with more testing scheduled to occur in the coming weeks. If results of further testing are looking positive, an underground test will be scheduled to stress test the device in the real working environment and gather feedback from end users.

There has been no further work on ALTIS since last report.

C26051
Machine Bolting and Geotechnical Monitoring System

CSIRO
Jonathon Ralston

Value: $275,490
Report Expected: March 2019
Industry Monitor/s: Roadway Development Task Group
ACARP Contact: Patrick Tyrrell

This project will develop a machine-based, bolt placement and roadway geometry profiling system based on laser scanning technology to provide new information streams to assist operational and geotechnical personnel achieve a more robust, deterministic and efficient roadway development process. The project objectives are to:

- Develop a laser-based 3D scanning system suitable for retrofitting on underground vehicles;
- Validate mapping software for bolt location and type, and local profile deformation; and
- Determine achievable sensing performance in stationary and mobile configurations.

The approach is based on the use of laser sensing to measure the roadway profile. This profile is then processed to identify the location of installed roof bolts. A parallel activity is to explore the degree to which roadway deformation can also be measured.

All experimental and technical aspects of the core work program have been completed. Major activities undertaken in the last quarter included an ongoing review of project process and key outcomes, analysis of major results and implications, ongoing writing for the final report and targeting recommendations to stage future high value activity to advance roadway development automation. The final report will be submitted for review in early February.
C27076
Underground Coal Mine Gateroad Development Continuous Haulage System

Premron
Mick Whelan

Value: $2,495,000
Report Expected: July 2019
Industry Monitor/s: Roadway Development Task Group
ACARP Contact: Patrick Tyrrell

This project is a continuation of projects C22009, C23017 and C24023, which aims to develop a semi-autonomous Continuous Haulage System for mine gateroad development, utilising the closed conveyor system of the ‘Premron CHS’ ©.

The project is based around the following key objectives:
• Complete mine systematisation studies with host mine;
• Manufacture and demonstrate a full scale, full length (180m), fully functional ‘mine compliant’ Premron CHS installed on the surface at Kestrel Coal Mine and mounted on a mine monorail test rig, simulating an operating gateroad;
• Production of O&M manuals, safety files and QA documentation;
• Continuous batch feeding and acceptance at host mine site (surface trial); and
• Installation and trial operation in a fully working gateroad panel (underground trial).

The Premron CHS installation has been completed and fitted to the monorail testing track, on the surface at Kestrel. Electrical components are all installed and terminated. Commissioning of the system is currently being completed and is likely to be handed over to Kestrel for the start of the surface trials late February.

The Gauley Robertson sizer feeder is currently undergoing the final stage of its build, with commissioning to follow the Premron CHS. Post this, the integration between the CHS and sizer will occur and be tested, included the autonomous functions of the machines.

The surface trial will include both dry/wet testing, standard rom coal (various lump sizes) and fully simulated operating gate road trial, with boot end, panel belt structure, fans, vent tube, services (power/air and water), catenary, sizer/feeder and other mining equipment, which will ensure integration of the Premron CHS machine.

The underground trials are likely to occur as early as May or within the second quarter of the year.

<table>
<thead>
<tr>
<th>Strata Control and Windblasts</th>
</tr>
</thead>
</table>

C24015
Convergence Based Roof Support Design

PDR Engineers
Terry Medhurst

Value: $245,800
Report Expected: February 2019
Industry Monitor/s: Brian Vorster, Gavin Lowing, Paul Buddery, Roger Byrnes
ACARP Contact: Patrick Tyrrell

A draft report is with the industry monitor(s) for review.

C25057
Review of Rib Failure Mechanisms and Performance of Rib Support

SCT Operations
Yvette Heritage

Value: $186,500
Report Expected: April 2019
Industry Monitor/s: Paul Buddery, Roger Byrnes
ACARP Contact: Peter Bergin

This project aims to review the mechanics of rib deformation during development and longwall retreat and to investigate effective support design to control the different mechanisms of rib deformation in order to minimise the occurrences of rib failure. The work program consists of a combined approach of deformation monitoring at underground sites and modelling to understand the mechanics of rib deformation and support interaction.

The rib deformation monitoring covered three different seams, across several different coalfields. Two of the mine test sites are now complete.

At the second New South Wales mine site the longwall retreat indicated the mechanism for deformation within the ribs was observed to be vertical shear failure occurring to at least 6m into the ribs. The roof deformation at this location also has a 6m HOS. Modelling is underway to investigate the link between roof and rib deformation at this site.

The monitoring to date suggests that the role of rib support is to stop the progression of failure further into the rib through controlling kinematic failures and generating confinement of the failed near rib. The observed mechanisms driving the rib deformation ranged from bedding shear failure along weak claystone bands, to vertical shear fractures, to kinematic failures driven by shear failure dilation. The site-specific failure mechanisms...
are required to be understood in order to effectively implement these controls.

The project is waiting on access to the last New South Wales mine to complete the last site in the development stress environment.

C25059

Intrinsically Safe, Integrated Wireless Communications Network with a Distributed Array of Geotechnical Sensors

SCT Operations
Stuart MacGregor

Value: $339,787
Report Expected: February 2019
Industry Monitor/s: Brian Vorster, Peter Corbett
ACARP Contact: Peter Bergin

The objectives of this project are to:
• Develop a wireless communications network to interface with existing mine communications networks that has IS certification ready for submission; and
• Develop a range of wireless capable geotechnical instruments including Tell Tales, Stress Cells, Instrumented Bolts, Shear Strips and Geophones to provide a distributed monitoring array for underground coal mines.

The following occurred during the quarter:
• Finalisation of all submissions related to the I.S certification was conducted during the quarter. This has involved extensive work developing multiple test units for destructive testing;
• Development of associated software for polling, interrogation and management of the communications network was finalised;
• The final field trial is yet to occur. Access to an underground site for remaining field trials has proved difficult. We are hopeful of gaining access to an active underground coal mine in the coming quarter.

C25060

Borehole Shear Monitoring Device for Routine Application in Roadways

SCT Operations
Stuart MacGregor

Value: $149,863
Report Expected: March 2019
Industry Monitor/s: Brian Vorster, Roger Byrnes
ACARP Contact: Peter Bergin

A draft report is with the industry monitor(s) for review.

C26063

Reliable Estimation of Horizontal Stress Magnitudes from Borehole Breakout Data

University of New South Wales
Joung Oh

Value: $123,000
Report Expected: March 2019
Industry Monitor/s: Brian Vorster, Roger Byrnes
ACARP Contact: Peter Bergin

The primary objective of this project is to develop a simple and reliable method to predict in situ horizontal stress magnitudes from existing borehole breakout data. Stress measurement techniques currently available in the mining industry are expensive and time consuming. The results of this project will produce an inexpensive and reliable method that can be included in stress measurement programs to identify high risk areas where the mining conditions will be adversely affected. To achieve this objective, the project involves four areas of investigations, namely, literature review, lab testing, numerical modelling, and back analysis.

Due to the large plastic deformation of the cement samples, they were replaced by hydro-stone samples with material to water ratio at 1:0.35. Experimental results revealed that both breakout geometries are stress dependent, similar to the sandstone experiments. It was also observed that the uniaxial compressive strength of the specimen has more influence on the breakout angular span than the normalised breakout depth.

As planned, based on the further study of the field data and numerical simulation, the improvement of the model has completed. The improved stress estimation using borehole breakout contains two sub-model for stress calculation and cross-checking. The final report has been prepared which covers the work done in the past two years. It is expected to be submitted in February.
C26064
Floor Stability: Comprehensive Investigation Into Failure Mechanisms and Controlling Factors

University of New South Wales
Serkan Saydam

Value: $298,940
Report Expected: March 2019
Industry Monitor/s: Adam Lines, Brian Vorster, Patrycja Sheffield, Paul Buddery, Peter Corbett

ACARP Contact: Peter Bergin

The main objective of this project is to conduct a comprehensive multidisciplinary investigation into floor failure mechanisms and controlling factors using experimental, numerical and analytical methods. The project aims to develop a reliable floor failure prediction model and definitive guidelines for mitigating or eliminating floor failures. The guidelines will be supported with a combination of effective monitoring and instrumentation techniques, innovative mine design strategies and new ground support technologies. A mine floor rating system that describes the floor performance is also sought to be developed.

The floor heave monitoring using the remote reading tell-tale systems and shear strips at Mine A has been completed. Since the beginning in July 2018, the movements detected from the instrumentation have been minimal as no significant floor heave has been reported around the monitoring sites of the mine.

The floor monitoring at Mine B will be conducted from February due to the delays associated with the operational issues at the mine. The shear strips and GEL extensometers will be used at two monitoring locations. The effect of longwall retreat on the deformation of floor will be investigated.

The data collection has almost been completed from Mine A, Mine B and Mine C. Data such as the floor lithology, mechanical properties of the floor, depth of cover and direction of horizontal stresses around the floor heave locations have been collected. The collected data, along with the failure mechanisms simulated by numerical modelling, will form the basis for the floor rating system.

C27040
Numerical Modelling Approach to Better Understand the Effect of Cable Bolt Performance on Roof Failure Mechanisms in Varying Rock Mass Conditions

University of New South Wales
Ali Mirzaghorbanali, Najdat Aziz, Paul Hagan

Value: $389,000
Report Expected: July 2020
Industry Monitor/s: Paul O’Grady, Peter Corbett, Peter Bergin

ACARP Contact: Peter Bergin

Numerical Modelling

Work on this aspect of the project is being undertaken concurrently at UNSW and USQ.

At UNSW, numerical models have been developed based on the data from Mine Site A and parametric studies on strata conditions have been conducted using Universal Distinct Element Code (UDEC). The study is to investigate the influence of material properties on strata movements when an excavation is made. The parameters investigated include elastic modulus, friction angle, cohesion, and tensile strength of each layer, bedding thickness of roof layers, and discontinuity properties. In addition, progress has been made on the literature review.

At USQ, comprehensive and detailed literature review was carried out. This is intended to classify past research studies and collect relevant experimental data. Preliminary numerical model development was conducted using Universal Distinct Element Code (UDEC) within a two-dimensional framework. The preliminary model will be further extended to include various cable types and pretension values. The numerical model will be then calibrated to simulate shear load transfer mechanisms of cable bolts having various angles to the shearing direction once experimental data becomes available.

Field Data Analysis

The project team has visited Mine Sites A and B to identify potential test site. Information has been collected during the visit and we also obtained permission from the mine site management to receive more field monitoring data in the future. The geology data and rock properties from Mine Site A has been used in developing preliminary numerical models. Information available from public domain relevant to these two sites have also been collected. Two shear strips designed to measure roof shear behaviour were order in November 2018 and expected to be delivered in Q1 2019.
C27045
Assessment of Longwall Mining Induced Connective Fracturing: Stage 2

CSIRO
Deepak Adhikary

Value: $201,250
Report Expected: December 2019
Industry Monitor/s: Paul Buddery, Peter Corbett
ACARP Contact: Peter Bergin

The objectives of the project are to:
• Further expand the science base and understanding of strata caving mechanics during longwall mining and specifically focus on the fracturing processes in coal measure rocks eg sandstone, siltstone, claystone, shale, coal etc;
• Extend and fine tune the technique developed in project C24020 of initiating and propagating fractures, estimating fracture aperture and connectedness and thereby calculating the mining induced permeability of strata from first principles; and
• Validate and quantify the height of connected fractures above longwall panels from studies of up to three additional participating mines with varying geology, and validate the proposed modelling method and come up with simple to use charts that can be used to (a) assess the height of mining induced connected fractures at other mine sites; and (b) further refine with additional mine site data when they become available.

Review of functionality of existing processes and software has been completed, a slight modification to PFC subroutines has been made.

PFC models representing Mine site 1 LW 3 and LW 9 are developed and run; the model results indicated a very different pattern of connective fracturing compared to the results obtained for a mine site reported in C24020. These data are being further analysed.

PFC models representing mine site 2 are being developed.

Mine site 3 has been contacted for the mine data; we expect to receive the mine data in the near future.

The project deliverable will be a report containing charts/tables and a numerical modelling guideline (including all the source codes developed in the project) for estimating the height of connective fracturing that can create pathways for increased groundwater inflow and excessive gas emission into longwall workings from adjacent gassy seams.

C27071
Intrinsically Safe Digital Networked 3D Roof Bolt

Holville
Anne Wylie

Value: $140,000
Report Expected: January 2020
Industry Monitor/s: Mick Stadler, Paul Buddery, Roger Byrnes
ACARP Contact: Peter Bergin

The project objective is to develop an intrinsically safe instrumented digital roof bolt that will:
• Accurately measure axial strain and bending in three dimensions;
• Interface to the Holville handheld terminal (project C25060), the wireless network of geotechnical sensors project C25059, and the IS certified (IECEx 12.0034X) Holville roofAlert™ communications and power backbone;
• Provide a cost-effective alternative to the routine monitoring of existing analogue quarter bridge strain gauged roof bolts.

Review of performance of low cost resistive and capacitive transducers has been completed. Inductive strain measurement is being reviewed. A prototype analogue multiplexer has been designed. The IS handheld data collection terminal to be used for this project is currently in the certification process with Ex Testing and Certification.

C27073
Roadway Stability Monitoring System

CSIRO
Chad Hargrave

Value: $239,565
Report Expected: March 2020
Industry Monitor/s: Jim Sandford, Paul Buddery, Roger Byrnes
ACARP Contact: Patrick Tyrrell

This project is an extension to an earlier project (C25062), which successfully demonstrated, in an underground field trial under realistic conditions, a new radar scanning technology that can detect millimetric changes in roadway structure. This project will take the next steps towards development of a practical monitoring system for operational use by addressing three key issues: spatial registration, temporal coverage and practical deployment. These objectives will be met by the achieving the following outcomes:
• Delivery of a new technology and method for both survey and continuous monitoring of underground structures;
• Clear indication of the capabilities and limitations of the technology for both the survey and monitoring applications; and
• Development of a roadmap for the implementation of the technology as a product available to the industry.

The goal of the project is to fulfil these objectives to the stage where this new rapid survey capability has been established as viable, and can be demonstrated to the mining industry for future take up and integration into their underground mine management processes.

After finalising the design of the next-generation scanning radar sensor, the new hardware has been ordered. As this improved radar system will become available in Q2 2019, the project monitors have agreed to an extension of the project to allow the bulk of the underground testing to take place using the new system.

The project team is therefore seeking to re-negotiate access and timing (Q3/4 2019) for a suitable target mine site for these trials, based on the following criteria:
• Non-IS system, would need to be registered as UPEE;
• Trial location should be in the NERZ, ideally a location with actual ground movement, rather than simulating change through manual changes to roof/rib features.

Developments with the current radar system in a monitoring configuration are proceeding with a view to providing a clear basis for comparison with the new scanning technology. The test tunnel built for the previous project is being used for this testing.

C25065
Specific Gas Emission Patterns from Different Coal Seams
CSIRO
Rao Balusu

Value: $277,340
Report Expected: April 2019
Industry Monitor/s: Bharath Belle, John Grievs, Paul O’Grady, Patrick Tyrrell
ACARP Contact: Patrick Tyrrell

The objective of this project is to characterise goaf gas emissions patterns from different coal seams and develop appropriate gas emission prediction models for Australian mining conditions. The project work will involve simulation of gas emissions from different coal seams during longwall extraction using numerical and empirical models, and field studies to obtain post-mining residual gas contents of different coal seams in Hunter Valley and Bowen Basin coalfields. The project aims to obtain greater insights into goaf gas release rates from different coal seams at various distances behind the retreating longwall face. The project studies also aim to establish relationship between coal seam position and residual gas content, and develop gas emission rate profiles along the longwall panels. The project results also help in planning parameters necessary to assess gas emissions after sealing, in addition to production related gas management.

All the project studies have been completed. The draft final report is now being prepared and is expected to be submitted soon for review.

C25066
Gas Management and Risk Mitigation Strategies for Longwalls
CSIRO
Rao Balusu

Value: $289,000
Report Expected: April 2019
Industry Monitor/s: Bharath Belle, John Grievs, Paul O’Grady, Patrick Tyrrell
ACARP Contact: Patrick Tyrrell

The objective of this project is to develop optimum goaf gas management and risk mitigation strategies for highly gassy longwall mines to support achieving benchmark production rates. The project work will involve field studies, modelling investigations, data analyses and demonstration of optimum gas management technologies and strategies at highly gassy mines. The project aims to obtain a fundamental understanding of the effect of different ventilation systems and various other parameters on effectiveness and performance of different types of surface and underground gas drainage.
technologies and designs. The project studies also provide greater insights into goaf gas migration patterns under different scenarios of main fans failure, large barometric pressure variations and major goaf falls, and an assessment of the risk of irrespirable atmosphere prevailing on the face through transient modelling analyses.

All the project studies have been completed. The draft final report is now being prepared and is expected to be submitted soon for review.

C25072
New Approaches to Mine Gas Analysis and Ratios

Simtars
Fiona Clarkson

Value: $103,689
Report Expected: February 2019
Industry Monitor/s: Bharath Belle, John Grieves

ACARP Contact: Peter Bergin

A draft report is with the industry monitor(s) for review.

C26050
Floor Seam Gas Emission Characterisation and Optimal Drainage Strategies for Longwall Mining

CSIRO
Qingdong Qu

Value: $153,075
Report Expected: April 2019
Industry Monitor/s: Bharath Belle, David Webb

ACARP Contact: Patrick Tyrrell

The project aims to characterise floor seam gas emissions in longwall mining and identify optimal gas drainage strategies. The expected objectives include:

- Characterisation of mining induced floor strata, groundwater and gas behaviours;
- An improved floor gas emission prediction model;
- Floor seam gas flow patterns; and
- Optimal floor gas drainage strategies.

The project works are almost complete and the final project report is being prepared. A project meeting with a supporting mine is scheduled in Mid-February for results discussion and collection of a little bit more data. The project report will be submitted by the end of April.

C26055
Control and Management of Outburst Risk

University of Wollongong
Dennis Black
Najdat Aziz

Value: $100,000
Report Expected: February 2019
Industry Monitor/s: David Webb, Russell Thomas, Sharif Burra

ACARP Contact: Peter Bergin

A draft report is with the industry monitor(s) for review.

C26058
Optimisation of the Coal Seam Gas Predrainage Process

Palaris Australia
Mark Blanch

Value: $293,220
Report Expected: April 2019
Industry Monitor/s: David Webb, Russell Thomas, Sharif Burra

ACARP Contact: Peter Bergin

No report received.

C27035
Automatic Leak Detection for Tube Bundle Systems

Simtars
Sean Muller, Snezana Bajic

Value: $220,000
Report Expected: October 2019
Industry Monitor/s: Bharath Belle, John Grieves

ACARP Contact: Patrick Tyrrell

The objective of this project is to develop a fully automated integrity testing system prototype which is based on information on the flow rates and pressures on tubes from this research. This prototype will be able to be retrofitted to any tube bundle system, regardless of the supplier. The basis for the design of the automated system is Delta Automation’s manual integrity testing system.

The project comprises of three phases. The first phase is the accumulation and evaluation of presently available information relating to flow rates, designs and pressures in tube bundle systems in underground coal mines. During the second phase the specifications for automatic system prototype will be developed. The final phase will be to retrofit the prototype to a tube bundle systems at the mines, which have existing tube bundle system
supplied by three different manufacturers (Delta Automation, SICK and ADT). The information from this testing will then be used to compile the final report.

An extension was requested for the project and granted due to events which required significant industry support from Simtars. Project work is recommencing in Q1 2019 along with a proposed review meeting to discuss an updated timeline for the project and to present the findings from the underground visits and investigation work completed so far.

C27037
Modelling of Strata Gas and Water Transport to the Mining Area

CSIRO
Zhejun Pan

Value: $89,900
Report Expected: May 2019
Industry Monitor/s: Bharath Belle, David Webb
ACARP Contact: Peter Bergin

The objective of this project is to further develop the reservoir simulator, SIMED II, to calculate the amount of gas (and water) migration to the working area, which is capable of accurately and simultaneously describing:

• Gas (and water) release mechanism from the working coal seam;
• Gas (and water) release mechanism from the goaf;
• Gas (and water) release mechanism from mined or unmined coal seams above and below the working coal seam;
• Gas (and water) release mechanism from gas containing sandstone/siltstone and mudstone/shale;
• Gas and water through the drainage boreholes.

In this reporting period, validation of the new development work has been carried out. Moreover, the impact of stress change on permeability for both overlying and underlying formations during the mining process was suggested to include in the modelling work during the mid-year review. Reports C23008 and C23009 have been studied for stress change and its impact on permeability has been also studied. Case studies on gas released from overlying and underlying formations to the goaf and working area for one selected coal mine are underway. The impacts of different rock properties on the gas rates are being investigated.

C27072
Intrinsically Safe Borehole Survey Tool

Holville
Anne Wylie

Value: $120,000
Report Expected: June 2020
Industry Monitor/s: Mick Stadler, Paul Buddery, Roger Byrnes
ACARP Contact: Peter Bergin

The project objectives are to develop an intrinsically safe borehole survey tool that will:

• Capture and store video and still images for later analysis;
• Record 3D spatial and temperature data linked to image capture; and
• Provide a local display for reviewing data as it is captured, allowing features to be examined in greater detail.

At the completion of the project it is expected to have a working prototype machine field tested and documentation submitted for Ex certification.

Most of the hardware required has now been specified. Lighting and lenses for the camera are now being evaluated with the objective of maximising the depth of field. Prototype borehole survey tool modules are now being designed and manufactured.
### OPEN CUT

#### Drilling and Blasting

**C25005**  
Mine Based Trials of Alternative Explosive Formulations to Eliminate Nitrogen Oxide Emissions: Stage 3  
University of Queensland  
Italo Onederra  
Miguel Araos  

- **Value:** $685,332  
- **Report Expected:** February 2019  
- **Industry Monitor/s:** Chris Bartley, Chris Davis, Ewen Mills, Travis Zolnikov, Cam Davidson  

**ACARP Contact:** Anne Mabardi  

A draft report is with the industry monitor(s) for review.

**C27034**  
Top of Coal Detection Phase 4  
University of Queensland  
Enver Bajram  

- **Value:** $395,310  
- **Report Expected:** April 2019  
- **Industry Monitor/s:** Max Ayliffe, Cam Davidson  

**ACARP Contact:** Anne Mabardi  

This project is currently gearing up for a field trial. All components have been designed and are currently in manufacture for the trial. It is envisaged the trial will take place late April to mid-May and will run for a three week duration.

### Environment

**C25031**  
Closure Criteria for River Diversions: An Alternative to Reference Sites  
Edith Cowan University  
Melanie Blanchette  

- **Value:** $232,293  
- **Report Expected:** February 2019  
- **Industry Monitor/s:** John Watson, Michael Moore, Anne Mabardi  

**ACARP Contact:** Anne Mabardi  

A draft report is with the industry monitor(s) for review.

**C25039**  
Long Term Salt Generation from Coal Spoils  
University of Queensland  
Mansour Edraki  
Neil McIntyre  

- **Value:** $239,150  
- **Report Expected:** February 2019  
- **Industry Monitor/s:** Claire Cote, Scott Diggles  

**ACARP Contact:** Anne Mabardi  

A draft report is with the industry monitor(s) for review.

**C27009**  
Tailings Revegetation through the Vegetative Water Pump  
CSER Research  
Carmen Castor  
Mike Cole  

- **Value:** $447,000  
- **Report Expected:** February 2021  
- **Industry Monitor/s:** Chris Urzaa, Shaun Booth, Trent Cini  

**ACARP Contact:** Patrick Tyrrell  

Weather events, both temperature and rainfall have impacted on field studies in this quarter. This was amplified by a major rain event at Mine 1 in December that led to all plants in the Species Selection Experiment (SSE) being inundated for days or weeks (plant stakes can be seen in the flooded area in the photo below, the water level had already receded a little).  

![Weather impacted field studies](image_url)  

Luckily the weather also delayed the planting of other species in the SSE. They will now be planted in March. Of those that were planted in the Crack-Plate Trial (CPT) and SSE, survival since planting is shown in the table following.

| Survival Since Planting (%) of 18 plants in the Crack v Plate Trial and of 36 plants (24 for Eucalyptus camaldulensis) in the Species Selection Experiment (in the latter, the mean ± standard error of the mean is shown). |
The losses cannot simply be attributed to flooding, because a pre-flood survey had not been undertaken for the SSE, and some plants had been lost before this event. An interesting comparison between the CPT and SSE is the survival rate for Eucalyptus camaldulensis. In the CPT, at least some of the plants were partially inundated for a short time but had already established to a level that they could survive flooding. Those in the SSE that died must not have been mature enough to develop the gas pathways in the stem to the root system known to occur in this species, to supply oxygen, when inundated.

Last year was very much about safety protocols and setting up experiments, this year will focus on base line models for the species used and measuring seasonal effects on transpiration and plant health in the field. Work will begin in the field on the CPT where plants are growing well, as shown below.

<table>
<thead>
<tr>
<th>Crack v Plate Trial</th>
<th>% Surviving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eucalyptus camaldulensis - Crack</td>
<td>50</td>
</tr>
<tr>
<td>Eucalyptus camaldulensis - Plate</td>
<td>89</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species Selection Experiment</th>
<th>% Surviving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia implexa</td>
<td>0 ± 0</td>
</tr>
<tr>
<td>Casuarina cunninghamiana</td>
<td>45 ± 11</td>
</tr>
<tr>
<td>Casuarina glauca</td>
<td>83 ± 8</td>
</tr>
<tr>
<td>Corymbia maculata</td>
<td>11 ± 6</td>
</tr>
<tr>
<td>Eucalyptus camaldulensis</td>
<td>17 ± 10</td>
</tr>
<tr>
<td>Melaleuca quinquenervia</td>
<td>56 ± 10</td>
</tr>
</tbody>
</table>

C27030

**Examination of Past and Present Mine Rehabilitation to Grazing Land as a Guide to Future Research**

**NSW Department of Primary Industries**

Neil Griffiths

| Value:     | $166,203 |
| Report Expected: | August 2019 |
| Industry Monitor/s: | Bill Baxter, Nigel Charnock, Stephen White |
| ACARP Contact: | Patrick Tyrrell |

The project objective is to undertake a desk top collation and review of past and present mine pasture rehabilitation work undertaken in the Hunter Valley coal region, and conduct field assessment on a range of selected sites to identify practices which are most successful and likely to support sustainable grazing.

This project will identify the main drivers and successful practices for re-establishing functioning soil and pasture systems, potentially leading to faster rehabilitation outcomes and sustainable grazing land use management options for mine closure. It will identify and prioritise research opportunities to further improve practices for mine rehabilitation to pasture which meet the needs of both the mining and farming communities.

Reports and monitoring data have been received from seven Hunter Valley mines allowing progress with the desk top review. Further information from these sites, plus additional contributions from other mines and individuals with knowledge of past rehabilitation will be added to the review as it progresses.

Field work has still not been possible due to extended drought in the Upper Hunter. Continued favourable growing conditions are needed to allow pastures to mature for reliable pasture species identification and to allow soil biology to recover from drought conditions for meaningful assessment and comparisons to be made of soil biological activity. Very hot weather has burnt off new growth from rain at end of 2018. Limited storms are providing hope in some areas that assessments will be possible in autumn.

Introductory site visits and discussions with mine representatives were conducted late November providing insights into assessments to be conducted in autumn.
C27038
Self Sustaining Ecological Mine Rehabilitation that Achieves Recognised Ecological Communities

Umwelt (Australia)
Travis Peake

Value: $286,970
Report Expected: November 2019
Industry Monitor/s: Bill Baxter, Nigel Charnock
ACARP Contact: Patrick Tyrrell

Core objectives are to determine if mine rehabilitation can support recognisable and self-sustaining ecological communities and habitat for a range of threatened fauna species, in temperate woodland Australian environments. The project aims to develop principles to inform industry in appropriate rehabilitation objectives, performance criteria and completion criteria, as well as provide guidance on benchmark successional stage criteria and monitoring of progressive ecological rehabilitation. The project has a national context, with a focus on the Hunter Valley. Comparison of existing mine rehabilitation will be made to Plant Community Types (PCTs), TECs and BioBanking benchmarks.

This project will provide guidance to industry and government on use of ecological mine rehabilitation as viable offsets, which will lead to improved ecological outcomes in mine rehabilitation.

To date, the project has undertaken comprehensive literature review of relevant ecological mine rehabilitation reports and published articles, as well as legislation, policies and guidelines. Consultation with NSW OEH is ongoing regarding programs on mine rehabilitation, with close liaison with NSW OEH helping to ensure the project is relevant and suitable.

Collection and collation of existing ecological mine rehabilitation data, specifically from relevant Coal Mines in the Hunter Valley, is largely complete, including Biometric and floristic data from multiple rehab and reference (analogue) sites. This data is being subjected to analysis and the intensive field work component of the project will commence in autumn 2019.

C27042
Adaptation of Design Tools to Better Design Rehabilitation and Capping Over Highly Mobile Mine Waste

University of Newcastle
Garry Willgoose

Value: $439,000
Report Expected: June 2020
Industry Monitor/s: Alicia Hooper, Chris Quinn
ACARP Contact: Patrick Tyrrell

The main objective of this project is to develop a set of mine rehabilitation design tools that can predict the performance of a rehabilitated mine with and without a capping layer. The specific application is in the containment of highly mobile mine wastes (e.g., dispersive, reactive shales, tailings). The tool will be developed by merging an existing mine rehabilitation design tool, EAMS-SIBERIA, with a new computer code, SSSPAM. SSSPAM models the sediment characteristics (e.g., full particle size distribution of sediment) of a landscape surface (in this case a post mining landscape) that are currently not modelled by SIBERIA. A secondary objective is to be able to predict the mobility of sediment (primarily a factor of the particle size distribution) so that assessments can be made of that portion of the erosion that can be captured on site in sedimentation structures, and that material that will move off-site (and is either captured on floodplains or is transported to the coast by the rivers).

There has been work on three of the four tasks in this project. Two of the three mines that are test sites for the software have provided us with LiDAR elevation data from their current operation. This will allow us to select the field sites to be for testing of the software. Work has commenced in earnest on the adaptation of the SSSPAM software for this project.

Mine 1:
- Mine 1 contacted and need for DEMs indicated;
- Field visit discussed but put on hold due to Environmental Team commitments regarding planning for mine expansion/upgrade and submission of plans to relevant authorities;
- Need to liaise now regarding the acquisition of LiDAR data over the site to capture erosion features;
- Need to liaise for representative mine spoil to be sent to University of Newcastle for erosion parameter development.

Mine 2:
- LiDAR DEMs and orthophotos have been supplied;
- They have been systematically worked through and we have found that while the data has extensive coverage over the site, the point density is quite low for much of the site. The point cloud data density is ~1.5 pts/m². This means that any erosion feature with a length scale less than this will not be captured in
detail. For rills and gullies a point cloud density of ~10 pts/m² is required. This means that to create accurate DEMs of gullies (for the SIBERIA) modelling is not possible as there are insufficient points to correctly represent the gully;

• Another issue is that the LiDAR data set is only for one time period. More recent LiDAR data at a higher point density needs to be collected. This will allow (a) gullies to be better defined and (b) difference calculations between data sets to be performed to determine erosion rates and erosion model parameters;

• However, we have found an area where the point density is somewhat higher and we have been able to create an acceptable DEM (see attached) (0.3m grid). Given the low point density, this has required more time to perform than if the data was at a higher resolution;

• We are now calibrating SIBERIA to match the gully form based on this DEM and are making good progress.

Mine 3:

• Mine 3 has not been approached for LiDAR data at this stage because to date we have been focused on Mines 1 and 2. They will be approached shortly.

Software development:

• Determining what components of the SSSPAM are necessary and focused efforts of speeding up SSSPAM simulations is largely finished. This facilitates more thorough testing at the field sites because more simulations can be carried out;

• Software testing to determine the minimal data requirements that are needed to gain accurate results is currently underway. This will influence the type of laboratory testing to be done on field samples when they are collected;

• Some preliminary simulations using SIBERIA for the DEMs for Mine 1 and Mine 2 have been performed but they are not yet ground truthed so are only preliminary at this stage.

C27043
Towards Closure of Saline Pit Lakes: Understanding Biophysical Processes for Condition Assessment and Remediation

Edith Cowan University
Mark Lund

Value: $246,040
Report Expected: January 2020
Industry Monitor/s: John Watson
Ross Gooley
ACARP Contact: Patrick Tyrrell

In Australia, many community members and regulators expect that final voids will be backfilled. However, a lack of backfill materials combined with prohibitive costs (tens to hundreds of millions of dollars) ensures that pit lakes will be a permanent part of the landscape. Pit lakes are considered the ‘greatest legacy of open cut mining’ due to the potential for safety issues, ground and surface water contamination, and in-lake toxicity. Additionally, pit lake science has struggled to find a foothold in mainstream literature, limiting wider scientific exposure to the issue of pit lakes and holding back advancement of the development of remediation and closure approaches. Therefore, the broad objective of our proposed research is to understand pit lake biophysical processes for condition assessment and remediation options of Hunter Valley and Bowen Basin pit lakes.

Salinity is a key water quality issue with many Australian pit lakes. Many natural lakes are saline and have valuable ecosystem values. Understanding the role of catchments and nutrients inflows in maintaining salinity within useful ranges and driving ecosystem processes is therefore important to determine the range of future uses for these pit lakes. These future uses may include conservation, recreation, and aquaculture.

The overall project approach has two main components:

• In situ lake biophysical; and
• Experimental.

In situ component. We will determine the quantity of salt in the lake in conjunction with thermal stratification – key considerations in lake processes and closure options. We will also assess the risk of toxic metal leachate from void walls or backfill through a comprehensive water quality testing program. Biological endpoints (including cutting-edge microbial work) will be collected over time from the lake. Companies wishing to close pit lakes will need evidence in the form of robust data to discuss closure options. Development of a simple, low-cost monitoring framework that can identify the risks and opportunities associated with individual pit lakes allows companies to make informed decisions about relinquishment, ultimately reducing the risk associated with closure. Another benefit to industry from this project component will be a pit lake ‘report card.’ We have developed a ‘sliding scale’ of pit lake assessment, whereby pit lakes are ‘graded’ on their difficulty to rehabilitate. Both the monitoring program and report card are transferable and adaptable to pit lakes in other areas of the Hunter Valley and Bowen Basin, across Australia, or internationally.

Experimental component. Carbon (in the form of terrestrial organic matter) determines the nature of the aquatic food web and creates important habitat. Using tank mesocosms (1000 L) on site, we will test the effects of adding coarse, low-cost organic matter on lake water and sediments on biophysical and chemical endpoints (as measured in the lake). The purpose of this experiment is to test the water quality and biodiversity benefits of carbon addition in the pit lake. Our previous work has demonstrated that modifications to the edges of pit lakes to support plant growth, addition of organic matter, and planting of riparian zones prior to filling offer an effective, low-cost way to promote more rapid evolution of the lake towards improved water quality and biodiversity. We will use data collected from the lake to validate the ‘controls’ (tanks with no organic matter) and compare seasonal
temporal trajectories of collected data. The experimental component of the project provides companies with an indicator of what could be achieved under different lake closure scenarios using the passive treatment approach.

Preparations are nearing completion for the first round (early February) of pit lake sampling and establishment and commencement of the field experiment.

C27044
Testing the Resilience of Mine Site Rehabilitation with Fire

University of Queensland
Phill McKenna

Value: $239,537
Report Expected: March 2021
Industry Monitor/s: Craig Lockhart, Pieter Swart
ACARP Contact: Patrick Tyrrell

The aim of this project is to apply controlled fire at a range of mine sites in Queensland and New South Wales and to use a combination of ground monitoring transects and remote sensing technologies derived from satellite, drone and LiDAR products to assess the post-fire recovery dynamics and measure resilience.

Work undertaken in this quarter includes:
• Field data collection at Mine 2 for the 3-month post-fire assessment. A team of CMLR staff collected field data in November and measured 6 burnt transects and 6 unburnt transects/
• Data analysis for all sites is continuing and progress reports have been delivered to Mine 2 and Mine 3 in November;
• Planet satellite imagery of the fires have been downloaded and assessed for fire severity at Mine 2 and Mine 3;
• Proposals have been submitted for fires at three new mines with work proposed in 2019 depending on weather conditions; and
• Additional discussions are ongoing with new sites for potential burns in 2019.

Presentations promoting the project include the following:
• Presentation at Life of Mine (LOM) conference in September 2018;
• Presentation at Society for Ecological Restoration (SER) conferenced in September 2018; and
• Presentation at Central Queensland Mine Rehabilitation Group (CQMRG) in December 2018.

C27061
Open Path Boundary Monitoring for Operational Dust Control

Pacific Environment
Damon Roddis

Value: $54,912
Report Expected: April 2019
Industry Monitor/s: Andrew Speechly, John Watson
ACARP Contact: Patrick Tyrrell

The objective of this project is to strengthen the conclusions and recommendations of project C25029 to enable the accurate detection of particulate matter (PM) movement across significant, and critical, sections of a site boundary. Such technology can ultimately assist the mining industry (in particular open-cut mining) by providing early detection of adverse PM movements across site boundaries. Such real-time information will enable the industry, to better manage on site dust emissions and improve general air quality in the area.

Since completion of the draft final report for C25029, ERM has entered into a professional collaboration with Dr Rami Hashmonay, an international expert in the development and implementation of optical remote sensing (ORS) and other advanced air monitoring methodologies. Dr Hashmonay is the co-inventor of the Radial Plume Mapping method (EPA Other Test Method 10 [OTM-10], Optical Remote Sensing for Emission Characterisation from Non-Point Sources).

Through our discussions with Dr Hashmonay, it is understood that the project outcomes could potentially be significantly augmented through both data mining of the raw data set gathered during the field component already completed, as well as further enhancement of Best Practice guidance for future Lidar deployment for operational dust control.

We have been evaluating the opportunity to solve the Lidar equation for the field of extinction using times and places where there was integrated extinction data from hard targets. The intent of this is to allow us to produce better plume maps for PM distribution at each historical test site.

We are close to completion of this task and will then progress to the production of Best Practice guidance for Lidar deployment.

We expect to provide a draft report by the end of February.
Exploration

C25025
Guidelines for Estimating Rock Mass Strength from Laboratory Properties

University of New South Wales
Ismet Canbulat
Joan Esterle

Value: $396,685
Report Expected: December 2018
Industry Monitor/s: Dan Payne
Gavin Lowing
Gift Makusha
ACARP Contact: Cam Davidson

A draft report is with the industry monitor(s) for review.

C26022
Real Time Prediction of Coal Top Through Guided Borehole Radar Wave Imaging for Open Cut Blasthole Drilling

CSIRO
Binzhong Zhou

Value: $210,985
Report Expected: February 2019
Industry Monitor/s: David Drakeley
Troy O’Reilly
ACARP Contact: Patrick Tyrrell

A draft report is with the industry monitor(s) for review.

C26023
Borehole Data Standard

GeoCheck
Brett Larkin

Value: $87,500
Report Expected: March 2019
Industry Monitor/s: Ben Thompson
ACARP Contact: Patrick Tyrrell

This project has the following objectives:

- A set of recommended colours for plotting lithotypes.
- A standard set of codes for -
  - survey company, geological logging organisation and geophysical logging company for borehole header data,
  - drilling company, rig type and hole size name (HQ, PQ, etc) for borehole drilling data.

All the above objectives have been completed and currently new copies of the CoalLog Manual and associated documents are being prepared to include all of the above improvements.

C26029
Controls on Fluorine and Phosphorus Distribution in Bowen Basin Coals

University of Queensland
Joan Esterle

Value: $141,050
Report Expected: May 2019
Industry Monitor/s: Damien Trickey
Peter Handley
Richard Ruddock
Tim Buddle
ACARP Contact: Patrick Tyrrell

The project aims to improve the predictability of in situ fluorine and phosphorus distributions within Bowen Basin coals. The approach is to map element variability within seams across various mine sites and then to develop a methodology to detect the domains and the geological controls. Elements of the project that are being investigated include primary deposition; subsequent burial and deformation; intrusive processes; or the influence of groundwater. Samples within and between seams in high and low domains under different settings will then be analysed to determine possible origins by geochemical (isotopic) means. This requires isolation of the primary fluorine bearing minerals, commonly fluorapatite, which occurs entrained within the cell lumens of semi-fusinite. Less commonly, the fluorine bearing minerals can occur within fractures or other macerals.

During the quarter the team continued with microanalysis of the apatites to confirm whether the rare earth element patterns between volcanic fluorapatite and that occurring as coal matrix attritus, inertinite pore fill and fracture fill could be consistently distinguished. This will continue into next quarter as there were laboratory closures over Christmas, precluding conclusion of the analyses. Additional data was sought from stratigraphic equivalents of the Rangal Coal Measures, and from Early Permian sequences, to also test the stratigraphic trends observed in the current data sets. These new data sets are under analysis, particularly those which show high fluorine and low phosphorus, to determine other forms of mineralisation.
C26034  
**Storage and Time Effects on Coking Properties of Small Coal Samples**

McMahon Coal Quality Resources  
Chris McMahon

**Value:** $151,000  
**Report Expected:** March 2019  
**Industry Monitor/s:** Alison Burke, Angus McIntyre, Richard Hingst, Richard Ruddock, Tim Buddle  
**ACARP Contact:** Cam Davidson

This project aims to examine coking properties deterioration in small samples. The project's objectives are to examine and quantify reduction in coking properties with time and conditions of storage on small samples that are commonly used in borecore and coal sampling generally.

Four potential coal sources covering a range of rank and coal quality have been made available for review and are their laboratory testing under different laboratory conditions (refrigerated and unrefrigerated) at different time periods and thus degree of oxidation has now been completed.

MCQR has checked the data as it has been received to ensure completeness of outcomes and has started review of trends and definition of those parameters deterioration effects with different coal character. Coal character will be assessed in terms or rank of the coal primarily with secondary effects of all other coal quality parameters examined that are non deterioration prone such as maceral composition ash chemistry.

Statistical regression outcomes will be applied and assessed for significance that will lead to grading of severity in deterioration for different coal quality testing outcomes for different coal quality character coals and quantification of effects for different time periods.

Limits of the testing outcomes versus trends observed will be considered to define the significance of the test outcomes.

The draft report will be submitted for review in February.

C28032  
**Test of downhole geophysical logging system that provides an assay from the in-situ rock mass**

Qteq  
Benjamin Birt, Masoud Jangani, Tim Hopper, Tom Neville

**Value:** $50,000  
**Report Expected:** May 2019  
**Industry Monitor/s:** De Nicholls, Gareth Johnson, Mark Laycock  
**ACARP Contact:** Patrick Tyrrell

Project work has not yet commenced. We are currently liaising with a number of mine sites to identify the best candidate location for field trials, which should commence next month.

**Geotech**

C25035  
**Coal Subsurface Mapping for Open Cut Selective Mining**

CSIRO  
Andrew Strange

**Value:** $412,660  
**Report Expected:** July 2020  
**Industry Monitor/s:** Brett Domrow, Margaret Stewart  
**ACARP Contact:** Cam Davidson

There is a need for a reliable seam sensing system to provide selective mining capabilities for open cut coal mining. This project extends the outcomes of the previous stage 1 to develop a machine-mounted radar sensing system that provides seam thickness measurements of the top layer to operators during mining. The sensing system will eventually be attached to a dozer or surface miner to provide the depth of the seam floor to operators in real-time as part of a production pilot trial.

Stage 1 of this project was to define the requirements of the sensing system and confirm specific details with the host mine site. The research team visited the host mine site and discussed the project along with aspects of the future pilot trial. Stage 1 is complete.

The current stage 2 involves conducting an evaluation of the sensing system attached to a mini-digger. The purpose of this stage is to establish the performance of the sensor when it is attached to similar mining machinery but prior to initiating modifications to a production machine. A new blade attachment that suits the mini-digger has been purchased. The preliminary work to determine how and where to mount the sensor on the
new attachment whilst minimising the introduction of noise and interference into the sensor from the mini-

digger is underway.

C25040
Shear Strength Characterisation of In Pit Mud to Ensure Low Wall Stability

University of Queensland
Adrian Smith
David Williams

Value: $210,000
Report Expected: March 2019
Industry Monitor/s: Gavin Lowing
Leigh Bergin
Shaun Booth
ACARP Contact: Patrick Tyrrell

The overall objective of this project is to identify spoil and floor materials that do not require removal prior to spoiling because they do not substantially degrade on wetting-up, and hence are unlikely to promote low wall spoil pile geotechnical instability. The specific objectives of the project are to:

• Geologically identify and sample selected fresh and degraded spoil and floor materials to assess their potential for water-softening;
• Carry out appropriate in situ shear strength assessment of water-softened in-pit spoil and floor materials that can safely be accessed;
• Characterise physically and chemically in the laboratory the representative spoil materials sampled, including testing for slake durability;
• Carry out laboratory shear strength testing on fresh, moistened and water-softened specimens of the spoil and floor materials sampled;
• Relate the laboratory shear strength of the spoil and floor materials tested to their physical and chemical characteristics;
• Confirm the shear strengths determined through the back-analyses of low wall failures due to the water-softening at the base of low wall spoil piles;
• Develop field testing protocols for the identification of degradable spoil and floor materials, and to develop design guidelines for enhancing the geotechnical stability of low walls for both durable and water-softened spoil; and to
• Disseminate the results of the project to the Industry through quarterly progress reports, approximately six-monthly review meetings, industry seminars, a timely final report, and conference and journal papers.

A draft report is complete and is currently being internally reviewed. All objectives of the project have been addressed and discussed. The results of the project have already begun to be disseminated to the industry through conferences, presentations and discussions. The outcomes of the project include:

• A greatly improved understanding of the physical, chemical, mineralogical and geotechnical parameters of in-pit mud, and an improved understanding of how different spoil types degrade to mud on wetting-up;
• Improved understanding of the rate and degradation process of spoil with respect to material characteristics and spoil category;
• Methodology for a modified slake durability test for quickly identifying spoil prone to degradation;
• New data on the consolidation and hydraulic conductivity of in-pit mud and degraded spoil within the Bowen Basin, as well as an improved understanding of the pore water pressures and dissipation rates experienced during loading of mud in a slurry consolidometer;
• Shear strength data on spoil and in-pit mud tested in the as-sampled, soaked, and degraded states, allowing for improved accuracy in the selection of parameters for the analysis of low wall stability;
• A statistically significant model for predicting the friction angle and shear strength of in-pit mud using simple particle size distribution data;
• Improved identification and testing protocols for in-pit mud;
• A detailed analysis of the influence in-pit mud on stability for four standard low wall designs, contrasting laboratory tested shear strengths against the current framework, highlighting the potential to safely spoil into in-pit mud; and
• Technology transfer including presentations to the industry and three published papers to date.

C26030
Improved Structural Mapping of Pit Walls using UAV Based Mobile Laser Scanning

University of New South Wales
Simit Raval

Value: $96,068
Report Expected: February 2019
Industry Monitor/s: Adrienna Robotham
Brian Vorster
ACARP Contact: Anne Mabardi

A draft report is with the industry monitor(s) for review.
C26032
Autonomous Sensors for Evaluation of Groundwater in Spoil Dumps and Tailings Dams

University of Queensland
Enver Bajram

Value: $349,760
Report Expected: April 2019
Industry Monitor/s: Kim Peckett, Martyn Robotham
ACARP Contact: Cam Davidson

The Autonomous sensors project has welcomed a new member of the team with Byron Wicks joining the project team in the last few months. Byron brings with him a great deal of experience in through the ground magnetic field signalling with his previous employment at Orica. Byron is currently working on the last component of the project which is the research into magnetic induction-based signalling between sensors.

C27011
Predicting the Impact of Complex Joint Structures on Mine Operations

University of Newcastle
Anna Giacomini, Marc Elmouttie

Value: $273,711
Report Expected: May 2020
Industry Monitor/s: Gift Makusha, Leonie Bradfield, Walter Kellich
ACARP Contact: Cam Davidson

This project will develop a method for improved prediction of the 3D spatial distribution of rock mass defects and their properties (including orientation, persistence, fracture frequency and intensity) ahead of mining. A second project objective is to demonstrate the relationship between rock mass structure and the frequency of highwall incidents and their subsequent contribution to production delays and overburden removal rates for a given blast pattern.

The quarter has focussed on refinement of data analysis to improve the reliability of the structural defect data being acquired, and on exploring options for the partitioning of the data spatially to define domains upon which the random fields can be based. Work has also begun in identifying which are the appropriate parameters upon which the random fields will be defined.

Operational data has now been received from a mine site, and a research assistant at CSIRO is now working to see what parameters/factors can be extracted from the available data to characterise operational efficiency, as it might be impacted by the geotechnical factors that are also being characterised.

C27046
True Vector from Slope Radar Monitoring

CSIRO
Marc Elmouttie

Value: $163,036
Report Expected: October 2019
Industry Monitor/s: Adrienna Robotham
ACARP Contact: Patrick Tyrrell

A well-recognised problem with slope stability radar monitors is that they only measure deformation directed towards the detector (line of sight bias). This bias can lead to misinterpretation of deformation size, rate and failure mechanism, and therefore miscalculation of failure volume, which can significantly impact safety and productivity. This project will field test integration of high precision computer vision technology with slope stability radars to address this problem.

In this quarter the benchtop analysis has progressed further using DSLR data acquired from mine A. This has included analysis of different variants of feature extractors for the tracking algorithm to use and application to synthetic deformations applied to real data (as shown in the figure below).

Detection of synthetic deformation in well and poorly illuminated regions of site A.

GroundProbe has provided corresponding radar and camera data and support for data acquired at the same site. Initial analysis has shown the data provides an excellent sampling of varying conditions for algorithm testing.

IDS GeoRadar has also sourced data from an overseas mine site for which a failure has been monitored by two radars. Initial analysis has shown that the data is ideal for testing the utility of the algorithm as the sensitivity of one of the radars to the deformation is very low due to line of sight bias.

In the next quarter, further analysis of the radar and imagery data provided by these radar companies will continue with quantification of algorithm performance.
Health and Safety

C25026
Reducing Risk Taking Among Australian Coal Miners

University of Newcastle
Anna Giacomini
Mark Rubin

Value: $302,235
Report Expected: April 2019
Industry Monitor/s: Bharath Belle
Doug Kennedy
Robyn Masters
ACARP Contact: Patrick Tyrrell

This project aims to investigate the causes of dangerous risk-taking behaviour in open-cut and underground coal mines in Australia. The research also aims to develop a practical intervention to reduce risk-taking and, consequently, accidents and injuries. The project will test the effectiveness of the intervention and develop a tool to enable industry users to assess its long-term effectiveness.

Phase 1 of the project, the investigation, is complete and the research team is currently focused on developing the phase 2 intervention. Phase 1 identified that safety norms predicted risk-taking: the more miners felt that people at their mine site had a poor attitude toward safety, ignored safety procedures, and engaged in unsafe risk-taking, the more risks they themselves took in the future. As such, the intervention will focus on changing (improving) perceived safety norms by increasing the extent to which miners see their co-workers caring about safety. A detailed proposal for the intervention has been developed and provided to our industry monitors for comment.

The intervention, referred to as the Safety Choices Task (SCT), will engage workers during a series of pre-shift briefings in discussion and consideration of site-specific safety issues. Participating crews will be presented with a scenario and then vote on the best solution. The outcome will be recorded on a dedicated SCT whiteboard positioned in the muster area. The collective process of voting, follow-up discussions, and the SCT whiteboard represent visible activities that should cue positive safety norms among the crew. Pre- and post-test surveys will determine any change in perceived safety norms.

In support of the intervention, it is also planned to include a survey to assess the actual safety commitment of mine management personnel. We are currently investigating options for a suitable survey among the scientific literature.

C25037
Health-e Mines: Virtual Health System to Improve Mental Health

University of Newcastle
Brian Kelly
Frances Kay-Lambkin
Ross Tynan

Value: $289,985
Report Expected: March 2019
Industry Monitor/s: Occupational Health and Safety Task Group
Tony Egan
ACARP Contact: Patrick Tyrrell

This project has three key objectives, which are to:
- Develop an online portal (‘Health-e Mines’) through which Australian coal miners can access confidential, evidence-based online treatments for mental health, alcohol/other drug use, and physical health concerns;
- Evaluate the use of Health-e Mines and associated online treatment programs in pilot mine sites in New South Wales and Queensland in terms of feasibility, acceptability, reach, and effectiveness; and to
- Develop a clear plan for dissemination and sustainability of Health-e Mines beyond this project.

The Health-e Mines website is launched and active across four mine sites in New South Wales and Queensland. Evaluation data has been collected and is currently undergoing analysis to determine how well the tool is able to engage people with information and interventions for the health and wellbeing.

This quarter, there have been 3,391 hits (page views) on the website. Of these, 86% have been new visitors to the website, and 14% have been returning visitors. This has translated into 556 sessions by people visiting the website, who have viewed, on average, two pages per session. This represents a doubling of visits to the site over the previous quarter. Health-e Mines had 352 new users to the site during the last quarter, and the majority of these are accessing the site Fridays and Saturdays at 1pm, Mondays and Tuesdays at 3pm, Fridays at 3am.

After the home page, the most frequently visited page on the site is the ‘service locator’ that puts people in contact with their closest health service. Next most popular are the sections that contain fact sheets and tips for maintaining mental health and wellbeing. The next most popular activity on the site is registering for access to the evidence-based programs that address depression, alcohol/other drug use, and healthy living. Importantly the web site will be maintained for 2019-2020 to facilitate wider access to the tool, with discussions currently underway to ensure future sustainability of the tool by partnering with the Mates in Mining organisation and MineSuper. If you would like to find out more about how Health-e mines can be offered at your site, please contact Frances Kay-Lambkin
frances.kaylambkin@newcastle.edu.au
C26026
Continuous Monitoring of Whole Body Vibration and Jolts and Jars Associated with Operating Earth Moving Equipment

University of Queensland
Robin Burgess-Limerick

Value: $328,704
Report Expected: January 2021
Industry Monitor/s: Ellen Roots, Shane Apps, Troy O'Reilly
ACARP Contact: Patrick Tyrrell

The objectives are to:
• Develop, demonstrate, and evaluate iOS and server software to allow continuous monitoring and analysis of earth-moving equipment operator vibration exposures using off-the-shelf hardware;
• Utilise this system to obtain an enhanced understanding of the sources of elevated whole-body vibration and impact loads associated with haul truck and dozer operation at a surface coal mine; and to
• Make the software freely available for adoption by other sites.

An iOS application was written to allow iPhones to be installed in haul-trucks, and accelerometer and GPS data was received from the phones by the UQ server software. However, regular breaks in transmission occurred as a consequence of the phone overheating, and this issue could not be overcome. Alternate hardware involving a miniature accelerometer located in the seat and utilising a Raspberry Pi microcomputer has been designed and software coded to replace the iPhone. A change of site was also required.

RPi modules have been installed in seven trucks. A further three modules have been sent to site and are progressively being installed. An additional 20 modules are in construction. These systems also include accelerometers located under the seat to allow the effectiveness of the seat to be assessed. The data from the accelerometers is currently relayed to a UQ server. The progress of the project and examples of the data captured were presented at the Queensland Mining Industry Safety and Health Conference in August 2018.

A video of the presentation is available at: https://qmihsc2018.evertechnology.com/conference-session/continuous-monitoring-whole-body-vibration/

A second company has requested to participate in the project and have the RPI modules and accelerometers installed in dozers at site. Technical discussion are underway, as well as discussions with Hexagon regarding a potential collaboration. Further software development is in progress to allow off-line analysis and integration of accelerometer data with existing equipment health databases.

C26028
Proximity Detection System Performance Testing Framework

University of Queensland
Joel Kok, Joji Quidim, Susan Grandone

Value: $268,000
Report Expected: March 2019
Industry Monitor/s: Matt Clements, Tim Gray, Tony Egan
ACARP Contact: Cam Davidson

A draft report is with the industry monitor(s) for review.

C27005
Interface Design for Haul Truck Proximity Advisory Systems

University of Queensland
Robin Burgess-Limerick

Value: $199,296
Report Expected: April 2019
Industry Monitor/s: Iain Curran, Matt Clements, Tony Egan
ACARP Contact: Cam Davidson

The project extends project C24028 by utilising a similar experimental paradigm to examine two of the issues identified as requiring further investigation: the relative benefits of proximity information based on distance only vs collision prediction information; and secondly, the relative benefits of auditory tones vs speech.

Preparatory work required for the experiment included replacement of the haul-truck simulator computers and programming of the revised proximity advisory interfaces. Data collection commenced in March 2018 and was completed December. 50 novice participants were recorded while they drove 21 x 15 minute circuits in one of five interface conditions:
• No proximity advisory interface;
• Schematic interface and two stage alert tone based on proximity only;
• Schematic interface and three stage alert tone based on proximity only;
• Schematic interface and three stage tones based on collision prediction; and
• Schematic interface and three stage verbal alerts based on collision prediction. The data are currently being analysed.
C27013
Evaluating Risk Control Performance

University of Queensland
Maureen Hassall

Value: $135,000
Report Expected: March 2019
Industry Monitor/s: Kevin Rowe, Kylie ah Wong, Stephen Broad, Tony Egan
ACARP Contact: Cam Davidson

This project seeks to identify, develop and assess leading-edge, evidence-based approaches for measuring the effectiveness of implemented risk controls. The objectives are:

- Collect and review current work being conducted by a diverse range of coal mining companies and others on the measurement of control effectiveness;
- Identify and specify potential practical methods for measuring control effectiveness;
- Develop worked examples that illustrate how the range of control effectiveness measurement options might be applied to a selection of common high priority controls; and
- Evaluate and critique options for measuring control effectiveness.

The project will capture and evaluate options for measuring control effectiveness trialled, in use and conceptualised in the coal industry and by others. The findings will be written in a report that describes, provides worked examples and critiques the range of ways control effectiveness can be measured for industry practitioners and others to use as a reference.

The literature review, survey of mining industry practitioners and a workshop with cross-industry critical control people has been completed to understand current practices for measuring control performance across different high hazard industries and to review options for measuring control effectiveness for different types of controls. Findings from literature review, survey and potential recommendations are being analysed and written up. Case study examples are also being developed for different control types. The outcomes will then be explored and tested with coal mining practitioners in follow-up interviews.

C27062
Augmentation to Emissions Factors

Pacific Environment
Damon Roddis

Value: $78,040
Report Expected: April 2019
Industry Monitor/s: Andrew Speechly, John Watson
ACARP Contact: Patrick Tyrrell

The project will conduct supplementary analysis and investigation to provide an additional level of assurance to (PE, 2015) project C22027, ‘Development of Australia-Specific PM10 Emission Factors for Coal Mines’.

The driver for this research stems from a detailed peer review of project C22027, commissioned by the Federal Department of Environment and Energy National Pollutant Inventory (NPI) group. This third party peer review was undertaken by Greg Muleski of McVehil-Monnett Associates (MMA) based in Denver, USA. MMA provided commentary on project C22027, advising areas where further research could be undertaken.

As part of MMA’s review, the following points of clarification were identified:

- Calibration of light scattering PM measurements against gravimetric equivalents; and
- Comparison of results between Confined Air Burst Chamber (CABC) method and those from an open-floor wind tunnel.

During January ERM has completed side-by-side comparisons of light-scattering and gravimetric particulate matter (PM) monitoring methods to provide evidence of a suitable calibration factor between the two techniques.

In alignment with recommendations of the peer review, ERM has also been validating the performance of the CABC against an open floor wind tunnel. We have completed this aspect of the field sampling at a Hunter Valley mine site, using a portable open floor wind tunnel. This instrument has been designed and constructed by CPP Wind Engineering (CPP) for use in the measurement of wind erosion potential from unsealed surfaces.

The researchers expect to provide a draft report to the Industry Monitors soon. Figures showing the field work completed in January follow.
The aim of this project is to test a theoretical method for prolonging asset life, reducing down time, and reducing weld repair costs. Rather than simply monitoring the condition of equipment and structures to identify cracking as it develops, and then having to carry out the repairs, it is theorized that significant savings could be achieved by proactively surface dressing locations that are known to be susceptible to fatigue cracking, in order to remove the fatigue damage accumulated at the surface. It is proposed that the proactive surface dressing would be carried out as part of a planned maintenance program, preventing cracking from developing.

Work has commenced in the treatment of steering arm castings on the Komatsu 830E truck fleet at the partner mine site for this project. At this stage, it is projected that it will take at least four months before all of the trucks have been treated. The steering arms across the fleet vary in age, ranging from original installed, to recently replaced. This offers the opportunity to demonstrate proof of concept on the older steering arms in the shorter term.

In the course of carrying out the treatments, it has already been noted that significant variation exists in the surface quality of the castings. In particular, some have heavy grind marks in regions known to be potential cracking sites. It is not clear whether the grinding marks relate to rectification of cosmetic defects in the castings, or whether weld repairs had been carried out of the castings at the foundry. This may introduce some further factors for consideration as part of this project.

In addition, early testing is underway for the lab based rotation bending fatigue test samples that aim to demonstrate ‘proof of concept’ for the fatigue damage removal process.
C26021
Verification of Interoperability - Collision Awareness and Avoidance Systems

CSIRO
Jeremy Thompson

Value: $105,844
Report Expected: June 2019
Industry Monitor/s: Iain Curran, Matt Clements, Paul Forsaith, Tim Gray, Tony Egan

ACARP Contact: Cam Davidson

We are yet to begin work on the extension portion of the project as the ISO standard ratification is still in progress.

C27074
Mining Truck Tyre Integrity Monitoring

CSIRO
Garry Einicke, Jim Callow

Value: $107,144
Report Expected: July 2019
Industry Monitor/s: David Goodale, Ivan Heron, Stephen Broad, Tim Gray, Cam Davidson

ACARP Contact: Cam Davidson

Deflating and re-inflating tyres with hidden cord damage has led to tyre explosions which have been responsible for injuries and fatalities at Australian coal mines, as well as costs due to equipment downtime. The previous project C25034 ‘Mining Truck Tyre Integrity Monitoring’, developed software that automatically detects hidden tyre carcass/cord anomalies. The previous project also developed basic manual wheel rotation hardware to prove the concept would enable assessment of entire tyres. The objective of this extension project is to further develop this into an automated version of the manual system to establish a basis for developing commercial tyre integrity monitoring systems and/or services at coal mines.

The project’s recent achievements include the development of the following:

- Software has been developed for better displaying sequential x-ray images and to highlight damaged regions of complete tyres;
- A stepper motor and 10:1 reduction gearbox was mounted on the wheel rotator by the CSIRO QCAT Workshop;
- Prototype motor control software application was developed to control the stepper motor;
- A portable stand that supports a flat-panel x-ray scanner was manufactured by the CSIRO QCAT Workshop. This stand can be dismantled and re-assembled to accommodate different x-ray scanners and positions;
- ALS Industrial provided x-ray equipment and a specialist technician at their Riverview Laboratories to support the project. In particular, a RIGARKU INDUSTRIAL RADIOFLEX Digital Detector Array (DDA) was used for acquiring radiographic images of a truck tyre sample on 23 November 2018.

The achievements above are consistent with the planned project milestones.

Overburden Removal

C26035
Dynacut Fundamental Development: Phase 2

University of Queensland
Mining3
Dihon Tadic

Value: $1,333,000
Report Expected: July 2019
Industry Monitor/s: Andrew Lau, Hans Hayes, Ivan Heron

ACARP Contact: Cam Davidson

This project follows directly from project C25041 ‘Dynacut fundamental development and scalability testing for high capacity mining of coal overburden’. There are three project elements: the first aims to examine the effect of key operating variables on cutting performance via further cutting trials; the second aims to extend cutter design work and test more advanced cutter designs; and the third will use the findings of the first two elements, combined with potential mining system concepts, to produce a design for an up-scaled test machine. This phase aligns with the overarching objective of completing core R&D to demonstrate the performance and scalability of the DynaCut technology, to ultimately justify a commitment by Komatsu and/or an industry consortium to develop a full-scale prototype system for coal mining applications.

Modifications to the existing test machine remain underway to broaden the operating variables controlling the dynamic action of the cutter disc. Improved cutter designs have further advanced also. Suitable rock samples are being procured following quarry visits and sample testing from a series of suppliers in New South Wales. Experimental plans are being finalised for upcoming trials at Komatsu’s test facility in New South Wales. Construction of the first of several rock bunkers is expected to commence in February, following rock delivery and further mechanical properties testing to confirm domain allocation.

Concurrent work on conceptual mining system designs has also progressed in the past two months, with key shortlisting completed and more detailed analysis and description currently underway.
C27063
SATS Automated Mission Planning

University of Queensland
Peter Beasley
Ross McAree

Value: $346,046
Report Expected: September 2020
Industry Monitor/s: Brian Neilsen
Hans Hayes
Shaun Booth
Stephen Broad
ACARP Contact: Cam Davidson

The Caterpillar Semi-Autonomous Tractor System (SATS) facilitates autonomous execution of production bulldozing in strip mining applications. The system is capable of performing several variants of production bulldozing; Push-To-Edge, Tip-Head and Pivot-Push.

To autonomously perform production bulldozing, the current SATS system must be provided with missions that are designed by an operator at a remote work station. Missions are the ‘packages’ of work that the bulldozer completes autonomously with one operator overseeing several bulldozers.

The task of manual mission planning is demanding which impacts the effective utilisation of the bulldozer fleet.

The project aims towards high utilisation of available time by planning plan missions autonomously building on the tactical planning algorithms created in an earlier ACARP project. This project aims to adapt and deploy these planning algorithms to deliver automated tactical planning capability to production dozing operations and help realise a significant reduction in the cost of overburden removal.

The project team has focused on three tasks to-date:
- Design of the control system and software architecture for implementation of the tactical mission planning algorithms;
- The preparation and initiation of a trial that will benchmark the performance of the current SATS technology with results to be used as a basis for quantifying the impact of the project; and
- Development and validation of algorithms for real-time terrain mapping needed as part of the system using data-sets collected in previous trials.
**COAL PREPARATION**

**Dewatering**

**C24040**  
Improving the Dewatering Efficiency of Fine Flotation Concentrates by De-Aerating Froth Products  
University of Queensland  
Yongjun Peng  

<table>
<thead>
<tr>
<th>Value:</th>
<th>$383,468</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report Expected:</td>
<td>October 2019</td>
</tr>
<tr>
<td>Industry Monitor/s:</td>
<td>Mario Salazar</td>
</tr>
<tr>
<td>ACARP Contact:</td>
<td>Nerrida Scott</td>
</tr>
</tbody>
</table>

This project focuses on direct plant tests of the deaeration techniques developed in the laboratory. The main objectives are to:

- Scale up the effective deaerating techniques developed in the laboratory (including deaeration devices and chemicals) and then directly test and optimise them in the plant;
- Study, define and optimise parameters that cannot be properly studied at a laboratory scale;
- Identify the most cost-effective froth deaerating strategy depending on the plant flowsheet;
- Evaluate the effects of different deaerating methods on upstream and downstream performance in the plant;
- Demonstrate economic benefits by implementing a deaeration technique in plants.

The fabrication of two pilot-scale physical deaeration devices has been completed. Initial continuous testing has been conducted in laboratory using coal samples collected from participating plants. A pilot scale Jameson cell was used to provide a continuous froth feed. The results showed that more than 95% of the highly stable froth was deaerated using the two devices, which are consistent with previous lab tests. For pilot testing in the plant, additional tanks and connection pipes are being fabricated in the workshop. Electrical safety devices are also being installed to meet plant requirement. All the fabrication and assembly are expected to be completed in two months.

In addition to physical devices, deaeration chemicals have been developed to break coal froth without affecting the subsequent flocculation. The chemicals are being optimized to further reduce the dosage while minimising the negative effects on upstream/downstream process.

Both physical devices and chemicals will be trialled at two participating plants after being fully tested in the laboratory.

---

**C24047**  
Steam Pressure Filtration Targeting Step Change Reductions in Filtercake Product Moistures  
QCC Resources  
Andrew Swanson  
Bob Drummond  

<table>
<thead>
<tr>
<th>Value:</th>
<th>$437,393</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report Expected:</td>
<td>June 2019</td>
</tr>
<tr>
<td>Industry Monitor/s:</td>
<td>Mario Salazar</td>
</tr>
<tr>
<td>ACARP Contact:</td>
<td>Nerrida Scott</td>
</tr>
</tbody>
</table>

Hyperbaric disc filters have been used to dewater fine coal concentrates in coal applications for approximately 30 years. There are in excess of 100 hyperbaric disc filter installations dewatering fine coal and froth flotation concentrate slurries, with the majority of these coal installations located in Eastern Europe and China.

The use of high-pressure steam to supplement pressure filtration has been used in various mineral and niche chemical applications where the final cake moisture specification is significantly less than what alternative, conventional dewatering technologies can achieve.

The objective of this project phase 2 is to confirm the scalability of hyperbaric filtration technology by comparing the batch-wise laboratory (or bench scale) data relative to the continuous pilot testing data (collected as part of the initial project stage). Once the scalability of the technology is confirmed a detailed laboratory assessment of 10 flotation concentrate samples provided to Bokela will determine the effect of filter feed (coal quality) characteristics, such as: coal rank; particle size distribution; and clay content; on filtration rate, final product moistures and air and steam consumption rates.

The evaluation of a wide range of flotation concentrate samples coupled with the deployment of the Bokela in-house coal processing data to expand the dataset (provided as part of Bokela’s in kind support for the project) will establish the operating limits of the pressure filter technology and provide the industry with nomograms and derived empirical relationships, relating the feed coal quality parameters to the filter throughput, air and steam consumption rates and moistures outcomes.

Initial internal assessment has identified 10 sites that have agreed to contribute a sample towards the research. Sample collection has been completed and all samples from the contributing sites have been delivered to Bokela. A laboratory specification has been developed and laboratory testing has commenced.

It is anticipated with three months of laboratory testing and allowing two months to analyse the data and prepare the report, that the research will be completed by the end of second quarter 2019.
C25012
Dewatering of Ultrafine Coals and Tailings by Centrifugation: Pilot Scale Studies

University of Queensland
Anh Nguyen

Value: $296,000
Report Expected: March 2019
Industry Monitor/s: Penny Walker
Rahul Patel
Steve Vaughan

ACARP Contact: Nerrida Scott

The objectives of the project are:
• Apply the high-g centrifugation effect on dewatering fine coals and tailings;
• Evaluate the Somerset dewatering technology at pilot scale and in continuous mode;
• Optimise the fine coal dewatering by using the concepts of split dewatering and combined centrifugal and chemical-enhanced de-wetting forces; and
• Compare pilot-scale findings to full-scale results.

An extension of the project was approved. The objectives of the extension are to:
• Design optimum operational condition of the pilot-scale solid bowl centrifuge for samples with different dewatering difficulty; and to
• Provide solid recovery by size analysis of the centrifugal dewatering for each type of the samples.

The pilot-scale centrifugal dewatering trials were completed on the tailings sample A, containing mostly kaolinite and montmorillonite with D50 of 18.7 microns. The feed rate for the pilot-scale centrifuge was set at a possible minimum rate of 0.2 m3/h with using 17% solid concentration slurry. 2000 g-force (maximum g-force) were kept constant during the test work. Three different pool depth settings (low, medium and high) at three different residence time (24, 20 and 14 differential rates) were tried to find out the machine’s optimum operational condition. The results showed minimum filter cake moisture of 28.5 % could be achieved at ~2000 g-force and 24 differential rate with the medium pool depth condition. The effluent water quality in this condition was around 0.64% solid concentration. It was also observed that with increasing particles residence time (higher differential rate) the effluent water quality was improved. Solid recovery by size analysis and pilot-scale centrifugal dewatering trials on the tailings sample B are underway.

C25018
Improving Solids Recovery and Moisture Reduction in Ultrafine Coal Dewatering

University of Queensland
Liguang Wang

Value: $184,000
Report Expected: March 2019
Industry Monitor/s: Justin O’Neill

ACARP Contact: Nerrida Scott

The objectives of this project are to:
• Develop an effective method to improve the solids capture and product moisture reduction in dewatering ultrafine coals with screen bowl centrifuge (SBC); and to
• Conduct a cost-benefit analysis to compare the cost of the chemicals to the increase in solids recovery.

The operational issues of the pilot-scale SBC test unit at University of Queensland have been addressed and the SBC is ready for planned pilot scale experiments. However, the fine coal slurry samples for these experiments remained unavailable, and consequently there was a delay in carrying out the planned pilot scale SBC tests for the reagents selected from bench-top scale tests. Once the required coal samples are received from the participating site, the SBC dewatering tests will be conducted immediately to validate the concepts developed in this project.

C26015
Characterisation of Coal Petrography for Improving the Dewatering of Fine Coals Using Chemicals

University of Queensland
Anh Nguyen
Graham O’Brien

Value: $199,436
Report Expected: March 2019
Naomi Pritchard
Rahul Patel

ACARP Contact: Nerrida Scott

The objectives of the project are:
1. Apply microfocus XCT facility to image fine coal grains and develop the specialist software to reconstruct 3D density maps of fine coal grains;
2. Apply the facility for the coal grain analysis by optical petrography to obtain detailed information on maceral constituents (vitrinite, inertinite, liptinite) and minerals on individual grains for calibrating and validating the XCT results of 3D density maps;
3. Conduct the float-and-sink analysis of coal grains to determine maceral density (three different coal ranks of mean vitrinite reflectance of 0.6%, 1.35% and 1.8%) for calibrating and validating the XCT results of 3D density maps (jointly with Objective 2);
4. Apply the coal grain composition information obtained in Objectives 1-3, develop matrices of dewatering chemical aids for the coal grain compositions, and conduct the corresponding dewatering experiments to gain an understanding of the response to dewatering of different grain types and predict the process performance under centrifugation conditions;
5. Apply the XCT calibrated procedure (Objective 1) and the procedure of matching the dewatering chemical aids with coal grain composition (Objective 4) to develop a reliable method for determining the composition characteristics of fine coals for dewatering.

During the quarter more coal samples from different mine sites were obtained for CGA and XCT measurements. 3D coal maceral density maps were completed for these samples. CGA measurements are in progress to validate the XCT results. Effects of dosage for five dewatering chemical aids on dewatering performance of different coal grain compositions were investigated. Fastest dewatering rates for both vitrinite-rich and inertinite-rich samples were achieved with cationic flocculant with medium dosage (0.1 kg/t). The lowest moistures of filter cake for vitrinite-rich and inertinite-rich samples were achieved by applying cationic flocculant with low dosage (0.05 kg/t) and with anionic surfactant with high dosage (2 kg/t), respectively.

C27016
Eriez HydroFloat in Plant Evaluation
Eriez Magnetics
Darren Mathewson
Liam Davis

Value: $155,600
Report Expected: April 2019
Industry Monitor/s: Clinton Vanderkruk
Steve Vaughan
ACARP Contact: Nerrida Scott

Eriez HydroFloat is a small footprint, high capacity coarse flotation technology capable of recovering coal from a fine (eg -2.0 +0.3-mm) material stream using both density and surface chemistry properties of the feed. This hybrid technology combines the capacity and throughput of a density separator with the selectivity of a flotation device.

The workplan for this project includes on-site testing at two Queensland coal processing plants. This testing is to be similar to previous test work conducted in the USA with the emphasis on this technology’s applicability to Australian coals. There are currently no Eriez HydroFloat units installed in the Australian coal industry and no pilot plant test work has been performed in Australia. Plant trials will allow the coal industry to properly assess the benefits of Eriez HydroFloat across a range of site-specific conditions, without requiring each site to individually assess the technology.

Trials on an existing TBS feed stream have almost been completed at the first test site. A number of feed, frother and sampling issues had to be addressed. While results from the laboratory have not been received yet the indications are that extremely high yields were achieved at low product ashes and high tailings ashes.

Testing at the second site (on a flotation tails feed stream) has been investigated with site personnel and a detailed schedule and scope of works has been developed.

C27064
Dry Beneficiation Using FGX and X-Ray Sorters
A&B Mylec
Glenn Sherritt

Value: $112,000
Report Expected: April 2019
Industry Monitor/s: Naomi Pritchard
Rahul Patel
ACARP Contact: Nerrida Scott

The main objective of the project is to determine the performance of single and combined dry-processing technologies, treating a coal sample sourced from a local coal resource. In addition, the project will undertake order of magnitude estimates for the impacts upon resource value for such processes.

The overall outcome is to assess the merits of this unique combination of technologies as a processing option for those Australian coal mine sites where either wet processing is an unpalatable option or an in-pit processing option improves the overall resource economics through reduced haulage of rejects. Dry processing, at a suitable throughput and metallurgical efficiency may also assist some projects in cold climate areas or remote locations which are being considered by Australian mining houses. The low capital cost profile and quick site establishment which are being considered by Australian mining houses. The overall outcome is to assess the merits of this unique combination of technologies as a processing option for those Australian coal mine sites where either wet processing is an unpalatable option or an in-pit processing option improves the overall resource economics through reduced haulage of rejects. Dry processing, at a suitable throughput and metallurgical efficiency may also assist some projects in cold climate areas or remote locations which are being considered by Australian mining houses. The low capital cost profile and quick site establishment which are being considered by Australian mining houses. The overall outcome is to assess the merits of this unique combination of technologies as a processing option for those Australian coal mine sites where either wet processing is an unpalatable option or an in-pit processing option improves the overall resource economics through reduced haulage of rejects. Dry processing, at a suitable throughput and metallurgical efficiency may also assist some projects in cold climate areas or remote locations which are being considered by Australian mining houses.

Following are key project milestones and status to date:
- A 3-tonne sample of ROM coal has been collected;
- Mining location, working section, bore core data and predicted product qualities and yields for the collected sample have been collated;
- The test procedure was upgraded to provide additional data for performance curve delineation;
- Initial sample preparation and bagging was completed at ALS Riverview;
- The bulk sample was then transported to ALS Maitland where initial crushing and sizing of the sample was completed;
- FGX test work including sizing and float-sink of product, middlings and reject has been completed at ALS Maitland/Richlands;
- The samples for the middlings test procedure using the XSS-T have been prepared and are awaiting despatch.
C27065
Integrated Investigation of Solid Capture and Moisture Reduction of Fine Clay Tailings

University of Queensland
Anh Nguyen

Value: $220,000
Report Expected: July 2020
Industry Monitor/s: Steve Vaughan
Tom Wilson
ACARP Contact: Nerrida Scott

The objectives of the project are to:

- Study mineralogy, surface chemistry and rheological properties of coal tailings clays (e.g. smectite and kaolinite; two main clay minerals in coal tailings);
- Design experiments and test work and examine the effect of chemicals (floculants and surfactants) on the coal tailings concerning the dual functionality of capturing fine clay particles and reducing the final moisture of dewatered tailings;
- Provide detailed information on the impact of the chemicals on the laboratory-scale dewatering performance of Australian fine coal tailings; and to
- Monitor the effect of chemicals on coal tailings dewatering at a pilot-scale solid bowl centrifuge, which operate in a continuous flow mode.

Pure montmorillonite (swelling clay mineral) and kaolinite (non-swelling clay mineral) were used to study the effect of NaI, NaF, CaCl2, and MgCl2 on their settling rate and zeta potential behaviour. The results showed that montmorillonite settling rate was slower than kaolinite in pure water. However, some salts showed improving effect on the minerals settling rate. There was a correlation between the minerals surface charge neutralization and their settling rate. Also, it was observed that the effect of salts on the water viscosity play critical role in the minerals settling rate. Further studies on the effect of different salts on the minerals settling behaviour is in progress.

C26009
Improved Precision for the Determination of Coal in Urban Dust Samples by Combining a Reliable Analysis of Soluble Particulates with CGA

CSIRO
Graham O’Brien
Michael Campbell

Value: $175,622
Report Expected: March 2019
Industry Monitor/s: John Watson
Kevin Rowe
ACARP Contact: Nerrida Scott

The objectives for this project are to:

- Establish a rigorous method for the collection and analysis of urban dust samples that accurately incorporates the contribution that water soluble particles make to urban dust in the entire sample (TSP) and respirable (PM10) fraction;
- Investigate if the current optical dust marker method developed using samples from Mackay, Gladstone and Newcastle can accurately identify the coal and non-coal particles in dust samples collected from Wollongong and Brisbane;
- Investigate whether this method is able to differentiate between dust generated during open cut mining operations and windborne dust from non-mining activities;
- Undertake a statistical analysis of the results generated that provides detail of the method’s accuracy.

The final report is currently progressing through an internal review process. It is anticipated that the report will be submitted to the Industry Monitors in February/early March. Key project findings are:

- Proportion of water soluble particulates in the TSP and PM10 samples collected in the Newcastle region varied from 10% and 90%. In general terms samples collected in winter had a lesser proportion of water soluble particulates, the samples collected in summer contained a greater proportion of water soluble particulates;
- For PM10 samples collected in the Newcastle region, CGA analyses determined that a significant proportion of the insoluble particulates (in excess of 50%) were greater than 10 microns in size;
- The CGA method successfully identified the coal particulates in samples collected in the Wollongong and Hunter Valley regions.
C27067
Tailings Management - Dewatering of Slurry Tailings at Disposal Site

University of Newcastle
Craig Wheeler

Value: $150,000
Report Expected: October 2019
Industry Monitor/s: Kevin Rowe
Tom Wilson
ACARP Contact: Nerrida Scott

The objective of this project is to investigate the feasibility of dewatering slurries at the disposal site via an open declined gravity chute, or simply, a flume. The project aims to develop a flume system that can suitably dewater a coal slurry that is pumped as a lean phase slurry. The goal is to increase the solids content of the tailings entering the tailings dam and recover water before it is deposited in the tailings dam. The recovered water would be recycled back to the CHPP as process water, thus limiting the volume of water stored in the tailings dam and reduce, or eliminate, the use of secondary flocculant in the tailings dam.

Bench scale settlement testing is complete, as well as characterisation testing of parameters including; particle size, tailings density and percentage weight-by-volume (W/V%). Furthermore, an open-air channel CFD simulation, consisting of three Eulerian phases for the water, tailings and air has been undertaken of a pilot scale dewatering fume.

A pilot scale dewatering flume is in the final stages of construction. The test facility allows for variable inclination angle, and includes a series of interchangeable flow restriction plates. The CFD simulation work will be validated using the pilot scale test rig, and used to optimise the design and configuration of the flow restriction plates.

C23045
Full Scale Trial of the Reflux Flotation Cell

University of Newcastle
Kevin Galvin

Value: $294,820
Report Expected: July 2019
Industry Monitor/s: Clinton Vanderkruk
Kevin Rowe
Penny Walker
ACARP Contact: Nerrida Scott

The objective of this project is to investigate the performance of the Reflux Flotation Cell (RFC) at full scale. This will be a two-stage study investigated at a volumetric throughput of up to 1,000 m³/h. A key focus of the study is on the physics that underpin the scale-up performance of the technology, in terms of delivering ‘Fast Flotation’, and ‘Desliming Flotation’. The existence of a system of inclined channels increases the segregation rate of the bubbles from the downwards tailing flow. This mechanism produces a significant gas-hold-up, a concentrated bubbly zone, ideal for counter current washing to achieve clean product. A further objective is to assess the potential for process control of the technology, and hence assess the reliability over extended campaigns.

A number of laboratory experiments have been conducted in order to inform the project on what is possible. These experiments involve a two-stage system, each with a 0.1mx0.1m cross-section, and vessel 2.0 m high. The rougher product was then cleaned in a second stage. In general, the final product ash values were about 5%, and always well below the result indicated using the tree curve. The work has built confidence on the potential for cleaning. Other experiments have been conducted to examine much higher throughputs, equivalent to well over 1000 m³/h in a 2.0 m diameter unit.

There have been significant changes to this project. The project has been moved to a new site in order to take advantage of the existing flotation infrastructure, including feed delivery, frother supply, collector addition, and screen bowl centrifuges for product dewatering. This change greatly reduces the cost of establishing a facility for the trial. Five organisations are involved in establishing the facility to trial the technology at full scale, and a strong financial contribution from the Federal government has been secured.

Following the tender process, it was necessary to review the design for trialling the Reflux Flotation Cell to bring the project into budget. Previously it was assumed that the existing Rix’s Creek facility would result in project savings, but that structure has become a liability due to the geotechnical costs, and multilevel refurbishment. The main conclusion is that a single RFC unit will now be sufficient for achieving high throughput, recovery, and high-level product cleaning. It will be possible to undertake a rougher trial at rates approaching 1,000 m³/h, and also a rougher-cleaner combination in the one cell. This is seen as a major simplification of the technology. A concept design has been prepared, and reviewed by the organisations involved, and the final engineering almost completed. Despite this review, and delay, the project will still be on time because the construction phase will be completed much more quickly.
C24049
Performance Enhanced Diesel Collector for Coal Flotation
CSIRO
Shenggen Hu

Value: $148,013
Report Expected: March 2019
Industry Monitor/s: Clinton Vanderkruk
Mario Salazar

ACARP Contact: Nerrida Scott

In laboratory tests, it has been found that a performance-enhanced diesel collector can achieve increased collecting abilities than diesel alone. The objectives of this project are to carry out preparation plant-based assessment/demonstrations of the performance-enhanced diesel collector for:

- Increasing the recovery of both coarse and fine coal particles; and/or
- Reducing the consumption of diesel oil while maintaining good flotation performance;
- Improving collector addition methods with enhanced dispersion of collector.

Plant-based trials were carried out at a CHPP site in February to investigate the effectiveness of two reagents (PES 80 and PEK 12) for enhancing collector performance. Results from the plant-based trials indicated that the performance-enhanced reagent (PES 80) can increase the collecting ability of diesel. The combustibles recovery obtained with this performance-enhanced diesel collector can be up to 5% higher than that with the same dosage of normal diesel collector if the intensity of mixing is sufficiently high. The performance-enhanced diesel collector does not cause negative impact on the dewatering of flotation concentrate.

Additional plant-based trials were conducted in June at another CHPP having a coal which is difficult to be floated. The combustibles recovery obtained with the performance-enhanced diesel collector in the primary Jameson cell can be up to 2 to 6% higher than that with the same dosage of normal diesel collector if the intensity of mixing is sufficiently high. The performance-enhanced diesel collector does not cause negative impact on the dewatering of flotation concentrate.

C25008
3D Flotation of Fine Coal
University of Newcastle
Kevin Galvin

Value: $185,260
Report Expected: February 2019
Industry Monitor/s: Mario Salazar
Tom Wilson

ACARP Contact: Nerrida Scott

A draft report is with the industry monitor(s) for review.

C25009
Rapid Extraction of Frothers from Process Water
University of Newcastle
Jamie Dickinson

Value: $122,965
Report Expected: March 2019
Industry Monitor/s: Kevin Rowe
Mario Salazar

ACARP Contact: Nerrida Scott

Frother is used to generate fine sized bubbles in coal flotation circuits through adsorption at the bubble interface. However, residual frother at typically very low concentrations remains in the process water and recirculates throughout the plant causing downstream issues, such as frothing out the dense medium circuit, sumps, thickeners and clarifiers. The aim of this project is to investigate the extraction of frother, such as MIBC, from process water using the novel Reflux™ Flotation Cell (RFC). Unlike conventional flotation cells, the RFC operates under the so-called flooding condition, thus permitting higher fluxes in both gas and liquid per unit vessel area to be applied. Hence, the objective here is to obtain up to an order of magnitude increase in the throughput rate compared to conventional flotation cells, while maintaining the recovery and enrichment of the frother to the concentrate.

Model experiments involving the surfactant CTAB, known for having a strong adsorption isotherm, have demonstrated respectable recoveries and upgrades using the RFC. However, experiments involving MIBC and coal flotation feed were fairly less successful, presumably due to the weak adsorption isotherm associated with MIBC. Yet, a novel feature of the RFC is the use of inverted fluidization water to achieve downward fluidization through a bed of bubbles. Experiments involving the dosage of MIBC into the fluidization water rather than into the feed have demonstrated good potential to reduce frother requirements in flotation, and hence the amount recirculating in process water. The draft report is underway for submission.
C25013
Evaluation of Residual Frother Minimisation Strategies

CSIRO
Philip Ofori

Value: $167,714
Report Expected: February 2019
Industry Monitor/s: Rahul Patel
ACARP Contact: Nerrida Scott

A draft report is with the industry monitor(s) for review.

C25014
Plant Scale Testing of Safe Aerosol Frother Addition to Reduce Residual Frother and Reagent Costs

CSIRO
Philip Ofori

Value: $165,582
Report Expected: March 2019
Industry Monitor/s: Justin O’Neill, Mario Salazar
ACARP Contact: Nerrida Scott

The objectives of the project are to develop the best implementation methodology and confirm the effectiveness and safety of aerosol frother addition at plant scale in:

- Improving flotation performance;
- Reducing frother usage; and
- Minimising residual frother in process water.

The project involves a large-scale investigation of the effectiveness of aerosol frother addition at a selected CHPP. The project team visited the selected mine site to determine the retrofitting position of the frother atomising systems in consultation with site personnel. Design and fabrication of frother dosing systems, atomising nozzle sizing and positioning and connections to existing systems were completed. Dosing pumps and atomising nozzles were procured and aerosol generation and delivery systems fabrication were completed.

The complete aerosol generation system was assembled and tested in our pilot plant and minor modifications required were implemented before site installation and commissioning Plant installation. The selected CHPP for the investigations had the ideal set-up for the planned experiments with separate feed pump and frother dosing system for each cell. This made it possible for one cell to be isolated for the aerosol frother experiments to be performed without impacting the other cells operating in parallel. However, this CHPP uses a proprietary frother.

industry and great effort was made to find a site that uses MIBC and with a suitable flotation circuit configuration.

No other site was identified with MIBC dosing setup that would allow the experiments to be performed as described. It was agreed for the tests to be conducted on a large pilot-scale Jameson Cell at a Bowen Basin mine site using MIBC frother. The required modifications to the pilot-scale Jameson cell were made and set up at the mine site. A major experimental campaign has been undertaken. Samples and data analysis are currently underway and a final project report preparation is at an advanced stage and should be completed by the end of this quarter.

C25019
Adaptation of Coal Grain Analysis to Improve Yield Estimation

QCC Resources
Bruce Atkinson

Value: $165,584
Report Expected: May 2019
Industry Monitor/s: Dion Lucke
ACARP Contact: Nerrida Scott

Accurate prediction of flotation yield is difficult. Modelling of density separation processes is reasonably straightforward, however existing methods of modelling of flotation yield are poor. This project offers further development of an already commercially available analytical tool (Coal Grain Analysis – CGA) that is likely to be able to provide a more accurate basis for modelling flotation yield. The information is generated in a form is able to be directly utilised in the likes of LIMN process models.

An earlier project (C24045) involved sampling of four separate CPP flotation circuits with CGA determined on each of fresh feed, concentrate and tailings streams. The CGA data have allowed flotation response of each grain type to be evaluated, and forms of CGA flotation model have been proposed.

The preliminary data demonstrate correlations between steady-state flotation rate constant and particle size for each of vitrinite and inertinite. Interestingly, vitrinite rate constant increases with increasing particle size, while inertinite rate constant decreases with increasing particle size. All sites have been sampled and the preliminary laboratory sample preparation work completed. CGA has been completed for four of the six sites, and preliminary assessment undertaken on those data. Laboratory fine float sink and tree-flotation data have recently been completed for each feed sampled. Detailed CGA data evaluation will be undertaken after CGA data for all sites are available. The CGA data are expected to be completed by early March. A draft report is expected to be submitted to the Industry Monitors during April/May, for review.
C26001
Impact of Sub Optimal Operation: Stage 2
CSIRO
Mike O’Brien

Value: $41,500
Report Expected: March 2019
Industry Monitor/s: Mario Salazar
ACARP Contact: Nerrida Scott

The objective of the parent project C24039 ‘Impact of Sub-Optimal Operation’ was the quantification of the effects of sub-optimal operation in a coal preparation plant. Methodology for a consistent approach to the analysis of the issues involved was developed by employing the concepts from ‘The Intelligent Plant’ project. This was tested with 19 case studies which covered some activities in the plant operation, and in all cases, a successful description of the situation was obtained consistently. Methodology for this project required the entry into ‘The Intelligent Plant’ diagnostic system via a different starting point to that used in the original system. Given the successful outcome of the original project, it was recommended that a second phase project is carried out with the objective to modify the existing ‘Intelligent Plant Diagnostic’ System to access not only from a Symptom/Measurement entry but also via a Sub-Optimal Operation (Health Issue) option. An update of spreadsheet is not yet complete.

C27012
Towards Better Fine Coal Classification
QCC Resources
Andrew Swanson
Mike O’Brien

Value: $99,920
Report Expected: August 2019
Industry Monitor/s: Mario Salazar
Rod Fox
Tom Wilson
ACARP Contact: Nerrida Scott

The objectives of this project are to:
- Review/correlate all past NERDDC and ACARP work on fine coal classification (going back to the original fine coal classification at CRL in circa 1979);
- Literature survey on what is happening in research and other minerals in fine classification;
- Hold extensive discussions with OEMs to work out what are the trends around the world;
- Identify current best practice in Australian and overseas coal industry;
- Carry out simulations to indicate what the potential current losses/future gains there will be from fine coal classification improvements;
- Provide a framework for plant operators and designers to make the best choices for fine coal classification equipment/installation; and to
- Make recommendations with regard to future R&D on fine coal classification and/or pilot plant trials.

The preliminary literature review of NERDDC and ACARP, Australian Coal Preparation conference papers and International Coal Preparation Congress papers has been completed. With this information a survey has been developed to collect information from fine coal classification OEMs. The survey includes questions regarding current best practice, common problems or challenges and the direction of the OEMs research and development in these areas. The survey has been sent out to several relevant OEMs and interviews will be scheduled to carry out the survey over the phone in the upcoming weeks.

A literature review of the fine particle classification from other industries is being carried out in parallel with the OEM surveys.

C27021
Model Informed Control Strategy for Coal Flotation
University of Queensland
Kym Runge
Nee San Yap

Value: $199,571
Report Expected: October 2020
Industry Monitor/s: Clinton Vanderkruk
ACARP Contact: Nerrida Scott

The objective of this project is to develop a model informed control strategy for coal flotation. The project will involve application of AMIRA P9 flotation models developed for metalliferous flotation informed by measurements performed by CSIRO’s new InterfloatTM sensor and a froth vision system. InterFloat™ is a robust, industrial-grade device which provides accurate measurements of both the position of the pulp froth interface and the height of the froth surface above the cell lip (Figure 1). It also provides information about the conductivity within the froth phase itself which can inform the flotation model about structure of the froth.

Figure 1 – Schematic of the Interfloat™ sensor
Figure 2 – CSIRO InterFloatTM Sensor
Test work for this project will be conducted on a coal mine site in Queensland. Sensors will be mounted above an operating Jameson cell which will be operated at different operating conditions. Sampling will be performed to determine yield and ash content and correlated with sensor measurements. Models will be calibrated and tested to determine if they can be effectively used for control – maximising coal yield and selectivity and minimising reagent use.

The masters student who will perform the experimental project test work has been recruited and commenced at the University in January. The student is currently reviewing the literature and planning the experimental site test work program. Meetings have been conducted with a company representative, and a preliminary site visit is tentatively scheduled in March to help with project planning. This will be followed by CSIRO constructing an appropriately sized InterfloatTM sensor and a data collection testwork program on site mid year.

C27025
Quantifying the Step Change Benefit of Reflux Flotation Cell Circuits

University of Newcastle
Kevin Galvin

Value: $167,020
Report Expected: October 2019
Industry Monitor/s: Kevin Rowe
ACARP Contact: Nerrida Scott

The project objective is to quantify the value proposition of applying the Reflux Flotation Cell (RFC) in a number of identified applications, utilising a broad range of feeds supplied by producers. Laboratory scale RFC circuits will be used to obtain the data. The concept of complete recovery of liberated fine coal and complete washing of the product will be investigated, thus quantifying the trade-off between the recovery, moisture, grade, and throughput, and hence return on investment. The project will provide a basis for maximising the feed throughput achievable and hence a clear understanding of the value proposition of applying this technology as a ‘bolt-on’ or green-field solution. New circuit configurations will be examined.

This study will be conducted in the laboratory using laboratory scale Reflux Flotation Cells. The expected outcome will be valuable knowledge showing the relationship between product grade and combustible recovery as a function of throughput. The Reflux Flotation Cell will be configured in new ways aimed at addressing known challenges. A first stage RFC rougher will be used to firstly maximize the overall system throughput, while the second stage RFC will be applied to the cleaning of the first stage product. A recycle ratio, R, will be applied to the first stage tailings, returning R x the tailings rate back to the feed. This approach ultimately permits complete recovery of the combustible material prior to the cleaning stage, and a basis for undertaking a cost-benefit analysis in terms of the throughput, and ultimately the required capital.

The initial phase of the project focussed on the cleaning achieved at relatively low throughputs of 1 cm/s. Multiple tree-flotation curves were generated to establish the uncertainty of the method, and to provide a benchmark. Those results are evident in the Figure below. Then continuous steady state runs were undertaken, with increasing levels of wash water, creating a strong bias flux. The discrete data points generated under continuous state conditions are evident to the left of the curve. This level of cleaning correlates with the bias flux and washing ratio. More recently, a new series of experiments was conducted using a higher feed rate. The samples are being analysed.

Figure 1 Performance of the Reflux Flotation Cell versus the tree flotation curve. The discrete points were produced by the RFC under continuous conditions at a feed flux of 1 cm/s.

C27026
Ultralow Ash Coal by 3D Binder Flotation

University of Newcastle
Kevin Galvin

Value: $152,020
Report Expected: October 2019
Industry Monitor/s: Kevin Rowe, Rahul Patel
ACARP Contact: Nerrida Scott

The objective of this project is to investigate the potential to produce a coal-water mixture fuel, ideally less than 1 wt% ash, through liberation by grinding, followed by beneficiation via a novel agglomeration method referred to as 3D Flotation. Different levels of grinding will be used to achieve increasingly lower ash product. The final clean coal product will be further investigated in terms of its size distribution, rheology and stability to quantify its suitability for transport, storage, and utilization. This study is a precursor to a larger scale trial using an engine system to generate electricity.

Different levels of fine grinding will be used to achieve different levels of liberation. Each feed will then be subject to the 3D Binder Flotation technology to produce
a fine coal product. A series of experiments will be undertaken to optimise the binder addition to maximise yield. The combustible recovery-versus-product ash will be plotted for different levels of liberation in order to assess the limits on what is possible for the coal. Several coals will be studied, ideally identified by coal grain analysis. The stability of the ultrafine coal slurry will be assessed over time using rheological measurements.

An initial program of experiments was conducted, commencing with a flotation product generated from the cyclone overflow stream that is presently sent to tailings. The flotation product is preferred for three reasons, firstly, because the agglomeration only needs to be applied to about 20% of the original feed volume, secondly the subsequent grinding only needs to be applied to the fine coal (and not the mineral matter), and the grinding proceeds at a higher solids concentration. This work provided a measure of the grinding time and energy required to reduce the Sauter mean diameter of the particles. This grinding in principle increases the liberation, allowing further reduction in the ash %.

We observed a small reduction in ash% from 6.2 to 4.9%. It is possible that this coal does not liberate very well. We are looking to conduct coal grain analysis to confirm this. Further analysis showed that the level of iron in the product had increased significantly, due to the use of the grinding media. The extra iron in the product gave the impression of a lower yield, but may also have led to a higher product ash % if the iron was also recovered. This can occur due to the SMO in the binder.

More recently, we have commenced a new series of experiments using a ceramic milling arrangement. The samples are currently being analysed. We are also seeking a broader range of coals, especially those with strong prospects for liberation.

C27033
Comprehensive Flotation Model using CGA Particle Surface Composition

Basacon Services
Bruce Atkinson

Value: $74,527
Report Expected: April 2019
Industry Monitor/s: Chris Urzaa
ACARP Contact: Nerrida Scott

This project involves the adaptation of an existing particle-based flotation circuit simulation architecture, developed by the SMI-JKMRC for metalliferous flotation circuits. This architecture is being adapted to use Coal Grain Analysis (CGA) data and its relation to coal flotation.

The objectives of the project are to:

- Employ CGA particle surface composition data for coal (surface CGA methodology developed under project C25017), to apply the SMI-JKMRC flotation model that has been developed for metalliferous ores (which use surface composition data from Mineral Liberation Analysis, MLA);
- Determine whether the simulation approach adequately forecasts the flotation product yield and quality given a change in the feed characteristics to the circuit, for example, a change in the overall size distribution, the proportions or size distributions of specific coal grain classes; and
- Recommend future work that may be required to validate the impact that changes to upstream coal processing stages may have on flotation product yield and quality.

The project is progressing to schedule. Image analysis has been completed for six coal types from project C25019 to measure grain perimeter (surface) data.

The JK modelling method uses the concentrate and tail CGA data to calculate flotation rate constants for each of the ‘pure’ maceral groups: vitrinite, inertinite etc. Overall recovery (yield) and grade (quality) are then predicted based on the surface coverage of each particle by each maceral or mineral group, and the flotation rate constant for each group.

The first stage of modelling has applied that approach to every particle in a sample for three coal types, across all size fractions (the way that the CGA was measured), but that approach has led to an over-estimation of actual circuit yields. The next stage of development is to investigate the efficacy of the approach for individual size fractions, since that is the basis upon which the technique has been successful in mineral applications.

General

C26008
Oxidation Monitoring Tools and New Reagents in Plants to Improve the Flotation of Oxidised Coals

University of Queensland
Yongjun Peng

Value: $116,600
Report Expected: February 2019
Industry Monitor/s: Mario Salazar, Rahul Patel
ACARP Contact: Nerrida Scott

A draft report is with the industry monitor(s) for review.
C26010
Multi-sloped Screening Efficiency with Changing Strokes, Frequencies, Feed Solids and Feed Rates - Pilot Plant Study

CSIRO
Mike O’Brien

Value: $140,025
Report Expected: March 2019
Industry Monitor/s: Clinton Vanderkruk, Rod Fox
ACARP Contact: Nerrida Scott

This project aims to provide the coal industry with usable data from a pilot scale multi-sloped screen that can be used to maximize screening efficiency while providing the lowest possible forces on the screen, screen components and screen structures. The project targets the priority of optimising maintenance practices and equipment designs to deliver improved process efficiency at lower costs.

Test work has been held up due to maintenance, final stages of the test work are expected to be completed by March.

C26011
CSIRO Instruments at Multiple Plants

CSIRO
Mike O’Brien

Value: $427,798
Report Expected: March 2019
Industry Monitor/s: Naomi Pritchard, Rebecca Fleming
ACARP Contact: Nerrida Scott

To maintain the momentum of industry access to the CSIRO technology, the project will manufacture and install CSIRO density monitors into DMC circuits at approximately six plants covering a range of mining companies, plant designs and coal types so that operating conditions from each plant and the dense medium conditions can be monitored by the plant operators to optimize the DMC circuit providing immediate benefits to the plant. This information will also be used to further CSIRO research and knowledge on improving the efficiency of DMC circuits. Exact number of participating plants will be subject to industry pressures influencing the feasibility of their committing to the project.

The objectives of this project are as follows:

- Communicate the benefits of the technology to the broader industry; and
- Identify and engage with potential commercialisation partners to build a sustainable commercially available source of instrumentation systems.

The new electrical impedance spectrometers were delayed in their production due to some communication issues with the company producing and populating the new circuit boards. CSIRO now has ten units nearing completion for use on this project. In the interim CSIRO has invested in new moulded electrode bodies and fully enclosed moulded electrodes which will reduce costs and ensure a well-sealed electrode unit. These new style units will be used in this project following testing which will take place in February. It is expected that the completed, tested units will be available by March 2019. Final details are currently under negotiation with two plants in regards to the installation.

C26012
Improved Flotation Recovery Via Controlling Froth Behaviour - Stage 2

University of Queensland
Liguang Wang

Value: $100,000
Report Expected: March 2019
Industry Monitor/s: Naomi Pritchard, Rebecca Fleming
ACARP Contact: Nerrida Scott

The objectives of this project are to:

- Demonstrate and evaluate a real-time froth control system for maximising and maintaining the separation efficiency of coal flotation; and to
- Demonstrate and evaluate a simple and fast tool for measuring the concentration of frother in flotation cells and water circuits.

The second round of plant trial for the froth monitoring systems has been postponed to February or March, in response to a change in the CHPP’s feed coal quality schedule. Compared to the previous round of plant trial, more data will be collected in this round to evaluate the froth monitoring systems in a more comprehensive way.
A prototype of the frother concentration measurement system, which is portable, has been built and assessed at UQ. The formulation to detect the frother concentration has been upgraded to improve the sensitivity and to speed up the analysis. In the following quarter, the frother concentration in flotation cells and water circuits in the participating CHPP will be measured.

C26014
Low Cost Online Measurement of Particle Size and Density for Diagnostics Across the Fine Coal Circuit

University of Newcastle
Peter Stepien
Rohan Stanger

Value: $119,633
Report Expected: March 2019
Industry Monitor/s: Kevin Rowe, Mario Salazar, Rebecca Fleming
ACARP Contact: Nerrida Scott

The objective of this project is to develop a prototype analyser for determining particle size and density in a slurry using an image-based system. It was found that for the proposed fine circuit particle size -2.0+0.125mm, a vertical gravity-based system could provide adequate particle velocities and the spiral-based track was shelved for lower particle sizes. The work over the quarter has involved preparation of the final draft report. The report is being written in its entirety as an internal reference but will have to be cut down to remove commercially sensitive material.

Part of the final work has been comparing measured size and settling velocity distribution profiles of density separated particles in the larger particle size fractions. As expected, coal particles above 500µm tend to settle at terminal velocities slower than predicted by the Stokes-Navier equation due to the effects of non-laminar flow around the particles (creating recirculation in the wake). The effects are to under-predict the particle density distribution. We have found that this may be calibrated for by using a size-based velocity correction to input into the Stokes equation.

Figure 1. Comparison of measured settling velocity profiles for two particle size ranges (S1.25-F1.30 RD) and the theoretical values based on the measure size distribution and bulk relative density.

Figure 2. Comparison of wetting time for dry coal in size range 1-2mm showing negligible difference.

C26016
Benefits of Online Thickener Underflow Rheology Measurements

Clean Process Technologies
Noel Lambert

Value: $251,000
Report Expected: April 2019
Industry Monitor/s: Mario Salazar, Naomi Pritchard
ACARP Contact: Nerrida Scott

The objective of this project is to find how useful are the rheology measurements generated by the Thickener Underflow Monitor (TUM). The TUM was developed by Clean Process Technologies (CPT) with ACARP assistance (project C24048).

The TUM is currently able to generate information regarding the rheology of coal thickener underflow (as well as solids concentration m/m and v/v, slurry density and particle density), but the usefulness of this information is not well understood.

It is the purpose of this project to determine if and how these rheology measurements can be applied to standard thickener operations, paste thickener operations, secondary thickening operations, belt filter presses and other mechanical dewatering devices to see if online rheology measurement of tailings thickener underflow can be used to:
- Optimise thickener operation;
- Optimise paste thickener operation;
- Reduce flocculant consumption to belt filter operations;
- Reduce flocculant consumption in secondary flocculation;
- Provide a means for maintaining more consistent operation of all the above systems.
This project has been delayed due to unforeseen workloads and personnel shortages. CPT are endeavouring to continue and complete this project as soon as possible.

Since the last project update, a few issues in regards to introducing the TUM equipment to the Bulga CHPP site have arose. Although our equipment operates on 12/24 VDC and has been installed and operated on a large number of other sites in New South Wales and Queensland, Bulga have a stricter enforcement of regulations due to previous incidents.

The major issues found have been in relation to the site electrical (ELV) requirements:

- Power supply not conforming to site regulations. A commercially purchased battery storage box does not comply with the site regulations in regards to battery storage and use. The battery needs to be housed in a vented enclosure with an appropriate clamping device and have a double pole battery isolator installed. No electrical connections can be contained within the battery enclosure. We are in the process of designing and constructing new units;
- Full wiring identification and diagrams required – even though it is a prototype/trial unit. We supply these for commercially available equipment, but have not encountered this with trial units in the past. This needs to be completed for introduction to site.

Due to these above points, the TUM needs to be reconfigured to meet site specifications. Even though it is only a short-term trial, the electrical engineer is not allowing equipment on site which does not conform to the site automotive/ELV regulations. Although we do not feel as though our equipment should need to conform to this specific regulation (it is more in regards to vehicles and earthmoving equipment containing batteries or permanent installations), the only option is to make the equipment compliant for the project to continue.

We are currently working with the site electrical engineer and process engineer as to what changes must be made to allow our equipment to have site compliance.

Timeline:

- Q1, 2019 - Liaise with Bulga site personnel and confirm what changes must be made for equipment to be site compliant;
- Q1, 2019 - Construct site compliant power supplies (batteries) for TUM operation on site;
- Q2, 2019 - Produce wiring diagrams and install cable identification on all equipment wiring;
- Q2, 2019 - Produce equipment documentation and manual for trial TUM;
- Q2-3, 2019 – Install TUM at Bulga CHPP and perform trial on thickener underflow streams;
- Q3, 2019 – Compile and analyse data and submit draft ACARP report for review.

### C27004

**Improving Coal Flotation with Oscillatory Air Supply**

**University of Queensland**

**Liguang Wang**

- **Value:** $217,000
- **Report Expected:** July 2019
- **Industry Monitor/s:** Diego Dal'Molin, Kevin Rowe
- **ACARP Contact:** Nerrida Scott

The objectives of this project are to:

- Demonstrate and evaluate coal flotation with oscillatory air supply at pilot scale; and
- Evaluate energy and reagent savings of oscillatory air flotation.

An issue with the newly installed dust extractor in the laboratory caused a delay in preparing the fine coal samples for the pilot scale flotation tests. The issue was recently resolved, and the pilot scale flotation tests are expected to be completed next quarter.

Following the suggestions received from the Industry Monitors at the last review meeting, additional work will be carried out to test a new concept of using oscillatory air supply to improve the recovery of a flotation column at a participating CHPP. Development of a new aeration system (ie diffuser and oscillatory air supply) is under way. Several different aeration systems will be tested prior to the on-site evaluation.

### C27028

**Lab Froth Flotation Testing Guide with Coal Quality**

**McMahon Coal Quality Resources**

**Chris McMahon**

- **Value:** $29,820
- **Report Expected:** May 2019
- **Industry Monitor/s:** Angus McIntyre, John Kelly
- **ACARP Contact:** Nerrida Scott

This project aims to examine data attained by MCQR in froth flotation across several deposits to define effective reagent dosages for effective froth flotation outcomes and to produce a guide for use with Australian Standards.

Three sample sets are due for review.

Three primary froth databases for review had trending studies with frothing conditions performed.

The focus with data review has been to provide different set examples of evenly distributed mass outcomes with successive effective liberation of coal from non-coal. The purpose being to establish what reasonable liberation / separation looks like for coals of different rank and coal quality character. Next stages will apply statistical methods to the good correlations established from typical
froth procedures with regression definition and limits for effectively frothed outcomes.

A significant part of this project has always been to establish reagent dosage effects with rank and other coal quality outcomes and supply guidelines for use. These effects have been observed through the trending analysis done to date and will be documented for use also.

Three secondary sets of froth data have been compiled for their special interest / notes for froth flotation methods. Formal reporting of outcomes is due for commencement.

C27032
Methodologies for Applications of CGA: Handbook
Basacon Services
Bruce Atkinson
Graham O'Brien

Value: $51,422
Report Expected: April 2019
Industry Monitor/s: Angus McIntyre
Chris Urzaa
Morgan Blake
Pam White
Richard Ruddock

ACARP Contact: Nerrida Scott

This project involves formulation of an ACARP Handbook that will detail current methodologies for applying coal grain analysis (CGA). It is a follow-on from the series of industry workshops held during 2017. The project involves formal documentation of the methodologies that are used to apply CGA data.

The Handbook will provide a sound basis for possible future publication as an Australian Standard Handbook for applications of CGA. Publication as an AS Handbook has been delayed for consideration by the MN-001 Committee until after the ACARP Handbook is first published and peer-reviewed. The Handbook will also document the methodology for determination of fine coal washability using CGA, and it is anticipated that this method may be able to be incorporated (in future) as a new Standard: Washability Determination of Fine Coal (minus 1 mm) under Australian Standard 4156.1.

The project is progressing to schedule. Drafts are well developed for six chapters. It is expected that the draft report will be completed and submitted for review by the end of March.

C27050
Detection of Non-Ferrous Broken Pick Tips and Clay Balls in the DMC
CSIRO
Mike O'Brien

Value: $61,280
Report Expected: March 2019
Industry Monitor/s: Clinton Vanderkruk
ACARP Contact: Nerrida Scott

The objective of this project is to adapt an acceleration sensor currently used on screens to ‘listen’ for and alert operators to the presence of non-ferrous pick tips from underground mining operations and for the formation of clay balls in the Dense Medium Cyclone (DMC). Detection and notification to the operators of the presence of pick tips in the DMC will prevent further damage and decrease repair/replacement cost and associated lost production due to down-time. The early detection of clay balls is essential to prevent build up and blockages resulting in misplaced material reporting to the product. Often these pick tips and clay balls go unnoticed while recirculating in the DMC for considerable periods before their presence is observed by the ‘noise’ they make; only then are steps taken to remove them from the cyclone.

The vibration-based detection system has been tested in the laboratory and is now ready for deployment. Electronics and communication equipment are currently being installed into a cabinet for installation at a site for a trial in April.

Gravity Separation

C24050
Options for the Addition and Control of Non-Magnetic Material in Correct Medium
CSIRO
Mike O'Brien

Value: $205,490
Report Expected: March 2019
Industry Monitor/s: Clinton Vanderkruk
Justin O'Neill
ACARP Contact: Nerrida Scott

The objective of this project is to investigate various options for the addition or maintaining/controlling the level of non-magnetic material in the correct medium following a period where the concentration of non-magnetics in the medium is low, e.g., after a shutdown or outage. The most prospective of these options and any operating procedures will be tested at a plant. We are awaiting internal report review.
C24051
Effect of Particle Crowding at the Vortex Finder and Spigot on Cyclone Operation

CSIRO
Mike O’Brien

Value: $145,255
Report Expected: March 2019
Industry Monitor/s: Mario Salazar
ACARP Contact: Nerrida Scott

This project aims to quantify the changes in DMC operational conditions on particle crowding of the vortex finder and spigot. The major outcomes of this project would be an improved understanding of the influence of particle crowding and medium stability on DMC cleaning capability. The understanding is based on well-defined experiments, and availability of improved quantitative relationships allows for better management strategies for DMC operation.

The report is complete and awaiting internal review.

C25015
Pilot Plant Scale Testing of Modified Downcomer in Jameson Cell

CSIRO
Shenggen Hu

Value: $184,149
Report Expected: March 2019
Industry Monitor/s: Clinton Vanderkruk, Justin O’Neill
ACARP Contact: Nerrida Scott

The objective of this project is to carry out large pilot scale investigations of the modified downcomer at a mine site for a comprehensive assessment of improved combustibles recovery and scalability, via:
- Designing and constructing a pilot scale test rig;
- Comparing the performance of the modified downcomer with that for the unmodified downcomer in terms of the combustibles recovery and product ash value under normal plant feed conditions and assess the scalability of the modifications;
- Carrying out residence time distribution tests to determine the effectiveness of modified downcomer in improving cell hydrodynamic behaviours.

The pilot scale test rig was developed by modifying a 500L Jameson cell from Glencore Technology with mass flowmeter and RTD test facilities. One suitable plant test site was identified based on the considerations of coal types, frother type and material handling. As there is no ground space for the test rig, the rig has to be installed at the second floor of the plant. The test rig was securely installed in August by considering the structure soundness of the plant floor and safe measures for holding the rig. Pilot scale testing of modified downcomer in Jameson Cell was carried out in September and October. Analysis of samples is being carried out. Based on results obtained from parts of samples, the modified downcomer increased the combustibles recovery by 3 to 8%. It was also found that the use of the modified downcomer can decrease the feed pressure by 21 to 25%.

The final report is being prepared.

C25016
G Force Reduction and Failure Monitoring of Multi Sloped Screens

CSIRO
Mike O’Brien

Value: $190,282
Report Expected: March 2019
Industry Monitor/s: Clinton Vanderkruk
ACARP Contact: Nerrida Scott

This project has two objectives, designed to address the priorities of optimising maintenance practices and equipment designs to deliver improved process efficiency at lower cost. It will provide a detailed proof of concept on desliming and drain and rinse screens by:
- Determining the effect of further reducing the screening force on desliming and drain and rinse screens on screening efficiency; and
- Monitoring a screen continuously for failure indicators using the CSIRO/ACARP-developed system to show that the system is viable for use as a long-term indicator of imminent screen failures.

The report writing is in progress.

Major Projects

C20052
Full Scale Gravity-Desliming Using Cascading Reflux Classifiers

University of Newcastle
Kevin Galvin

Value: $215,480
Report Expected: February 2019
Industry Monitor/s: Kevin Rowe, Tom Wilson
ACARP Contact: Nerrida Scott

A draft report is with the industry monitor(s) for review.
C22046
Reflux Classifier to 4mm Top Size - Full Scale Trial (Construction of Test Rig)

University of Newcastle
Kevin Galvin

Value: $1,318,748
Report Expected: February 2019
Industry Monitor/s: Kevin Rowe
ACARP Contact: Nerrida Scott

This project will move an innovative process improvement from the laboratory and pilot scale to a trial in an operating plant at full-scale. The project has a committed host site, with strong engineering and scientific support from contributors.

A larger size feed, up to 4mm, will be directed to the Reflux classifier, thereby reducing the load to the dense medium cyclones. This will in turn increase the capacity of the slimes screen which has been the limiting factor in the capacity of coal preparation plants. The work has the potential to increase plant throughput for a given Capex, and may even deliver higher yield.

In a second project, C20052, the facility will be used to undertake a full-scale trial of cascading Reflux Classifiers, involving gravity separation and then desliming of the final overflow product. The goal is to provide alternative methods for processing fine coal, extending the recovery to lower particle sizes via the controlled desliming of the clean coal product.

From a research perspective, this construction project is a major undertaking, involving four organizations and other consultants. The final construction phase for the first research project, C19001, was completed in November 2015. The project work was then undertaken through 2016, and the draft final report lodged in January 2017.

In preparation for Project 2, C20052, a modified circuit was required. The modifications commenced in the second half of 2016 and were largely completed by the end of November 2016. Thus, commissioning of the new circuit was undertaken by December, followed by initial experimentation. The need for a number of circuit adjustments was identified and some changes were made to improve the operability. The need for these adjustments reflects the substantially lower processing rates for the much finer feed. The -1 mm feed is sourced from a -16 mm feed; hence it is still necessary to convey particles up to 16 mm in size onto the large screen. The diameter of the pipe on the main pump inlet side is too great, hence there is a tendency for the feed to segregate and cause a blockage. This pipe was replaced allowing the work to resume.

The facility worked very well, generating high quality gravity separation and desliming as noted in the quarterly report on Project 2, C20052.

The final stage of this project has been completed and the Industry Monitors have accepted the interim summary. Plans are underway for the removal of the facility this year. Tender RFQs have been placed, and then modified. The outcome is being reviewed and a decision will be made very soon.

Process Control

C26013
Effect of Flotation Water Chemistry on Coal Chemistry, Fluidity and Coke Quality

University of New South Wales
Noel Lambert
Seher Ata

Value: $169,000
Report Expected: March 2019
Industry Monitor/s: Clinton Vanderkruk
Rebecca Fleming
ACARP Contact: Nerrida Scott

The aim of this project is to expand on project C25011 that was initiated at the beginning of 2016. An increased salinity of the water was found to reduce coal fluidity. The second part of this project is integrating flotation experiments. It is believed that the presence of inorganic electrolytes may affect the quality of the coal recovered by flotation, which would further affect the fluidity of the product.

Preliminary flotation experiments were conducted with an experimental design that involves various flotation conditions. It was found that the water recovery was significantly increased when the salinity of the water was increased. Increasing frother dosage further increased the water recovery while water salinity was increased.

Another series of experiments were carried out to determine the effects of flotation reagents on the thermoplastic properties of coal samples. The series involves the use of an automated stirrer with timer, artificial water samples made of Na2CO3 (10 mM) and NaCl (0 mM, 40 mM, 100 mM, 160 mM, and 200 mM), and different concentrations of frother (MIBC, 0 g/t, 3.2 g/t, 8 g/t, 12.8 g/t, and 16 g/t) and collector (dodecane, 0 g/t, 30 g/t, 75 g/t, 120 g/t, and 150 g/t). The recovered coal was dewatered and dried in a vacuum oven. Fluidity test and free swelling test were carried out on the dried coal samples. It was found that MIBC had a positive effect on the maximum fluidity of coal, and this positive effect could be offset by the presence of dodecane and salt (see Figure 4). The plastic range of coal was mainly affected by the amount of salt present, higher concentration of salt in the water seemed to reduce the plastic range of coal, which meant that the thermoplastic transformation was shortened. In addition, the negative impact of salt on the plastic range was found to be more profound while the collector or frother concentration was increased. On the other hand, the free swelling index did not seem to be affected by the designated factors.
Another series of experiments have been started which involves flotation tests and surface analysis. The surface analysis will also be conducted on treated coal sample and pyrolysed coal samples for surface chemistry changes.

Figure 4. 3D surface diagrams showing the effects of (a) NaCl – MIBC interaction and (b) NaCl – Dodecane interaction on coal maximum fluidity.
TECHNICAL MARKET SUPPORT

General

C25053
Coal Sample Bank

CSIRO
Keith Vining

<table>
<thead>
<tr>
<th>Value:</th>
<th>Report Expected:</th>
<th>Industry Monitor/s:</th>
<th>ACARP Contact:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$279,329</td>
<td>October 2021</td>
<td>Technical Market</td>
<td>Ashley Conroy</td>
</tr>
</tbody>
</table>

The main objective of this project is to operate the ACARP Sample Bank to make coal and coke samples available to researchers and to enhance the systematic provision of the samples for research projects funded by ACARP.

32 coal samples were delivered and stored at -18°C and their details updated to the database. Out of 32 stored coals, 27 were fully analysed and analysis results provided by the coal producers. Coal samples missing the samples analysis.

ACARP Sample Bank updated testing forms are in use to follow the standard reporting formats within the industry which are covered by Australian standards. To accommodate the expanding collection of samples, new refrigerated container was purchased, installed, electrically connected and fully equipped (signs, safety bell, floors, heavy duty shelving and lights) and it is currently in use. Moreover, pilot scale ACARP coke samples were carbonised within August and provided to the researchers within the same month including all coke testing results.

Coal and coke samples banked since February 2018

<table>
<thead>
<tr>
<th>COAL:</th>
<th>April</th>
<th>May</th>
<th>July</th>
</tr>
</thead>
<tbody>
<tr>
<td>075-T-001</td>
<td>075-C-001</td>
<td>075-T-001</td>
<td>075-T-001</td>
</tr>
<tr>
<td>076-T-001</td>
<td>076-C-001</td>
<td>076-T-001</td>
<td>076-T-001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COKE:</th>
<th>April</th>
<th>August</th>
</tr>
</thead>
<tbody>
<tr>
<td>101-K-001</td>
<td>101-K-001 (no longer available)</td>
<td></td>
</tr>
<tr>
<td>102-K-002</td>
<td>102-K-002 (no longer available)</td>
<td></td>
</tr>
<tr>
<td>104-K-001</td>
<td>104-K-001 (no longer available)</td>
<td></td>
</tr>
<tr>
<td>105-K-001 (no longer available)</td>
<td>105-K-001 (no longer available)</td>
<td></td>
</tr>
</tbody>
</table>

Coal and coke samples were provided to the following projects in 2018 - C27017, C26046, C26043 and C27047.

C26003
Management of SA and ISO Coal Technical Committees Work Programs

Carbon Connections
Barry Isherwood

<table>
<thead>
<tr>
<th>Value:</th>
<th>Report Expected:</th>
<th>Industry Monitor/s:</th>
<th>ACARP Contact:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$185,550</td>
<td>June 2020</td>
<td>Graeme Harris</td>
<td>Anne Mabardi</td>
</tr>
</tbody>
</table>

This project is a continuation of ACARP support for the management of and input into both Australian and ISO Coal Sampling, Preparation and Analysis Standards. It is pleasing to note and appreciated that this project has been granted an extension till end Dec 2020.

SA Committee MN/1/1, Coal Analysis held a meeting in November and continued discussions on ISO Standards which were undergoing systematic review and Australia’s position on each Standard. The outcome of such reviews will be discussed in detail at the forthcoming ISO TC27 meeting to be held later this year. Work continues to compare and align where possible, all ISO, AS and ASTM Standards, with Barry Isherwood compiling a master sheet highlighting current inconsistencies. This spreadsheet will be discussed at the next MN/1/1 meeting, to develop a position to take to the next ISO meeting.

In October, Barry Isherwood prepared and presented to the ACARP Coal Preparation Committee, on current SA and ISO activities along with strategic direction being developed and followed and the need for ACARP to provide input to the strategic drivers. He repeated this same presentation to the SA MN/1/2 Coal Preparation Committee in November.

It was noted that the Coal Preparation Committee is very well attended by representatives of most coal companies, whereas the SA Committee has much less company input and ideally the SA Committee is the channel for the required input and it is hoped that increased company participation can be achieved.

SA Committee MN/1/2 Coal Preparation, at its November meeting, discussed a range of projects including the SA Float/Sink, Sampling from CPP’s Handbook and Density Tracers Standards (all in the final stages of publication). It was noted that an ACARP project on Dust Moisture Relationship has now been published and will be the basis for a revised Australian Standard. A number of ISO standards were also discussed including Graphical Symbols, Coal Cleaning Equipment Performance and Online Analysers.

Discussions are progressing with the Japanese, to host the next ISO TC27 meeting in Tokyo from October 6 to 11, with a formal announcement expected this month.
In an attempt to increase the involvement of the 40 plus member countries involved with ISO TC27 (currently only around 30% actively participate), in his role as TC27 Chairperson, Barry prepared and sent an information pack to over 40 delegates/member countries who were registered on the ISO TC27 website. To date, some promising responses have been received from Egypt, Tanzania and India. It is noted that Egypt has just recently announced plans to build a 6600MW coal fired power station.

C26037
Australian Participation in Development of ISO Methods for Sampling, Analysis and Coal Preparation and National Technical Committee Support: 2017/2018

Standards Australia
Ahshanur Rashid

Value: $77,500
Report Expected: February 2019
Industry Monitor/s: Graeme Harris, Kevin Rowe, Kim Hockings

ACARP Contact:
Anne Mabardi

SA support for Australian Mirror Committee—Schedule of meetings.

MN-001 (Coal and Coke)—Mirror Committee for ISO/TC27
Chairman: Barry Isherwood
Next meeting: July 2019, Brisbane (TBC)

MN-001-01 (Coal analysis) —Mirror Committee for ISO/TC27/SC3 and SC5
Chairman: Barry Isherwood
Last meeting: 21st November 2018, Newcastle
Next meeting: 14th March 2019, SA Office, Sydney
Meeting objective: Review ISO/TC27/SC5 & SC3 documents including systematic reviews and finalise Australian mirror Committee position on ISO ballot (and comments).

MN-001-02 (Coal Preparation) —Mirror Committee for ISO/TC27/SC1 and SC4
Chairman: Dave Osborne
Last meeting: 22nd November 2018, NIER, Newcastle
Next meeting: 12th March 2019, CSIRO, Pullenvale

MN-001-02 Subcommittee has three active projects to develop Australian Standards

SA HB 196 Guide for Sampling in Coal Preparation Plants, Drafting Leader: Jim Docherty—Published Dec 2018.
AS 5213 Density tracer testing for measuring performance of coal density separators, Drafting Leader: Chris Wood—At Ballot Stage.

MN-001-05 (Coal Mining and Geology)
Chairman: Walter Pickel
No meeting planned; Subcommittee has no work program.

MN-001-06 (Determination of Gas Content)
Chairman: No Chair
No meeting planned; Subcommittee has no work program since publication of AS 3980-2016.

Major Projects

C27001
Maritime Regulation Project: Self Heating and Corrosivity Test Evaluation

Goodwin Port Solutions
Ash Goodwin

Value: $1,877,614
Report Expected: January 2021
Industry Monitor/s: Maritime Regulation Task Group

ACARP Contact: Anne Mabardi

The project includes research to investigate issues identified in relation to the accuracy, repeatability and reliability of the IMSBC Code corrosivity test. ACARP work is closely linked with a Global Industry Alliance addressing similar issues from an international perspective for other cargoes. Initial research is now complete for coal and other cargoes and has been peer reviewed. Findings and recommendations were reported to the IMO in September 2018 resulting in guidance note ‘MSC.1/Circ.1600 – Interim guidance for conducting the refined MHB (CR) corrosivity test’ being issued by the IMO in January.

The second aspect of the project relates to similar issues of accuracy, repeatability and reliability when testing coal cargoes for self-heating potential as required under the IMSBC Code. Outcomes and recommendations from the initial phase of test work were reported to the IMO in September 2018.

Experimental work is continuing to evaluate application of a European test protocol to determination of self-heating potential of coal cargoes.
Metallurgical Coal

C24057
Estimating the Fusible Content of Individual Coal Grains and its Application in Cokemaking

CSIRO
David Jenkins
Karryn Warren
Merrick Mahoney

Value: $230,026
Report Expected: March 2019
Industry Monitor/s: Kim Hockings
Nick Andriopoulos
Oliver Scholes

ACARP Contact: Anne Mabardi

The objectives of this project are to use three recently developed analytical techniques to obtain new insights into the link between the size distribution of the fusible and infusible macerals and minerals and resultant coke structure and strength. This has applications in optimising the preparation of coal for coking and in obtaining the highest strength coke from coals. The techniques to be used are enhanced Coal Grain Analysis (CGA), the analysis of 3D microstructure of coke from Computed Tomography (CT) scanning and the analysis of fracture surfaces using fractographic techniques.

All of the analyses are complete and the final draft report is almost complete. The extension project to analyse a further two coals grind series is also underway.

In the next quarter we hope to submit the draft report.

C25045
In Situ High Temperature Strength of Low CSR Cokes

University of New South Wales
Pramod Koshy

Value: $190,000
Report Expected: June 2019
Industry Monitor/s: Kim Hockings
Nick Andriopoulos

ACARP Contact: Anne Mabardi

This project is a joint collaboration between UNSW Sydney, ANSTO, and UoN. From the work in Stages I and II, the strength at high temperatures was seen to not have a clear correlation with the CSR values, with the high-temperature strengths being generally higher for the low CSR cokes. Moreover, the strengths increased generally with increase in temperature and showed had close correlation with the extent of graphitisation. The work in Stage III has focussed on the effects of reactive atmospheres on the high-temperature strengths of one high and one low CSR coke (from Stages I and II, respectively).

The objectives are to:

- Determine the in-situ high-temperature strengths of high and low CSR cokes after reactivity tests;
- Determine and predict the creep deformation in the reacted cokes at 1550°C; and to
- Correlate the coke CSR values with the actual modification of strength at high temperatures (before and after reactivity tests) and to associate it with parent coal attributes.

The high-CSR and low-CSR coke were supplied by the industry monitors. From these cokes, cylindrical samples (~21 mm height, ~19 mm diameter) were cored and then end-polished and subjected to reactivity tests using temperatures and atmosphere profiles simulating conditions in a blast furnace. Both the high CSR and low CSR coke samples showed similar weight losses after reactivity tests (~10%). Room temperature strength tests showed that the strengths were quite similar, with the high CSR samples showing slightly higher values. These values were in similar range to the samples not subjected to reactivity tests. Constant stress tests for the high-CSR cokes at 1400°C and 1550°C showed that the strengths increased with the testing temperature. These strengths were lower than the samples that were not subjected to reactivity tests.

C25048
Automated Optical Image Analysis of Coke Texture and Structure and their Connection with Coke Porosity, Reactivity, Strength and Parent Coal Blend

CSIRO
Eugene Donskoi

Value: $149,913
Report Expected: February 2019
Industry Monitor/s: Oliver Scholes
Sean Flanagan

ACARP Contact: Anne Mabardi

A draft report is with the industry monitor(s) for review.

C25049
Fusibility of Coal Blends and Behaviours of Minerals in Coking

CSIRO
Merrick Mahoney
Priyanthi Hapugoda

Value: $193,020
Report Expected: March 2019
Industry Monitor/s: Kim Hockings
Stephen Brant

ACARP Contact: Anne Mabardi

Three main objectives of this project:

- Understand the fusible reflectance range for major Australian coking coal basins, via the method demonstrated previously. This requires an extension of the number of coals in the database of results;
Test the fusible range of the coals in a binary blend and investigate the interactions between the components of a blend that change the fusibility characteristics of the individual coals;

Identify the major minerals in the different basins and the way they transform during coking without the need for coal and coke ashing;

Extension for C25049; CGA analysis of standard petrographic samples to predict coal fusibility for 15 coals (6 coals from C21059 and 6 coals and 3 blends from C25049 coals).

Progress to date:

• All the analysis completed and report writing in progress;

• To date all the coking of coal lumps were completed by the collaborator Newcastle University (Task 2 and 3) and coking images from Pearson's were already received and characterization in progress- All completed;

• CGA analysis of coke oven feed size fractions for each of the 6 single coals and 3 blends; All size fractions (+2mm, -2+1mm, -1+0.5mm and -0.5mm) of coke oven feed (24) and 3 blends (12 samples) imaged and processed using CGA- All completed;

• Fusible reflectance threshold range for each coal and retrieving CGA data with fusible inertinite thresholds for all size fractions for each of the 6 single coals - All completed;

• Modification of CGA software to characterise coal blends for Task 6 - All completed;

• SEM assessment of coal and coke halves - All completed;

• Analysis of all standard petrographic samples from this project 6 coals from C25049 and 4 coals C21059 completed - All completed;

• MTA analysis of the cokes produced for these 9 samples (collaborators, New Castle Uni) - All completed.

The draft report was completed and internally reviewed. The final review is being undertaken by the second project leader before submission.

C25051
Links Between Microstructure Development in Softening Coal and the Characteristics Controlling Coke Quality

University of Newcastle
Merrick Mahoney
Richard Sakurovs

Value: $139,715
Report Expected: June 2019
Industry Monitor/s: Nick Andriopoulos, Oliver Scholes
ACARP Contact: Anne Mabardi

The project is an extension of project C23048 'Investigation of the links between microstructure development in softening coal and the characteristics controlling coke quality' and extends the successful outcomes of the previous project. It addresses the questions of how coke structure is formed within the plastic layer during coking and how these structures control strength of the final coke. It also addresses the question of how different inertinites in coal affect the development of structure and strength in coke. Specific project objectives are:

• Further develop understanding of the relationships between key microstructural features of coke and coke failure mechanisms and strength indices;

• Understand the development of key microstructure features by identifying key processes in the plastic layer contributing to the development of coke microstructure;

• Develop some understanding of how different inertinite types can influence structure development by modifying processes in the plastic layer.

The draft report is about 70% complete. It is expected that the submission of the draft report will be delayed until June.

C25052
Concentrating Coke Oven Sized Inertinite Particles: Behaviour in Targeted Coking Blends

University of Newcastle
Wei Xie

Value: $91,690
Report Expected: February 2019
Industry Monitor/s: Shaun Booth, Tim Manton
ACARP Contact: Anne Mabardi

A draft report is with the industry monitor(s) for review.
C26039
Nanoporosity in Cokes: Their Origin and Influence on CO2 Reactivity

CSIRO
Mihaela Grigore

Value: $149,756
Report Expected: April 2019
Industry Monitor/s: Kim Hockings, Nick Andriopoulos, Oliver Scholes
ACARP Contact: Anne Mabardi

Project C24060 found that closed nanoporosity occur in large proportions in cokes, and almost all pores less than 5 nm are closed. The amount of closed porosity in cokes was influenced by the maceral composition of the parent coals. In addition, the study on two cokes and their parent coals suggested that many of the closed nanopores are inherent to the parent coal, even down to nanometer-sized pores. The aims of this project are to determine the role of nanoporosity in cokes on the gasification rate, establish to what extent nanopores are inherited from the original coal or formed during coking and determine association of closed nanoporosity with macerals in coals.

The experimental work has been completed and the final report is in preparation.

C26040
Fusible Content of Individual Coal Grains and its Application in Cokemaking

CSIRO
Karryn Warren, Merrick Mahoney

Value: $161,640
Report Expected: April 2019
Industry Monitor/s: Kim Hockings, Nick Andriopoulos, Oliver Scholes
ACARP Contact: Anne Mabardi

The objectives of this project are:
- To understand the link between coke oven coal grain composition and coke structure and strength and improve our ability to explain/predict anomalous strength results;
- To help to confirm new insights obtained from C24057 into the links between the size distribution of fusible and infusable macerals and minerals, associations of maceral structures in coke oven feed coal and resultant coke structure and strength; and
- To further understand the mechanisms behind why coals from the Rangal Coal Measures have unexpected coking behaviour.

Fractographic analysis for three IRF grinds per coke series has been completed. For cokes D and E, a weak negative association was observed between the size range of the inertinite maceral derived constituents (IMDC) and the degree of their interfacial contact with the reactive maceral derived constituents (RMDC). Further, for both coke series, the amount of transgranular cracking of the IMDC was found to decrease as the IMDC size range increased. This trend was also evident for coke C (assessed as part of ACARP C24057), whereas cokes A and B (from different parent coal measures to cokes C, D and E) showed the reverse behaviour.

CGA of the size fractions from coal D IRF grinds is almost complete and is underway for the size fractions for coal E IRF grinds. Size information for each of the fusible and infusible structures will be extracted for each sample and the data analysed in the next quarter.

3D image analysis of the microstructure of the cokes using reconstructed CT images of coke lumps is underway using Geodict for the analysis. Pore size distributions, estimate of wall thickness and estimate of relative number of high stress points in each coke structure (finite element analysis of the response of the structure to compressive load) will be determined.

C26041
Australian PCI Coals Under Industry Scale Conditions of Ironmaking Blast Furnace using 3D Computer Modelling

University of New South Wales
Yansong Shen

Value: $200,000
Report Expected: May 2019
Industry Monitor/s: Chris Urzaa, Kim Hockings, Morgan Blake, Stephen Brant
ACARP Contact: Ashley Conroy

This project aims to evaluate the combustion behaviour of the blends of Australian PCI coals under industry-scale blast furnaces (BF) conditions using an improved 3D computer modelling. In Stage 1, the single Australian PCI coals were evaluated using a 3D PCI model. In the Stage 2 of the project, the model will be further developed for evaluating the blends of Australian PCI coals by means of explicitly considering interactions between the component coals in a blend, and then will be used to optimize blending parameters for improving overall burnout of the blends.

During this quarter:
- Coal data - three coal blends are designed, including LV/MV, LV/HV and MV/HV coal blends. The data of LV, MV and HV coals are from TMS members. They will be used in stage 2;
- Parametric study of pilot-scale PCI model of coal blends has been conducted in aspects of some key PCI operational variables such as blast temperature and PSD etc. under pilot-scale test rig conditions. Some blending fractions will be studied for the three blends,
in addition to 50%+50%. Over 100 simulations have been done;
• Model improvement - Significant effort has been made to further develop the PCI model for coal blend from pilot-scale to industry-scale. Specifically, in this quarter, the key improvements include:
  1) The computational domain is extended from blowpipe, coal lance, tuyere and raceway mainstream to blowpipe, coal lance, tuyere, raceway and coke bed,
  2) In addition to coal blends, coke is also considered in the industry scale model,
  3) Two component-coals are considered separately, in aspects of flow and chemical reactions (rather than simply treating the blend as one coal with averaged properties), and
  4) The interactions between the component coals in the blends are considered explicitly;
• The literature reviews for the topics from Industry Monitors (reasonable size distribution for HV coal) are completed. They have been tested in this quarter;
• Shen visited Baosteel and Hebei Steel of China in January and discussed the possibilities of collaboration between Baosteel / Hebei Steel and ACARP in the field of Australian PCI coal. UNSW/ACARP delegation was invited to visit China again in 2019 for further discussion;
• The team is still exploring India BF data for developing India-BF PCI simulator.

C26042
Coal Swelling in PCI Lance Conditions

University of Newcastle
Liza Elliot

Value: $179,500
Report Expected: April 2019
Industry Monitor/s: Chris Urzaa, Jason Nunn
ACARP Contact: Anne Mabardi

Deposition of coal within a tube heated to 1200°C as coal is conveyed under pneumatic transport, as in PCI, is being measured. Calculations and experiments completed without heat have shown that particle flow is consistent and above the saltation velocity. When the tube is heated to 1200°C, significant deposition within the tube occurs for all except one of the coals considered. Experimental data for the coals tested are shown in Figure 1.

![Figure 1: Experimental data; pressure drop measured across the heated tube during feeding of coals.](image)

The pressure drop along the tube is a direct measurement of the build-up occurring within the tube. The initial slope of the curve is used as a measure of the deposition potential for each coal and has been compared with the coals' crucible swell number (CSN), shown in Figure 2. It is clear from the figure that, on its own, CSN is not a legitimate tool for determining a coal's propensity for blocking the PCI lance.

![Figure 2: The slope of pressure drop along the tube with time compared to each coal's CSN.](image)

Computer aided thermal analysis (CATA) has also been completed on these coals. This technique provides the swelling behaviour at low heating rates but also provides the thermal conductivity and the heat capacity of the coals at temperature. While there is no correlation with the swelling measured by CATA, there may be a link between the blockage behaviour and the heat capacity of the coal at temperatures when annealing of coal occurs after pyrolysis. There also appears to be a link between the coals transport behaviour, as measured by Carr indices, and the blockage potential, though outlier occur for both trends.
SEM Imaging is still to be completed and progress has been made on the report. Delays associated with setting up the experimental rig, mill failures and CATA experimental technique have caused the project to fall behind its proposed project schedule. An additional six months has been requested to allow the project to be completed concurrently with another project.

C26043
Characterising the Degradation of Cokes made from Australian Coals and Subjected to Simulated Blast Furnace Operating Conditions

University of New South Wales
Paul Zulli
Xing Xing

Value: $362,620
Report Expected: September 2019
Industry Monitor/s: Stephen Brant, Tim Manton
ACARP Contact: Ashley Conroy

The key objective of this project is developing further understanding of the degradation of cokes under blast furnace (BF) conditions and methodologies for the characterisation of cokes under simulated BF conditions.

Specific objectives of this project include:
• Understanding effect of high/low rank coking coal addition on coke performance under more realistic BF conditions;
• Further development of investigative methods to simulate BF operating conditions by the addition of water vapour into coke gasification atmosphere and the introduction of CO and H2 to the gas atmosphere in a study of coke annealing; and
• Further elucidation of effect of coal interactions during coking on the coke performance under the BF conditions.

Progress to date:
• Pilot scale coking of commercial coal blend and four-compartment charge coal blends were completed;
• Conventional characterisations of all the cokes were completed;
• Gasification and annealing of all the cokes and cokes made from single coal constituents were completed;
• Comparison of BF performance of cokes produced in pilot oven and commercial coke battery was completed;
• The macro strength, micro strength and crystallinity of four-compartment charge cokes and cokes made from single coal constituents were determined using I-drum tumbling testing, tensile testing, ultra-micro indentation, XRD and Raman spectroscopy. The crystallinity and micro strength were measured separately on different coke microtextural types.

The reactivity of cokes under the simulated BF conditions was determined by the weight losses of cokes upon BF gasification and annealing. The measured weight losses of cokes made from coal blends were consistent with the weighted average of values calculated from the cokes made from single coal constituents. The development of coke crystallinity upon simulated BF conditions was determined using XRD and Raman spectroscopy. Both measurements confirmed that the measured crystallinity of cokes made from coal blends were higher than the weighted average values calculated from cokes produced from single coal constituents. The degradation of coke macro and micro strength under the simulated BF conditions were determined using tensile and ultra-micro indentation test, respectively. The measured macro and micro strength of cokes made from coal blends were general consistent with the weighted average of values calculated from the cokes made from single coal constituents at each treatment condition.

Next quarter work:
• The feed coke of all the cokes in this project has been submitted for Pearson petrographic analysis. The proportion and distribution of each coke microtextural type will be analysed when the results are ready. The development of coke pore structure and degree of degradation will be determined using image analysis in January to March.

C26044
Physical and Chemical Interactions Occurring Between Macerals During Cokemaking and their Influence on Coke Strength

University of Queensland
Karen Steel
Wei Xie

Value: $149,750
Report Expected: April 2019
Industry Monitor/s: Ashley Conroy, Nick Andriopoulos, Oliver Scholes
ACARP Contact: Anne Mabardi

This project is a follow on from project C24055 of the same name. We are studying the effects that inertinite has on coking behaviour, focusing on the effect that inertinite has on viscosity. We have produced maceral concentrates and studied various blends using rheometry, DETA and TGA (100 mg).

All test work has been completed and we are completing the analysis/interpretation and writing the final report. Our final test work involved blending vitrinite (lots of pores) and graphite (no pores) to better understand how the pore structure of a solid influences viscosity development. Given that volatile release affects viscosity we have also conducted studies where we blend a high viscosity silicone oil (emits no volatiles) with graphite and activated charcoal in order to understand the effects of solids on viscosity when no...
volatiles are emitted. This is helping us to piece together the different influences and explain the effect that inertinite has on viscosity. As a final bit (not part of the original project proposal) we are also carrying out CT analysis on the coke buttons produced from the DETA tests to examine the influence that inertinite has on pore structure as we observed that for some blend combinations there is very little expansion.

C26045
Mineralogy Effects on the 3D Porosity of Coke

University of Wollongong
Brian Monaghan
Richard Sakurovs

Value: $189,140
Report Expected: March 2019
Industry Monitor/s: Kim Hockings, Oliver Scholes, Tim Manton
ACARP Contact: Anne Mabardi

The specific focus of the project will be to utilise the coke analogue in combination with 3D micro-CT analysis to evaluate not only the effects of mineralogy on reactivity but specifically how the minerals are affecting porosity development with time and temperature. Key outcomes of the project will be:

- A brief review of 3D measurement and characterisation techniques applied to coke; and
- A validated and extensive 3D data set of coke reactivity data with time and temperature that can be used to inform extant CSR/CRI data and its application.

Feedback from the other researcher team members has been obtained and the draft report has been submitted to the Industry Monitors for review.

C26046
Relevance of Maceral Concentrates to Whole Coal Coking Predictions

University of Newcastle
Wei Xie

Value: $69,500
Report Expected: May 2019
Industry Monitor/s: Graeme Harris, Kim Hockings, Oliver Scholes, Anne Mabardi
ACARP Contact: Anne Mabardi

The first aim of this project is to clarify how to concentrate maceral components from coke oven feed particles combining the reflux classifier and Coal Grain Analysis. The second goal is to examine what maceral concentrates represent in whole coal and the extent of the concentrates and the blends modify industrial fluidity of whole coal. The third goal is to establish the relevance of coal maceral concentrates on whole coal coking prediction.

To achieve these goals, this project uses Coal Grain Analysis (CGA) for analysing coal maceral populations and compositions of whole coal, Reflux Classifier feed and products; Reflux Classifier for concentrating coal maceral concentrates; and Gieseler plastometer for evaluating the fluidity of the concentrated maceral particles containing heterogeneous vitrinite and inertinite, and particles of similar maceral compositions produced from a blend of vitrinite and inertinite dominant particles.

We have completed all maceral separation based on the CGA results of the raw coals, received the results for three quarters of the CGA tests and half of the fluidity tests for coals macerals and the blends. Next quarter, we are expecting to complete all CGA and fluidity tests, and get the draft report ready by May.

C27014
Plastic Layer Formation during Blending of Australian Coking Coals with Weakly Coking and Non-Coking Coals using the UoN 4kg Lab Scale Coke Oven

University of Newcastle
Jianglong Yu

Value: $135,500
Report Expected: October 2019
Industry Monitor/s: Morgan Blake, Sean Flanagan
ACARP Contact: Ashley Conroy

The objective of this project is to achieve fundamental understanding of the plastic formation in coal blends during coking, in particular to investigate the interaction of coal particles/grains in the blends from different types of coals during coking and its impact on coke formation and coke quality. The project extends the previous project C24054 which was focused on in-situ investigations of the plastic layers formed from single Australian coking coals. This project will utilise the 4kg lab-scale dual-heated-wall coke oven testing rig at the NIER site of the University of Newcastle and try to gain insights into blending strategies in coke plants at steelworks and provide suggestions to blending options in order to reduce the cost of coke making using coal blends.

Coking coal sample selection has been done under the support of the industry monitors and some coals have arrived. The research team is now using the coals left over from previous project to carry out some preliminary experiments and the plastic layer samples have been produced based on a few blending ratios of two sets of coking coals with different rank and vitrinite contents. Synchrotron Micro-CT, ATR-FTIR and in particular the C13NMR have been done for some of those samples. The current data from FTIR and the C13 NMR have shown that the blending may have significant influence on the plastic layer chemistry. Data analysis on the C13 NMR results are currently being undertaken.
C27017  
**Influence of Evaluated Temperature on Interface Properties in Blast Furnace and Pilot Oven Cokes**

**University of Newcastle**  
Hannah Lomas  
Richard Sakurovs

*Value:* $159,849  
*Report Expected:* October 2019  
*Industry Monitor/s:*  
Kim Hockings  
Morgan Blake  
Ashley Conroy

We have previously demonstrated that techniques used in tribology, i.e., the science and engineering of interacting surfaces in motion, can be applied to metallurgical coke to better understand the abrasion resistance of their different microtextures, and the strength and properties of the interfaces between these different microtextures. In this current project we aim to apply tribological testing techniques to coke samples at temperatures of up to 950°C in both inert and carbon dioxide atmospheres, in order to determine the abrasion resistance of the microtextures and the strength of their interfaces at temperatures similar to the top of the cohesive zone in a blast furnace. We will then use this information to identify steps to help improve coke strength prediction and its resistance to abrasion.

In the last quarter, we further analysed the results of trial tribological tests conducted at both room temperature and the intermediate temperature of 400°C, focusing on the change in the coefficient of friction (COF) over time for both sets of tests. The higher COF observed for coke samples tested at 400°C is speculated to be due to an increased displacement of inertinite particles having a greater abrasive effect on the coke surface. Further, SEM analysis of preliminary tests revealed the abrasive damage was more pronounced on the surface of the coke tested at 400°C compared to its room temperature counterpart. Conversely, cokes tested at room temperature showed greater characteristics of delamination wear processes due to the occurrence of sheet-like particle removal.

The design of the tribometer upgrade to allow tribological testing at temperatures of up to 950°C and in gas-controlled atmospheres is almost complete. The upgrade will take place in the next quarter, with trial tribological testing using the new system expected to take place in July.

C27031  
**Evolution of the Pore Structure in Coke and Implications on Coke Strength**

**University of Queensland**  
Karen Steel  
Merrick Mahoney

*Value:* $108,050  
*Report Expected:* April 2019  
*Industry Monitor/s:*  
Kim Hockings  
Sean Flanagan  
Ashley Conroy

This project follows on from project C23048 and C25051. We are interested in finding the factors controlling pore contraction because the densification of coke plays a key role in strength development and we are examining the extent that the pore structure has preferential pathways as directionality could be a factor with regards to coke strength.

We have established an experimental capability to study the permeability of coke samples. This capability is coupled with our CT scanning and GeoDict analysis to examine flow through the pore structure computationally. We have reliable results for one cube (1.5cm³) so far, obtaining experimental permeability measures of 423, 315 and 315 mD in the x, y and z directions (5 bar confining stress). Using CT and GeoDict we obtained simulated permeabilities of 3060, 2060 and 2520 mD in the x, y and z directions (no stress). This indicates that the x-direction is preferred for this sample. We are now studying samples for which we know their direction in the coke oven. One issue that has slowed progress is the presence of micro-fissures in the samples, which dominate the flow behaviour. To overcome this we perform CT analysis on the coke to see where they are and avoid them when cutting cubes and we have reduced the sample size to 1.5 cm³.

C27036  
**Understanding of Coke Quality using 3D Immersive Visualisation and Statistical Characterisation of Microstructure Properties**

**University of Newcastle**  
Keith Nesbitt  
Merrick Mahoney

*Value:* $92,880  
*Report Expected:* June 2019  
*Industry Monitor/s:*  
Kim Hockings  
Tim Manton  
Ashley Conroy

The project addresses:

- Fundamental and applied understanding to relate properties of cokes to those of the coals from which they are made;
- Effective and consistent characterisation techniques for thermal coals, metallurgical coals and cokes to enable rational market valuation.
Specific project objectives are:
- Further develop understanding of the relationships between key microstructural features of coke and coke failure mechanisms and strength indices;
- Understand the development of key microstructure features by identifying key processes in the plastic layer contributing to the development of coke microstructure; and
- Develop some understanding of how different inertinite types can influence structure development by modifying processes in the plastic layer.

During the last three months – four weeks were spent on leave and three weeks full time on other projects that were completed prior to Christmas. So, there was an extended break from work on this project.

Work on the statistical characterisation of microstructure features continues using the supervised deep learning approaches has continued. Some further refinements have been identified for testing. (Matthew has also been on leave for four weeks and overseas. Work is due to commence in the second week of February).

The main focus during the remaining time has been on identifying key locations/structures in the data that can be evaluated against the different stress measures. Coding on the von Miser stress calculation has begun and will be evaluated specifically at these locations (cracking around or through features in the coke).

Previous project reports that were identified as relevant to this project (C7054, C13067, C16047, C23051, C23053, C20010, C21056, C23048) were reviewed. This has provided further background to the statistical characterisation phase.

Some further collaboration possibilities with ANU (Drishti) are being investigated. This might allow direct coding of statistical calculations into Drishti.

C27053
Method to Compare Chemistry vs Structure Effects of Fusible Inertinite in Coke Making

CSIRO
Karryn Warren
Merrick Mahoney

Value: $173,196
Report Expected: October 2019
Industry Monitor/s: Chris Urzaa, Tim Manton
ACARP Contact: Ashley Conroy

The objective of this project is to demystify coking behaviour of some coals that have similar ranks and maceral composition, but behave differently during coke making. We aim to determine the relationship between reflectance, chemistry, size and fusibility for the different macerals and try to answer the following questions:

- Is there a link between the fusibility of inertinite and its chemistry/reflectance?
- Is there a chemical difference between vitrinite and inertinite structures with the same reflectance?
- Are there differences in aliphatic/aromatic ratios and oxygen functional groups of maceral structures with a range of reflectance values?
- Do these ratios determine the level of reactivity/fusibility of the maceral? Or
- Does the size of the internal component structures within grains, and/or the association of the macerals and minerals within grains, play a role in determining the coking attributes? and finally
- Can these be correlated with the coking attributes?

A team from CSIRO and University of Newcastle had a successful trip to the Australian Synchrotron in December, using the Fourier Transformed Infra-Red (FTIR) beam line to collect the FTIR spectra of the different macerals. Spectra were collected along matched transects of macerals that transitioned from vitrinite to inertinite (including fusible/infusible inertinite material) Figure 1. These were collected over at least two of these transitional zones for each of two lumps of coal for seven coals.

A team from CSIRO and University of Newcastle had a successful trip to the Australian Synchrotron in December, using the Fourier Transformed Infra-Red (FTIR) beam line to collect the FTIR spectra of the different macerals. Spectra were collected along matched transects of macerals that transitioned from vitrinite to inertinite (including fusible/infusible inertinite material) Figure 1. These were collected over at least two of these transitional zones for each of two lumps of coal for seven coals.

C27056
Imaging Gas Penetration Inside Coals and Cokes at Nanoscale and Determining its Influence on Coke Reactivity

CSIRO
Merrick Mahoney
Sherry Mayo

Value: $100,935
Report Expected: May 2019
Industry Monitor/s: Graeme Harris, Steve Lempereur
ACARP Contact: Ashley Conroy

The aim of this project is to use Xenon gas K-edge subtraction in synchrotron micro-CT imaging for probing the fine scale porosity and gas transport behaviour in coking coals and cokes. We have characterised the fine pore structure of inerts in coal lumps and IMDC in coke lumps.
lumps before and after reaction in a furnace. We will use this data to deepen our understanding of the specific reaction behaviour of inerts by comparing changes in the gas uptake behaviour of coke samples before and after reaction as well as looking at gas uptake in a related coal.

As reported previously all data was initially scaled to 8bit and converted to Avizo format for further image analysis in Avizo. This image analysis involves 3D alignment of all images of a given sample to facilitate identification of regions of mass loss, or gas uptake. This initial cycle of analysis demonstrated that relatively little xenon is taken up into the fused material or most of the inerts prior to reaction whereas following reaction there was significant mass loss from many inerts and some thinning of the fused material.

This initial analysis while sufficient to show the main features of gas transport also showed that the 8bit grayscale format was inadequate to capture the full image dynamic range for a fully accurate analysis. As a result, all datasets have now been converted to 16bit grayscale Avizo format and image alignment and re-analysis of this data is in progress.

---

**Thermal Coal**

**C27003**

Review of ACARP Research to Support Marketing of Australian Thermal Coal

University of Newcastle
Terry Wall

Value: $102,200
Report Expected: February 2019
Industry Monitor/s: Chris Spero, Kay Palmer, Kerry Atkins
ACARP Contact: Anne Mabardi

A draft report is with the industry monitor(s) for review.

---

**C27022**

Slagging and Fouling During Co-Combustion in HELE Boilers

University of Newcastle
Liza Elliot

Value: $164,350
Report Expected: April 2020
Industry Monitor/s: Chris Urzua, Jason Nunn
ACARP Contact: Ashley Conroy

Each mechanism responsible for slagging and fouling in pulverised fuel boilers are dependent on particle density and size, ensuring only certain parts of the ash are involved in deposition. However, indices used previously to assess coals for fouling and slagging behaviour are based on the whole ash sample. The chemistry and size of each ash particle is a function of the location of the minerals within the coal during combustion, which is not replicated when the coal is ashed in a muffle furnace. The indices ignore the impact of mineral associations within the coal (i.e. does the mineral exist on its own when fired (excluded), in a coal particle (included) or with other minerals in the coal particle such that the minerals will combine to form one ash particle) and the importance of the mechanism of deposit formation.

This project aims to maintain the associations within the coal particles during ash formation by combusting the coal in a drop tube furnace. Collecting the ash produced in specific density/size bins will allow parts of the ash to be analysed for melting behaviour by thermomechanical analysis (TMA) providing a better technique for assessing coals for deposition and allowing selected coals to be assessed for slagging and fouling.

Deposits and matching feed coals from two Australian power stations have been collected. The deposits are being prepared for analysis and imaging by SEM. A third set of deposits and feed coal from a Chinese power station has been collected but I am currently having difficulty getting the samples exported from China.

Significant electrical issues with the TMA have been overcome and it is now operational.

---

**C27029**

High Tech Testing Facility for Evaluating Combustion Performance of Thermal Coals and Establishment of Testing Methodology

University of Newcastle
Jianglong Yu

Value: $236,750
Report Expected: December 2019
Industry Monitor/s: Chris Spero, Greg Wickman
ACARP Contact: Ashley Conroy

The objective of this project is to develop a high-tech combustion testing facility at the University of Newcastle and to establish a comprehensive testing methodology for evaluating the combustion performance of Australian thermal coals, in particular under HELE coal combustion conditions. Given the increasing needs for Australian thermal coal producers to have convenient access to such an advanced high-tech combustion testing facility and expertise inside Australia to provide fundamental supports to marketing sectors, the construction of such a lab-scale high-tech combustion testing facility at UON will greatly enhance the existing capability to assess combustion performance of Australian thermal coals and provides strong support to the Australian thermal coal industry.

The research team has completed the preliminary design of the combustion rig and has submitted to the
manufacturer for engineering design for quotation. The design was based on the information of the technical survey on the current R&D status of HELE combustion technologies worldwide, in particular in the countries where Australian thermal coals are sold. CFD modelling of the combustion furnace was carried out using the Fluent software to assist the combustion rig design. There were intensive communications between the research team and the manufactures during the design. Some analytical instruments including Micro-GC have been purchased. The NIER site at K100 has been evacuated to allow sufficient space for the combustion rig construction.

C27047
Combustion Characteristics of Australian Export Thermal Coals using Advanced Imaging Techniques

CSIRO
Chad Hargrave
Ed Lester
Silvie Koval

Value: $60,644
Report Expected: June 2019
Industry Monitor/s: Graeme Harris, Greg Wickman
ACARP Contact: Anne Mabardi

The project objective is to benchmark the combustion characteristics of Australian export thermal coals by:

- Establishing a focused research collaboration between CSIRO and The University of Nottingham researchers based on their complementary imaging capabilities of coal and combustion char and their world expertise in this field. This framework might be expanded in future collaborations between the current partners and Asian research organisations;
- Linking CGA information for coal particles to information acquired by using image analysis methods for char particles to quantify the transformation of different coal grain types (ie pure components and composite particles) to specific char types to gain a better understanding of combustion performance. For selected samples the analysis will also include the identification of the major minerals in the parent coal particles and in the daughter char particles (by incorporating the mineral marker capability developed in C23050). The analysis should compare chars generated in drop tube furnace with real samples from power plants via pyrolysis and refire tests at comparable temperatures and residences times;
- Comparing the results obtained for five Australian thermal coals of different ranks with three non-Australian thermal coals which are imported into the UK to determine combustion properties.

In December the project leader, Silvie Koval resigned from CSIRO and returned to the Czech Republic. Her former CSIRO team leader, Chad Hargrave, assumed administrative responsibilities for the project and entered negotiations for Silvie to be granted a CGA license so that she would be able to complete her technical tasks and work with the University of Nottingham and CSIRO researcher to prepare the final report. The software license agreement with CSIRO was signed late January 2019.

Next quarter - CSIRO, the University of Newcastle and Silvie Koval will complete all outstanding technical tasks and work on the final report. It is anticipated that the final report will now be submitted to ACARP in June.
MINE SITE GREENHOUSE
GAS MITIGATION

C23052
Stone Dust Manifold Gas Switching Thermal Swing
Reactor: Abatement of VAM Streams with Ultra Low
Methane Concentration Phase 4

University of Newcastle
Behdad Moghtaderi

Value: $1,219,962
Report Expected: April 2019
Industry Monitor/s: Jim Sandford, Trevor Stay
ACARP Contact: Patrick Tyrrell

The current project is Phase IV of a multi-phase project that is concerned with the development and demonstration of the Stone Dust Looping (SDL) process for abatement of the ventilation air methane (VAM). Previous ACARP funded projects on this topic designated for abatement of the ventilation air methane (VAM). The emphasis in Phase IV is to furnish the SDL process with the necessary means for in-situ regeneration of these particles. This is driven by the fact that additional heat is released when the CO2 formed by the oxidation of VAM reacts with the calcium oxide particles undergoing the in-situ regeneration. This, in turn, enables the SDL process to reach the state of auto-thermal operation (ie self-sustaining) at methane concentrations as low as 0.2 Vol% and temperatures well below the auto-ignition temperature of methane (about 450°C). The Phase IV project aims at pilot-scale demonstration of the above configuration as well as determining its scaling principles and techno-economic merits. Phase IV has been defined as a two-year project with the primary aims of:

- Design, construction, commissioning and field trials of a 200 m³/hr (~56 L/s) twin-reactor SDL unit fitted with a manifold gas switching (MGS);
- Derivation of the scale-up rules for the twin-reactor in the MGS configuration; and
- A detailed techno-economic assessment of the twin-reactor in the MGS configuration.

Design modifications for the pilot-plant were completed during Q2 2018. Safety procedures, including hazardous area classification assessment, hazard and operability (HAZOP) studies, risk assessments and internal safety reviews and approvals have been completed. Site specific construction work and the extension of services to the location of the pilot-plant has been completed in preparation for the delivery of the pilot-plant to The University of Newcastle.

Fabrication of the skid-mounted pilot-plant is nearing completion. The fabrication works include the electrical and instrumentation components of the pilot plant, which are also ongoing. It is anticipated that the pilot-plant will be delivered to the University in early February with completion of the field trials in March.

C26004
CFD Modelling of Reverse Thermal Oxidisers for VAM Abatement

University of Newcastle
Behdad Moghtaderi

Value: $381,520
Report Expected: May 2019
Industry Monitor/s: Donna Dryden, Jim Sandford
ACARP Contact: Patrick Tyrrell

The project is part of a larger multi-phase program of study aimed at Computational Fluid Dynamics (CFD) modelling of Reverse Thermal Oxidizer (RTO) devices for mitigation of Ventilation Air Methane (VAM). The emphasis however, is not to model the operation of the RTO devices. The aim is rather to determine whether in the event of an explosion within or upstream of the RTO device, the device could reflect the pressure wave and the reaction front sending them back down the mine ventilation shaft, in turn, causing an explosion in the mine itself. Therefore, the principal vision here is to numerically assess the detonation and/or flame arresting properties of RTO devices. In doing so the simulations should create an explosion wave and model its progress as it travels into the RTO to investigate what happens to the pressure wave and reaction front. The relevant research work will be conducted in two phases, namely:

- Phase I CFD modelling of ceramic-brick RTO devices;
- Phase II CFD modelling of fixed-bed RTO devices.

Phase I of the project was completed in early 2018. The emphasis in Phase II is on fixed-bed RTOs due to the dominance of this configuration in the global supply chain for VAM abatement hardware with several US and European companies marketing their fixed-bed type products to the mining sector. The key outcome of Phase II will be a versatile and validated CFD model capable of assessing the detonation and/or flame arrestor properties of fixed-bed type RTO devices.

The progress so far has been on track and on budget. The milestone activities undertaken in Q4 of Phase II project are as follows.

Milestone Task III – Add a CFD model of the fixed-bed RTO to the base-model and run this case for a variety of upstream and downstream conditions. (100% Completed).

Milestone Task V – Perform simulations using the same fuel load as in milestone task IV which was completed in Q1 (70% Completed).
The focus of research activities in Q1 2019 is on completion of milestone task V as well as milestone task VI.

Milestone Task VI – Provide a write-up of these cases for peer review and independent assessment (60% complete).

We have experienced delays in running simulations associated with milestone task V, and as a result milestone task VI; as noted from percentage of completion listed above, we are still aiming to complete the project in March.

C27008
Selective Adsorption of Methane by Ionic Liquids

University of Newcastle
Andrew Maddocks
Behdad Moghtaderi

Value: $147,320
Report Expected: February 2019
Industry Monitor/s: Alex Neels
Jim Sandford
Patrick Tyrrell

ACARP Contact:

The selective absorption of ventilation air methane (VAM) in ionic liquids has the potential to be a step-change in VAM abatement technology. The absorption process would occur at temperatures less than 200°C, which is several hundred degrees Celsius less than the autoignition temperature of lean methane/air mixtures. Operating at temperatures less than the autoignition temperature of VAM completely eliminates the safety concerns related to a mine fire or explosion caused by connecting a ventilation shaft to a VAM abatement plant.

The principal vision of this project was to carry out fundamental investigations into the chemistry of ionic liquids and low-concentration methane mixtures and develop a proof-of-concept process for the absorption and desorption of methane using ionic liquids. To fulfil the above vision, the following objectives were defined:

• Determine the effect of temperature on methane solubility and selectivity;
• Determine the effect of pressure on methane solubility and selectivity;
• Determine the optimal ionic liquid properties for the absorption of methane from low-concentration methane-air mixtures;
• Determine the effect of temperature and pressure on the desorption rate of methane from ionic liquids;
• Evaluate the performance of ionic liquids and undertake a preliminary feasibility assessment; and
• Report the key findings and provide recommendations for advancing the next phases of the program of study.

The tasks proposed to achieve the project objectives and the progress to date are outlined below.

Task 1. Screening ionic liquids using high pressure thermogravimetric analysis (TGA). This task was completed in Q1 2018.

Task 2. Selectivity experiments in stirred-tank reactor. Selectivity experiments for single component gases (ie nitrogen, methane, oxygen and carbon dioxide) and multi-component gas mixtures have been completed.

Task 3. Desorption experiments in stirred-tank reactor. Desorption experiments have been completed.

Task 4. Evaluation of the performance of ionic liquids and project reporting. The results of the experimental program have been analysed and the draft project report has been forwarded to the industry monitors for comments.

C27054
Optimisation of a Thermal Flow Reversal Reactor for VAM Mitigation

CSIRO
Jon Yin

Value: $190,173
Report Expected: January 2020
Industry Monitor/s: Alex Neels
Ben Klaassen
Trevor Stay
Patrick Tyrrell

ACARP Contact:

Ventilation air methane (VAM) capture, mitigation and utilisation are on-going challenges faced by the Australian coal industry. Throughout the previous ACARP project C19055, CSIRO has developed and demonstrated a novel pilot-scale VAM Mitigator (VAMMIT) with a newly-structured regenerative bed consisting of honeycomb monolith ceramic blocks. This bed also incorporates an innovatively-designed flow diverting section located at the bed centre with connections to a gas burner for easy start-up and a bursting disc for safety management. The technology has been fully proven feasible through pilot-scale prototype unit development, experiments at CSIRO laboratories, and site trials with actual VAM at an Australian coal mine. The VAMMIT unit is the first of its kind in the world, possessing significant advantages (i.e. less dust deposition, less footprint and lower energy consumption) over other packed bed mitigators.

This project aims to optimise the VAMMIT thermal oxidiser through design calculations and CFD simulations to achieve lower pressure drop, higher methane oxidation efficiency, and stronger dust deposition and corrosion resistance. The project will also investigate the feasibility of a catalytic VAM mitigator to operate at much lower temperatures (~450-700°C) to completely avoid stone dust decomposition and at lower methane concentrations (≥0.2%). The specific objectives are:

• Optimisation of the honeycomb bed structure of VAMMIT;
• Optimisation of operating parameters of VAMMIT;
- Feasibility study of a new catalytic version VAMMIT; and
- Investigation of safety management associated with VAMMIT.

The project has been progressing well so far. The CFD model has been debugged and successfully operated under various conditions. At first, a few input parameters were screened by operating the model under various conditions against the experimental results, including the kinetic parameters for methane oxidation in air, and the permeability to predict the pressure drop. Then the model was re-configured with those parameters to optimise the honeycomb bed structure, being the bed height based on previous experimental results. Four cases with different bed heights have been successfully operated, with the simulation results yet to be analysed. Due to the large mesh number, the computing time was long, leading to a slight delay to the project. Once the bed height is optimised, the model will be re-configured to optimise the operating parameters.

C27058
Technological Assessment of a Recycle Reactor for VAM Abatement

University of Newcastle
Michael Stockenhuber

Value: $264,672
Report Expected: April 2019
Industry Monitor/s: Alex Neels, Jim Sandford, Trevor Stay
ACARP Contact: Patrick Tyrrell

Despite the low methane concentration (well below flammability limits), ventilation air methane (VAM) is one of the major greenhouse emissions associated with mining owing to its high flow rates. As typical combustion processes are unable to be employed, alternative methods need to be investigated to address the associated undesirable environmental impacts. This project investigates the catalytic oxidation of methane in lean VAM streams for the mitigation of potential greenhouse emissions.

A previously identified catalyst able to obtain high conversions under typical VAM streams (Pd/Al2O3) has been exposed to 7 000 ppm methane in humidified air, achieving high conversion for over 100 hours. Reactor conditions required for in situ catalyst reactivation, including temperature and time on stream, have been identified and optimised. The project is currently investigating requirements for a larger scale processing unit, whilst continuing a time on stream analysis of the lab scale unit. The unit being tested consists of dual catalyst beds which alternate between oxidation and reactivation for extended and continuous VAM abatement operation.