This report is a summary of current projects for the months February, March and April 2019
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UNDERGROUND

Coal Burst

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: | May 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: | May 2019 |
| Industry Monitor/s: | Coal Burst Task Group |
| ACARP Contact: | Peter Bergin |

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

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: | May 2019 |
| Industry Monitor/s: | Coal Burst Task Group |
| ACARP Contact: | Peter Bergin |

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: | May 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: | June 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 has been undertaken to understand the role of micro fabric in the burst process. The 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. 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 financially on track and within the timeframe anticipated. The project is in the early stages of reporting.

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

| Value: | $612,200 |
| Report Expected: | June 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 which was 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. Due to this and along with a current surge in external work, Sigra has sought to delay submission of a draft report beyond February. The report is currently being prepared. This is designed to be short and eminently readable by engineers or geologists. It reverts to the fundamentals of the processes of outbursting and coalbursting and from that the various stages of risk assessment and minimisation.

C26066
Energy, Burst Mechanics Required for Coal Bursts and Energy Release Mechanisms

University of New South Wales
Ismet Canbulat
Winton Gale

Value: $357,500
Report Expected: June 2019
Industry Monitor/s: Coal Burst Task Group
ACARP Contact: Peter Bergin

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 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.

The results at this stage are consistent with expectation and the risks of bursts from these various sources. Ongoing work is being done to confirm the risks of each form of energy. 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.

A review of energy sources and risks for coal bursts had been presented for a special edition on coal bursts in the International Journal of Mining Science and Technology. A comparison of energy-based mechanisms with ‘traditional quantitative’ approaches has been made and the results are consistent with experience.

An analytical coupled model has been developed to predict (for any given mine layout and geological setting) if there exists the possibility of a coal burst of unacceptable intensity. A burst is deemed unacceptable if coal fragment velocity exceeds a given threshold value.

Risk-based definitions of threshold values have been established for development and longwall faces. The development threshold value is based on (i) the currently used ‘conventional’ roof bolts’ energy absorption capacity; and (ii) the distance of the bolt operators to the face. The longwall threshold value is based on the distance of the operators to the face.

The project is in the final stages of reporting.

C27020
Coal Bursts and Pillar Burst in Deep Mines

University of Adelaide
Murat Karakus

Value: $257,240
Report Expected: March 2020
Industry Monitor/s: Coal Burst Task Group
ACARP Contact: Peter Bergin

This project will provide new, fundamental knowledge on the damage evolution of coal leading to coal burst. The Influence of confinement and deconfinement on the overall mechanical behaviour of coal inducing coal burst will be investigated. Specific aims of the project are as follows:

- Develop an experimental methodology to investigate the deconfinement influence on coal burst;
- Develop qualitative and quantitative damage assessment processes to define pre-peak and post-peak mechanical behaviour of coal at high pressure by using acoustic emission;
- Develop a damage mechanics-based plasticity model for coal accounting localization nature of failure and size effects in coal; and
- Forecast coal burst by large scale mine layout simulation.

Work completed includes:

- The first set of tests has been completed on coal samples from Mine X. A new control method was developed to obtain snap-back behaviour of coal samples under uniaxial and triaxial loading condition to calculate excess stored strain energy. This is a unique experimental methodology applied to coal samples for the first time. Currently, we are analysing these tests results and will have a better understanding of how excess energy is accumulated and released with this unique testing system.
- The second batch of samples will be supplied from Mine Y in mid-April and will be subjected to our new testing methodology to calculate excess energy. In order to capture the macroscale behaviour of the coal burst, realistic true-triaxial unloading system will be used. This system uniquely creates a free surface replicating the coal excavations. We will be able to measure the velocity of the fragments to be ejected from the free surface to calculate kinetic energy
released so then we can relate with the excess stored energy. These coal burst test will be conducted in China at the end of May.

- A parallel work to the experiments, constitutive modelling is carried out for coal that is focusing on the inclusion of damage evolution function in the incremental stress-strain constitutive driver. We are currently implementing the new model into a numerical method.

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

It has been found in previous studies and internal studies that the effect of intermediate stress can modify the strength of the rock. The stress anisotropy can lead to lower strength and modify the failure distribution about a roadway or ribs.

The aim of this project is to measure the strength of coal measure rocks under a range of true triaxial stress conditions. The rocks will be tested with variation in maximum, intermediate and minor stresses. Samples have been sourced for testing and sent to Curtin University. Initial results have been reported and more will be reported shortly.

C27041
Ground Support Requirements in Coal Burst Prone Mines

University of New South Wales
Ismet Canbulat

Value: $150,000
Report Expected: August 2019
Industry Monitor/s: Coal Burst Task Group
ACARP Contact: Peter Bergin

The objectives of this project are to:
- 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 Australian experience, regulations, mine design, and operational practices.

Work undertaken includes:
- An extensive review of the ground support systems that are used in rock and coal burst conditions;
- Data gathering from static and dynamic tests on support elements;
- Data gathering from static testing to calibrate the numerical models;
- Modelling of the cable behaviour under laboratory conditions;
- Establishment of a Factor of Safety concept based on the kinetic energy release in a coal burst event and the energy absorption capacity of roof bolts;
- Establishment of a coal burst threshold value for development panels based on the factor of safety concept;
- An update has been made on the framework for coal burst management plan, which was proposed as part of C25004.

The project is financially on track and is progressing within its anticipated timeframe.

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 objective of this project is to investigate a distributed fibre optic sensing (DOFS) 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.

Analysis of seismic data acquired by a comprehensive DOFS experiment is in progress. The sensitivity and detectability of both military-grade and ordinary fiber cables were compared with a number of geophones that were installed at different locations next to the fibers. Signals from both active and passive sources recorded by the optic fibers were investigated. Preliminary results have shown that DOFS has good sensitivity to detected broadband seismicity induced by active and passive sources, and high accuracy for event location. It has identified that dealing with big data recorded by continuous DOFS is a challenge. New strategy and algorithms must be developed to solve the problem.
A comprehensive field trial has been planned, thanks to a New South Wales mine for their support to this experiment. This experiment will use an optic fiber installed in 1 or 2 deep boreholes (~300 m deep) and in ~2 km long trenches on the ground surface above longwall panel 108. The design of the survey layout is in progress. The experiment is planned to be completed by July.

**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, nominally South Coast (Bulli/Wongawilli), Hunter Valley and Narrabri (Hoskissens seam);
- Review the seismic activity at the 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;
- 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 Narrabri mine. 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 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. A micro seismic monitoring site has been installed at Narrabri mine and data is being collected. The project is on schedule and budget.

**Detection and Prevention of Fires and Explosions**

**C28013**  
**Use of Compressed Air Foams (CAFs) to Alter Goaf Air Circuits and Mitigate Spontaneous Combustion Events**

**Mines Rescue**  
Clive Hanrahan  
Matthew Fellowes

| Value: | $392,500 |
| Report Expected: | February 2020 |
| Industry Monitor/s: | Bharath Belle  
David Webb  
Paul Wild  
Peter Baker  
Rae O’Brien  
Sharif Burra |
| ACARP Contact: | Patrick Tyrrell |

This project has very recently commenced.

**Environment - Subsidence and Mine Water**

**C20038**  
**Standardised Subsidence Information Management System**

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

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

A draft report is with the industry monitors for review.

**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: | June 2019 |
| Industry Monitor/s: | Bernie Kirsch  
Gary Brassington |
| ACARP Contact: | Patrick Tyrrell |

This project focuses on two threatened Persoonia species – P. hirsuta and P. hindii – that occur on mining lease land. The outcomes of this project will be:
- Determine the techniques required to optimise survival of Persoonia in the revegetation context; and
• Determine the environmental conditions required to improve plant propagation success and plant survival.

Site preparation has continued during the quarter and is nearing completion for the two translocation sites. Translocations are planned for the first half of May when the weather is conducive for planting and minimising the risk of ‘translocation shock’ on the plants. A total of 280 P. hindii and 128 P. hirsuta plants have been prepared for planting. The translocations represent major milestone in the project, reflecting the extensive propagation work that has been conducted at the Australian Botanic Garden Mount Annan over the last several years. Exemplifying this was our recent scientific publication on the germination of P. hirsuta—a first for this species. This work continues in parallel with the preparation of the final draft report.

A rigorous post-translocation monitoring plan is in place, and further translocations are planned following a successful project extension to expand on the outcomes of the current project.

C25056
Change Detection in Complex Vegetation Communities
Biosis
Andrew Fletcher
Richard Mather
Tony Cable

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

All imagery data has been collected for sponsor sites by local contractors and received in March by the research team. Processing of this data is nearing completion. Spectral band selection and processing methods have been developed to allow reproducible capture of tree canopy with less than 4% difference between seasons. Methods for reconstructing elevation models to remove terrain have also been demonstrated allowing topographic removal and vegetation height model construction. A journal manuscript to be submitted before final report submission date in nearing completion. Image classification workflows have been developed to meet site use requirements and will be tested on the final sets of imagery. Classification includes an ensemble of classification algorithms with full confusion matrices that provide robust and transparent output products. Classification algorithms are trained and validated on independent image sets captured at the same time as the multispectral imagery. The final report has several sections to be completed but is on schedule for submission.

C27052
FO-RO Site Trial at Newstan Colliery
CSIRO
Ramesh Thiruvnenkatachari

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 ACARP 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.

The mechanical work in assembling the FO-RO prototype test unit has now been completed. Electrical works on the control board cabinets and the instrumentation wiring have also been completed. Control and instrumentation program are being developed. On-site infrastructure preparation is being carried out. Preliminary evaluation and checks are now being undertaken on the test unit before it is transported to the mine site.

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
Patrick Tyrrell

ACARP Contact: Patrick Tyrrell

This project aims to investigate the resilience of Temperate Highland Peat Swamps on Sandstone (THPSS), in response to changes in soil moisture content induced by underground mining activities and climate variability. This study also aims to develop a hydrological model that can predict soil moisture variability in a range of swamp conditions. The case study swamps overlie two underground coal mines.
A stepwise approach was adopted for the monitoring and modelling of variations in the soil moisture content of swamps. Literature review, review of company reports and collection of accessible existing data, have been conducted. 20 sensors were purchased to monitor the soil moisture conditions (water pressure) of selected locations in swamps overlying mine 1. The permission process for installing the sensors and measuring plants’ leaf water potential at these locations is underway. Soil samples from the swamps overlying mine 2 were collected and soil root systems observed. Three replicate samples were taken from six locations (within four swamps) up to a depth of 75 cm. The soil samples are being analysed for gravimetric water content, soil water retention characteristics, hydraulic conductivity, organic matter content and bulk density. These parameters will permit the calibration of an unsaturated zone hydrological model, which has been developed using HYDRUS and run so far without calibration. The next steps of the project are to calibrate and validate the model for the swamps overlying mine 2; and to install the monitoring equipment in the swamps overlying mine 1 to support modelling of these sites.

C28024
Optimisation of Water Management for Coal Mines - Water Tracer Tools
Deakin University
Wendy Timms

Value: $296,100
Report Expected: March 2021
Industry Monitor/s: Peter Corbett, Steve Downes
ACARP Contact: Patrick Tyrrell

Water tracer tools can optimise water management for coal mines. The objectives of this project are to collate and review industry experience applying water tracers, demonstrate the application of suitable tracers for soil and surface water management, and demonstrate opportunities for water tracers in groundwater management. The project will review water tracers used locally and in mining operations around the world that could have implications and potential for the coal industry. Demonstrating the application of suitable water tracers will include suitable tracers that are not yet commercially available and that complement physical water methods, empirical predictions and numerical modelling.

This project is in the start-up phase. Initial planning discussions have commenced with the research partners, Australian Nuclear Science and Technology Organisation. A part-time postdoctoral fellow has commenced in mid-April at Deakin University and a new PhD scholarship has been advertised that will help develop suitable water tracers. Water quality information and data requests were forwarded to mine site A and B in March. Mine site A has provided a report on some geochemical and isotope tracers that were recently used to assist in evaluating vertical hydraulic connectivity between different overburden strata across the site. An initial listing of possible water tracers is currently being compiled, along with various practical criteria such as costs and applicability to specific water management challenges.

C28028
Inclusion of High Interest Native Plants in Mine Site Restoration Programs: Propagation, Translocation and Field Reintroduction
Royal Botanic Gardens and Domains Trust, Sydney
Cathy Offord

Value: $318,500
Report Expected: April 2022
Industry Monitor/s: Bernie Kirsch, Gary Brassington
ACARP Contact: Patrick Tyrrell

This project has very recently commenced.

Exploration

C25067
Seismic Diffraction Imaging for Improved Structural Detection in Complex Geological Environments
CSIRO
Binzhong Zhou

Value: $374,000
Report Expected: March 2020
Industry Monitor/s: Cheryl Miffin, Heather Schijns, Paul O’Grady
ACARP Contact: Patrick Tyrrell

This is an extension project that builds on the recently successfully-completed ACARP project: C25067 ‘Seismic diffraction imaging for improved structural detection in complex geological environments’. Project C25067 focused on an evaluation of the algorithms developed in 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.

A new diffraction extraction method has been developed. This new method incorporates the automatic dip estimation algorithm, based on the seismic plane wave gradients, with the moving average error filter (MAEF) process. Therefore, the new method can be applied to
more complex geological environments without the need of a manual horizon-tracking and flattening process. Following the preliminary test of the implementation of the new method, further tests have been conducted on many different 2D seismic sections (Figure 1) in the past quarter. It has been proven that the new method is effective for assessing different geological environments. Now the project team is in the process of extending the new method for 3D seismic data. Initial tests will be carried out on a 3D seismic dataset that has just been received from a supporting company of this project.

Figure 1 Diffraction extractions by with a 31-trace MAEF filter: (a) Original seismic stack section overlaid with a picked reflection in the red curve; (b) extracted by a direct application of the MAEF filter to the section in (a); (c) Created by applying the MAEF filter to the flattened section of (a) with the picked reflection followed by restoring the flattening process; (d) Obtained by applying the MAEF filter in the local dip direction estimated by the dip estimation algorithm. The result in (d) is comparable to the one in (c) but without the need for the manual horizon tracking and flattening process. The two red arrows point to the extracted diffractions associated with two known dykes.

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 the acoustic logging to extract the poro-mechanical responses of the coal seam at in situ condition and predict stress redistribution as a result of degassing. The Biot coefficient of coal with sorbing gas (so-called Pseudo-Biot coefficient from now on) was derived based on a thermodynamic approach as:

$$\alpha_{\text{pseudo}} = \alpha_{\text{poroelastic}} \frac{RT \lambda}{p}$$

where $\alpha_{\text{pseudo}}$, $\alpha_{\text{poroelastic}}$, $R$, $T$, $\lambda$ and $p$ are Pseudo-Biot coefficient, Biot coefficient, gas constant, temperature, gas swelling coefficient and pore pressure. Eq. 1 indicates that the Pseudo-Biot coefficient is stress-pressure dependent. It should be also noted that this Pseudo-Biot coefficient is directional dependent as swelling is also directional dependent. The acoustic responses (shear and compressional wave velocities and amplitudes but not phase shift) were slightly sensitive to sorbing gas mainly due to closure-opening of the fracture system which we characterised using X-ray micro-computed tomography (Fig. 1).

The bulk modulus obtained from acoustic measurements was however relatively insensitive to type of gas. We therefore used the percolation theory to identify the solid bulk modulus and were able to predict the Biot coefficient of the coal at field scale:

$$\alpha_{\text{product}} = \frac{1}{\phi_t} \left( \frac{V_s^p}{V_s^s} \right)$$

By applying percolation threshold to shear wave velocity measurements:

$$\phi_t = \frac{V_s^p}{V_s^s}$$

where $\rho_b$, $\rho_s$ are bulk and solid density, $V_s^p$, $V_s^s$ are shear wave velocities of bulk and solid phase and $\phi_t$ and $\phi_N$ are total and threshold porosities respectively. We have also started looking into the anisotropy response of the mechanical properties and related it to the stress, material and fracture induced anisotropy (Fig. 2) using micro-to-core scale numerical simulation of acoustic propagation.
Fig. 2. Segmented and meshed core sample to be used for numerical simulation of acoustic propagation with different stresses.

**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, Claire Morton, 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.

The focus of the work in this quarter was on point cloud data registration and co-registration in a challenging underground mine environment. Data registration refers to attaching a coordinate system, either local or global, to generated 3D point cloud while co-registration refers to multi-point cloud alignment into a common reference coordinate system. Both of these are essential for spatial and temporal data analysis such as change detection. Coalmines, in general, are geometrically featureless and most of the available features are highly repetitive in nature e.g. roof bolts, ventilation pipe, etc. These factors together with incurred sensor drift tend to deform the 3D maps created through SLAM based mobile laser scanner. This compromises the use of 3D data for further applications. Therefore, a method is needed which could reduce the mapping drift for temporal data analysis, aid in data registration and help in co-registration under such conditions. To address these problems, a mechanism was developed in which change in the scanning environment is proposed for better registration and co-registration. Implementation of the proposed methodology will also help in vehicle localisation and act as a control for change assessments. Initial lab-based experiments were conducted (see Figure) to assess the feasibility of the method and to identify associated challenges that might arise for its implementation at mine sites.

![Figure: Lab-based model tests for various shape, size and reflective properties to develop innovative control for data registration and co-registrations.](image)

**C28031**  
Longwall Geological Risk Minimisation using Advanced Electromagnetic and Sonic Technologies  
CoalBed Energy Consultants  
Scott Thomson

**Value:** $178,750  
**Report Expected:** February 2020  
**Industry Monitor/s:** Eric Battig, Owen Salisbury  
**ACARP Contact:** Patrick Tyrrell

Geological surprises that halt or slow longwall production are still relatively common in Australian coal mining and may have severe financial consequences for an operation. This is despite the benefit of development driveage from both sides and, in many cases, extensive inseam drilling. There is a need to apply modern scientific technologies and analytical techniques to the problem and provide operators with as close to 100% assurance as possible prior to the commencement of the longwall.

What we envisage is a considered scientific approach to establishing the extent of geological risk in a longwall panel. This will be best achieved through the use of geophysical techniques (primarily RIM and In-Seam Seismic) using access from underground entries. The outcome will be a grading of potential risk based on the use of modern tomographic imaging software. Both proposed methods have been used only sporadically and in isolation in Australian coal mining and for disparate reasons, are underutilised and poorly understood by most operators.

Our aim is to integrate the data provided by these technologies to provide a unique evaluation of geological integrity within a longwall panel prior to mining.
**Health and Safety**

**C24009**
Establish 'At Risk' Distance from Hydraulics

University of New South Wales  
Gary Nauer  

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

Last input from Rema Oliver at UNSW, was that they would not be starting work for another three months due to limited availability at the lab.

**C24010**
Proximity Detection Systems Specification for Underground Coal Mining Machines

Simtars  
Andre De Kock  

- **Value:** $565,988  
- **Report Expected:** November 2019  
- **Industry Monitor/s:** Brad Lucke, Glenn Owens, Peter Nelson  
- **ACARP Contact:** Patrick Tyrrell  

The objectives of the project are:  
- Develop a proximity detection system specification and minimum acceptance criteria for the underground coal mining industry;  
- Determine the gap between the specification from the coal mining industry and the performance of systems offered to the industry by proximity detection system manufacturers;  
- Determine if future developments by the proximity detection manufacturers will address the specification from the coal mining industry.

At the start up meeting it was decided to add a literature review to the project. The aim of the literature review was to document:  
- The status of suppliers, and their systems involved in the original project C24010;  
- Identify any new entries into the underground coal mining proximity detection arena.

A working group was established to support the researchers in conducting the research. The working group consists of representatives from Anglo American, BHP, Centennial Coal, Glencore and Peabody. The working group held a workshop on the 16th and 17th April. During the workshop the base data for a set of interview topics was determined. Possible mine sites as well as inspectors from Queensland and New South Wales to participate in the interviews were identified. The working group furthermore identified the roles at mine sites to be included in the interviews.

During the next phase of the project the data from the workshop will be processed to develop a set of interview topics. This will be circulated to the working group for comment before the actual interviews are conducted.

**C26047**
Real Time Dust Monitor

University of New South Wales  
Charles Harb, Duncan Chalmers  

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

Dust samples collected have been retrieved from the testing facility and have been sent for re-analysis at the Mark Wainwright Analytical Centre. The MWAC has analysed these samples for Silica and so the final report can now be completed and submitted.

**C26048**
Improving Respirable Coal Dust Exposure Monitoring and Control

University of Queensland  
David Cliff, Mark Shepherd, Nikky La Branche  

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

The project objectives are to improve the Australian coal mining industry 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; and  
- 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 – in light of draft exposure standards for respirable coal dust and silica released for comment by SAFework Australia;
• Collection and collation of literature relating to respirable dust monitoring techniques;
• Respirable dust samples results have been received from the University of Virginia for particle sizing and chemical analysis, as they already have a large database from US mines and analysis of the data is in hand.

In the next quarter:
• The literature review will be completed;
• Analysis of the exposure data collected from DNRM and Coal Services will be completed, including comparison of different sample flows on cyclone elutriator;
• Results from prototype particle size and chemical analysis will be completed; and
• Final report will be drafted.

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. The problems with one of the respirable dust sampling heads led to the need to re-evaluate the monitoring data to see what adjustment to the dataset is required. In addition there has been an additional workshop occurred in November 2018 in conjunction with DNRM to discuss the future research needs and planning is well in hand to take particulates research forward. 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: June 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; and
• Measurement of dust concentrations after the implementation of the new systems and comparison with previous dust levels.

Work in the past quarter has included:
• Continuation of 3D-CAD/CFD modelling of Development Phase of project;
• EnviroMist supply of equipment to be used on continuous miner;
• Laboratory testing of spray equipment;
• Organised extension of project with ACARP, some OEMs and up to three mines to deal with delays in finding a site to conduct installation and testing (e.g. installing equipment on a miner during overhaul)

In the next quarter it is aimed to:
• Finalise proposed system for continuous miner dust suppression;
• Install proposed system on a suitable continuous miner;
• Conduct dust monitoring of installed system and evaluate the performance.

C27007
Assessment of Pyritic Coal Dust Induced Pneumoconiosis

B3 Mining Services
Basil Beamish
Graeme Zosky

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

ACARP Contact:

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 CWP can be translated to Australian coals. The project will answer two key questions: does Australian pyritic coal dust pose a health hazard (produce bioavailable iron) and what is the severity of the physiological response (degree of toxicity)?

The preliminary results were discussed at the review meeting in February and it was decided to extend the project by six months for completion by July and final reporting by August. During this period an interim report of the preliminary results will be made available to ACARP and the project monitors for the laboratory investigations conducted on natural pyritic coals. Additional laboratory investigations will be conducted on artificial pyritic coal mixes to provide a direct comparison with the previous US studies. These samples have been prepared and are waiting to be tested in the laboratory. In addition, a further batch of reactive pyritic coal samples has been obtained from a different coal sequence to provide another example
of natural pyritic coal response. This extended work program is achievable within the existing budget for the project.

**C27010**

A Clinical, Occupational and Radiological Review of Lung Disease

Uniting Care Medical Imaging
Bob Edwards
Katrina Newbiggin
Rhiannon McBean

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

ACARP Contact: Patrick Tyrrell

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

**C27015**

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 proposed to be 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. Key objectives of this project 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
- Develop guidelines relating to best practice dust management for Australian coals considered particularly problematic with regard to CWP risk.

During the last three months our research has focussed on the impact of size on coal dust reactivity, measuring cellular toxicity of different Australian coal dusts as well as examining acellular oxidant production patterns. Using our ball mill to prepare samples under a nitrogen atmosphere, we have been working with reactive coal dusts with an average size of 1.5 µm. These ground coal samples have interesting physical properties including angular morphology (FIGURE 1(A)) and a propensity to aggregate over time, both of which have implications for physiology. Using a model human lung cell line (A549), minor iron-containing coal loading does not cause significant cellular response in our current short-term studies. Importantly though, the cellular production of ROS (a self-defence mechanism) increases significantly over time after the particle loading reaches a particular threshold (FIGURE 1(B)). Our research has also found increased ROS production from ‘iron-absent’ samples, indicating that other factors, such as the presence of other reactive metals, silica or carbon may also play a role. The contributions of these factors and how the lung inflammation process progresses, post-dust inhalation, cellular response from differentiated cells (ALI model) will be the focus of our research over the coming quarter.

![Figure 1. SEM imaging of ground coal dust (Panel A), enhanced ROS production from A549 cell after being treated with different concentrations of coal dust from Mine 1 (Panel B).](image)

**C27049**

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

Project objectives:

- 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;
- 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;
• Enhanced productivity for mining machinery, where operation is impaired due to dust, smoke or water vapour.

Further testing of the new radar unit was undertaken. There was difficulty experienced in getting the radar to operate in the correct mode; the manufacturer assisted with various firmware updates and emails. Eventually the radar was made to operate in the desired mode; it then performed as specified.

It was important to get this new radar operating properly for two reasons:
• It uses a higher transmission frequency and exhibits better target discrimination than the old unit; and
• It is significantly smaller and hence will fit in a much lighter and smaller flameproof enclosure.

Development has progressed on the software algorithms for tunnel navigation. Algorithm parameters have been significantly enhanced and these parameters can now be changed on the fly to observe their effect on the tunnel visualisation. Further testing has been done in a variety of above-ground environments. Large metallic surfaces were found to still dominate the signal returns and would swamp the returns from more diffuse surfaces such as rock walls. This is unfortunately inherent in the radar physics, but the effects can be mitigated somewhat by adjusting the algorithm parameters.

The next step will involve testing the system in the presence of smoke and dust at Simtars in order to validate the new radar’s performance under these conditions.

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: September 2019
Industry Monitor/s: Brad Lucke, Sharif Burra
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, toxicity, and personnel status. This project will:
• Develop a UAV that is capable of self-hoovering 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 (e.g. 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 taken delivery of a customised UAV from a Canadian company specialising in 3D LiDAR scanning, robotics, geotechnical monitoring, and point cloud data processing. The UAV was marginally upgraded with improved lighting and a camera prior to testing at the Southern Mines Rescue Station’s underground simulator. The UAV successfully demonstrated its ability to:
• Hover safely should signal be lost;
• Avoid collisions utilising optical cameras to avoid contacting objects and walls (but not roof);
• Manage low velocity ventilation currents; and
• Be driven via a simple driver interface.

Identified shortcomings from testing were:
• Sensors inability to navigate any significant level of smoke in the atmosphere;
• 1 metre minimum effective range of sonar sensors;
• Less than ideal on-board lighting;
• Lack of collision protection system from protruding roof objects; and
• 12-14 minutes flight time (as tested).

More detailed assessment of capabilities and investigations will now consider:
• Extending flight time;
• How close the UAV will drift to a wall in total darkness (i.e. total reliance on sonar sensors);
• Determining suitable ‘top’ protection system (include sensors or is UAV exoskeleton sufficient);
• How easily can the ‘almost’ open platform allow us to modify settings? What can be modified, and to what extent?
• Test effect of dust on performance;
• How easily can additional sensor information (e.g. gas, thermal camera) be integrated in existing platform?
• Determining its ability to fly in low density atmospheres?

Further design and development of the UAV will now be undertaken with a view for a final ‘proof of concept’ demonstration on July 23.
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 project is progressing well and is on schedule. 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. Standards exist for limiting exposure to the respirable fraction of coal dust in most industrial settings. It will have a very low detection limit that will meet or exceed current and anticipated exposure limits, and AS2985-2009 requirements for such continuous testing.

Quick dot point status of project:
- Intrinsically safe electrical architecture complete and reviewed by third party consultant -
  - for an intrinsically safe product this is fundamental to achieving product compliance. It is a detailed exercise to calculate electrical safety circuits, power dissipation, temperature rises;
- Product physical and aesthetic concept design complete (pending final flow path testing) -
  - internal component layout prepared in preliminary 3D,
  - size, shape, physical features,
  - product aesthetic concept renders produced;
- Air flow path components prototyped for performance consistency verification testing -
- Intrinsically Safe Certification houses being vetted for compliance partner;
- Detailed electronics design commenced -
  - focus on critical Intrinsically safe sub-circuits. Will be working closely with compliance partner to ensure design aligns with regulations;
- Mechanical System Design Commenced -
  - non-core mechanical components being designed,
  - third party elements being sourced;
- Firmware development and testing ongoing.

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 is with the industry monitor(s) for review.

C26056
Optimisation of Low and High Pressure Longwall Hydraulic Systems

Quantise Consulting Engineers
Russell Smith

- **Value:** $80,000
- **Report Expected:** July 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 further delayed. Resource allocations have been set for completion in July.

C26057
Electrically Safe Variable Speed Drive for Underground

University of Newcastle
Galina Mirzaeva, Peter Stepien

- **Value:** $158,202
- **Report Expected:** June 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
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.

The research to improve the EST’s test logic has been completed, with good results obtained from tests on a number of commercially available PSUs. This includes units with smart load detection and shutdown, which were the cause of previous difficulties. Feedback on the test results has been provided to the relevant manufacturers. A Mk. IV research prototype has also been built and commissioned, which will be used for upcoming demonstrations. To mark the completion of this phase of the research, an EST workshop and demonstration is planned for early June, with participation from test laboratories, manufacturers and end users anticipated. Interested parties are requested to contact Mining3 for further details.

C26070
Industrialisation of Proof of Concept Wall Flow DOC/DPF System

Orbital Australia
Nick Coplin

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

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 regarding options for the site assessment of the DPF package. Additional system assessments of the insulated wall flow DPF with older mechanical injection systems have also been undertaken focusing on thermal performance with elevated ambient methane.

Final verification site work is expected to be undertaken in May which will allow for project completion in June.

DPF for Coaltram system ready for sending to site for trial work (show mounted atop the wet exhaust scrubber tank).

Installation of Industrialised DPF for thermal testing on the mechanical injection engine (thermal testing config.).
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 project 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 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 & electronics 30% complete.

Test Safe in Londonderry to test the following:
- Casing material with technical data for testing - testing is in progress;
- Battery cells along with all their technical data for testing - testing in progress;
- Internal encapsulant material along with technical data for testing – testing;
- Electronics drawings, PCB layouts. Revised to allow output spark testing - testing / evaluating; and
- Sample operator interface. Issues with LCD display - now resolved - testing in progress.

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; and to
- 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 braking system was delivered in February but was not suitable for the physical application, further component sourcing is ongoing. The intrinsically safe lighting system was also unsuitable and did not achieve the desired outcome. Further design is underway with an Intrinsically Safe Assessment being conducted by an independent engineering company. The assessment is due 31st May.

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

C27069
Reduce Time Required for Certification of
Equipment for Use in IS Zones

Jandar Consulting Services
John Rose

Value: $100,000
Report Expected: May 2020
Industry Monitor/s: Barrie Alley
Brad Lucke

ACARP Contact: Patrick Tyrrell

The objective of this project is to reduce the time required to obtain certification for explosion protected electrical equipment. Intrinsically Safe equipment certification is being utilised as a selective sample for the first part of this project.

The initial objective is to conduct a scoping study to define the problem more clearly and determine if there are practical measures that could be implemented in the next five years.

To date:
- A review of ACARP projects was undertaken and suitable projects were selected to take part in the project; and
- Initial contact was made with the personnel involved in each of the projects.

Currently:
- Initial interviews are currently underway with personnel involved in the Queensland based projects.
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

ACARP Contact: Peter Bergin

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 exploratory 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. This phase of work is now complete.

The feasibility study phase is now underway with the conversion of the exploratory clustering discoveries into workable algorithms. Two algorithms have now passed the proof of concept stage and these are:
- A self-adaptive method of compensating for laser pulse power losses along the length of the fibre; and
- A self-tuning method of measuring the true conveyor speed and the different diameters of the carry and return idlers.

Other machine learning algorithms are currently being developed from the exploratory phase information.

A contract was signed in December with Future Fibre Technologies, a Melbourne company owned by the AVA Group which is an international electronic security company. From January until end of March, the entire team plus a contractor was fully committed to converting the experimental program code developed up to the end of phase 2 of the project into operational program code written in the C language.

The operational code for the first ‘off the shelf’ DAS product was shipped to the manufacturer on April 1st and is currently being incorporated into an initial production prototype instrument. The first true conveyor belt trial of the new product is due to take place early in May with a longer term trial at a Vale iron ore port in Brazil to commence in June.

The current program is running behind schedule. However, the machine learning algorithm feasibility study is progressing faster than expected with two of the self-adaptive algorithms passing the ‘proof of concept’ stage.

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

3ME Technology
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

ACARP Contact: Patrick Tyrrell

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

Key activities conducted to date include:
- Engaging a Hazardous Area Expert external to the company to assist in finalising the design and supporting manufacturing and testing of the battery;
- Executing contract with Accelerating Commercialisation, matching ACARP industry funds and supporting production plans;
- Procurement of long lead time components for the battery builds;
- Continuation of reviews of broader local and international standards. Development of a Risk Register;
- Reviews of effective Isolation and dissipation with a plan developed for assessment by industry experts;
- Development of a life cycle management plan (in draft) to identify additional design requirements and possible usage on site;
- Conduct of functional safety allocation assessment (in draft) to assist with design requirements;
- Agreement reached on the integration strategy for an underground vehicle with mechanical integration partner for the proof of concept vehicle (ongoing);
• Electric flame proof motor strategy completed;
• Custom on-board charger project for Australian standards initiated;
• Preparations for review and update of the FMECA ongoing;
• Design risk assessment continues to advance.

Key tasks to be conducted include:
• Updating the FMECA, design and operational risk assessments with input from additional 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 electric vehicle system into a proof of concept vehicle;
• Field trialing of the proof of concept electric vehicle in an underground coal mine.

C28005
Low Cost, Wireless, Intrinsically Safe Sensors for Underground Coal Mines

Vayeron
Mark Walter
Ryan Norris

Value: $170,000
Report Expected: February 2020
Industry Monitor/s: Brad Lucke, Dave Young

ACARP Contact: Patrick Tyrrell

This project aims to re-deploy existing wireless condition monitoring technology currently being commercialised for an application on conveyor systems in new ways such as underground coal mine Longwall system monitoring and large external Plummer block bearings found in conveyor pulleys, snub rollers, and other rotating equipment. The intent is to gain maintenance and operation advantages from the use of internet/wireless connected devices for generic/adaptable sensing of conditions such as voltage, temperature, position, vibrations, pressure in these applications.

The project was initiated in February with a technical meeting between Vayeron’s electronics engineer and the industry monitors. Scope of the meeting was to discuss product requirements/‘wish list’ and to brief both parties on the goals of the prototype design, construction, deployment and then data analysis.

Vayeron then proceeded to conduct the modification of the existing electronic hardware to include battery power and specification of an enclosure which would conceptually represent the final product. This enclosure was 3D modelled and then 3D printed to produce a proof-of-concept that could be shown to the industry monitors for on-site deployment paperwork to be completed and a site visit scheduled.

Materials and components have been sourced and prototype unit construction will be complete in early May, prior the field testing. A Vayeron electronics engineer will attend site accompanied by an industry monitor to conduct testing and data gathering over the course of a day. This testing will include, enclosure design suitability assessment, radio performance measurements, data type and transmission suitability assessment and assessment of possible use-case situations which would influence final product design.

The site visit is yet to be scheduled but currently anticipated for some time in May.

C28010
Towards Better, Safer Mines - Optical Technologies for Software Defined Instrumentation

University of New South Wales
Francois Ladouceur

Value: $334,200
Report Expected: March 2021
Industry Monitor/s: Brad Lucke, Dave Young, Greg Briggs
ACARP Contact: Peter Bergin

This project very recently commenced.

Mining Technology and Production

C20033
Development of a Safer Underground Explosive

University of New South Wales
Andres Castro
Duncan Chalmers

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

The Resources Regulator is awaiting funding approval to refurbish the facility and once that it done then recommissioning can recommence. Until this happens the project is stalled.
C25069
Adaptive Protection Techniques in Mining Electrical Systems

ResTech
Clint Bruin

Value: $304,150
Report Expected: August 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. The objectives are:

- 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 in a mine as well as on a bench top model. 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; and
- Analyse all data obtained and report on the results.

In this quarter the software for the trial was completed and fully bench tested. It was also tested communicating with two IPX relays over the network. A typical screen shot during system configuration is shown below.

The system has now been successfully installed and commissioned at the trial site and is gathering data. The aim is to operate the trial for at least two months. Initial data will be analysed as the system continues to operate and a report generated after analysis of the results and feedback from the mine staff.

An extension for the project has been granted with completion now planned for the end of July.

C26052
Low Cost Laser and Video 3D Imaging Equipment

CSIRO
Peter Reid

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

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

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; and
- 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.

Progress this quarter includes several interactions with host mine site to clarify important practical implementation details including equipment availability, logistics, system capabilities, required performance, interaction, OEM engagement, timing and staging of evaluations. The only gap identified so far relates to the availability of a suitable computer-controlled control steering interface, and so plans are being coordinated to determine the best approach to provide the required interface to achieve intended shuttle car auto-steering functionality.

The first underground evaluation was also undertaken at the host mine site. The primary goal was to observe the shuttle car operating under production conditions to gain first-hand understanding on normal and nuanced operational behaviour. This opportunity was also used to
conduct an early on-machine sensor evaluation. This initial sensor-only UPEE evaluation provided important validation information regarding candidate sensor mounting locations, physical machine accessibility, sensor coverage and performance. This information is now being used to determine the configuration for the next stage of formal underground evaluations.

C27055
LASC Automation 10 Years On

CSIRO
Jonathon Ralston

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

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

C28017
Integrated longwall creep control system

CSIRO
Jonathon Ralston
Richard Porteous

Value: $263,305
Report Expected: May 2020
Industry Monitor/s: Loz Hemmings, Richard Porteous
ACARP Contact: Patrick Tyrrell

This project aims to develop a new automatic longwall creep control system prototype to help minimise the need for corrective fly cuts and maintain equipment in an optimal roadway position.

The current approach for managing longwall creep relies on manually monitoring to maintain equipment within creep control limits. This measurement and prediction process task are often complex and time consuming with impacts on mining performance. In response to this problem, this project’s objectives are to:

- Measure and model the relationship between longwall creep and lead-lag factors;
- Develop a control algorithm to generate a recommended incremental fly-cut correction profile suitable for integration into an existing LASC face alignment system; and
- Stage a series of controlled, supervised evaluations on a production longwall – from manual open loop to automatic closed loop – to determine system performance.

This project formally commenced in February, to date, the following outcomes have been achieved:

- Negotiated and confirmed access to the target mine site to undertake the full proposed scope of works. Technical and administrative support has also been secured with mine site to assist in logistics, installation and networking activities;
- Physical inspection of key longwall equipment during earlier minibuild configuration;
- Installation of ExScan laser in the maingate as the primary sensor for measuring creepage;
- Installation of the position measurement systems in the TMU and CME to provide high-performance validation of longwall lead and lag.

Initial sensor data validation has been completed to validate underground networking and base device accessibility. Ongoing discussions and coordination with mine site are presently underway to develop a means to make a side-by-side comparison of current manually creepage measurements with an automatically measured creepage.

C28018
Longwall Floor Horizon Sensing

CSIRO
Andrew Strange
Peter Reid
Zak Jecny

Value: $269,680
Report Expected: August 2020
Industry Monitor/s: Claire Morton, Jarod Chadwick, Paul Buddery, Richard Porteous
ACARP Contact: Patrick Tyrrell

Effective horizon control is essential for safety and productivity in underground longwall mining. The key to achieving this outcome is a reliable means of actively sensing the geological strata. A ground penetrating radar sensor was demonstrated on a longwall for this purpose in project C25064. However, it was not in a suitable form for installation on a production longwall. This project will undertake the necessary engineering tasks required so that a long-term trial of the sensor can be completed on a production longwall. This includes the development of a non-metallic flameproof enclosure.

The first stage of this project was to define the requirements of the sensing system and confirm specific details with the host mine site. As part of this stage, the project leader met with staff from the host mine site and discussed expectations for the project along with aspects of the future pilot trail.

In the long-term trial the sensor will be housed inside a non-metallic flameproof enclosure. Therefore, experiments have been conducted to determine how the performance of the sensor will be affected when it is housed within the non-metallic flameproof base. The data from these experiments is currently being analysed. This information will be used to ensure that optimal performance of the sensor can still be maintained when it is in operation on the longwall.
Roadway Development

C25058
Self Drilling Bolt Automation Trial

OKA Rock Bolt Technologies
Mark Levey
Paul Charlton

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

The project objectives are as follow:

- The OKA Technology is further refined using findings from ACARP Project C25058 and integrated into the design and development of a hazardous zone compliant retro-fit pack for a continuous miner;
- 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 the 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 has now confirmed that the continuous miner for use in the trial will be available mid-July to conduct the underground trial.

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

No progress on this project this quarter.

C26051
Machine Bolting and Geotechnical Monitoring System
CSIRO
Jonathon Ralston

Value: $275,490
Report Expected: June 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 objectives of this project 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;
- 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 is currently being prepared.
C27076
Underground Coal Mine Gateroad Development
Continuous Haulage System

Premron
Mick Whelan

Value: $3,055,000
Report Expected: December 2019
Industry Monitor/s: Roadway Development Task Group
ACARP Contact: Patrick Tyrrell

This project is a continuation of ACARP 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 systemisation studies with host mine;
- Manufacture and demonstrate a full scale, full length (180m), fully functional ‘mine compliant’ Premron CHS installed on the surface at ‘the host 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);
- 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 ‘the host mine’. Commissioning of the CHS is completed in a semi functional state, to allow surface trials to commence. The electrical subcontractors will be returning to site in late April to provide a fully functional machine.

Completion of the sizer feeder machine build has recently been taken by Premron. This machine has been at our premises, since early March. We expect delivery it to site in May, where full system commissioning and testing can take place. 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. Underground trials are likely to occur towards the second half of this year.

Strata Control and Windblasts

C25057
Review of Rib Failure Mechanisms and Performance of Rib Support

SCT Operations
Yvette Heritage

Value: $186,500
Report Expected: June 2019
Industry Monitor/s: Claire Morton 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. The monitoring at two sites is complete. 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.

Some conclusions from the modelling of rib support performance include:
- Confinement of the rib is key. Whether it is due to an increase in horizontal stress increasing the rib confinement or keeping the rib confinement by designing support to minimise slabbing.
- Rib bolt length from 4ft to 6ft does not appear have a major impact on rib deformation, except for angled bolts providing confinement on weak bedding planes.
- Rib bolts need to be located in the zones of highest deformation to provide confinement to these locations. The location of these zones can vary depending on the rib lithology.

The project is awaiting access to a final site to complete the project site testing.
C25059
Intrinsically Safe, Integrated Wireless Communications Network with a Distributed Array of Geotechnical Sensors

SCT Operations
Stuart MacGregor

Value: $339,787
Report Expected: July 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 to
- 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 underground.

Work during the quarter:
- An underground field site for a limited ‘full’ trial of 20 wireless dual height Tell Tales has been confirmed at Angus Place Colliery. Work is underway to finalise aspects of the trial to comply with relevant site requirements and meet the objectives of the research program;
- It is anticipated that a fully functioning remote reading wireless system will be installed through the next quarter. Work in this quarter has focused on finalising system design and purchase and manufacture of instrumentation.

C25060
Borehole Shear Monitoring Device for Routine Application in Roadways

SCT Operations
Stuart MacGregor

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

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

C26064
Floor Stability: Comprehensive Investigation Into Failure Mechanisms and Controlling Factors

University of New South Wales
Serkan Saydam

Value: $298,940
Report Expected: June 2019
Industry Monitor/s: Adam Lines
Brian Vorster
Claire Morton
Patrycja Sheffield
Paul Buddery
Peter Corbett
Peter Bergin
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.

A set of floor instrumentation including shear strips and GEL floor extensometer was installed at mine B in March. Another set of floor instrumentation including the shear strips and tell-tale is planned to be installed shortly. The effect of longwall retreat on the deformation of the floor will be studied. Monitoring will continue until June or July.

Data collection is complete from mine A, B and 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. In addition, a coal mine floor rating system, which is similar to the Coal Mine Roof Rating, has been developed. Using the new floor rating system and collected data, a simple tool called Floor Heave Index has been proposed to identify the potential areas for significant floor heave.
The research team are aiming for the rating system and Floor Heave Index to be applicable to as many Australian coal mines as possible, further data collection from other mines is planned. In early April, the research team visited mine D and mine E to further collect relevant data. Also, the rating system is being applied to the US coal mine floor heave cases in collaboration with West Virginia University.

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

ACARP Contact: Peter Bergin

In order to understand the resistance to shear loading by a cable bolt, a UDEC numerical model has been developed that will allow a sensitivity analysis to be undertaken. A study has been undertaken to increase the robustness of the UDEC model. This has led to a better understanding of the modelling approach providing more reliable and accurate results. The next phase will consider the mechanical properties of the cable bolts, grout, and rock/confining medium used in the models.

Figure 1. Boundary conditions in the UDEC numerical model of the double shear test.

In addition to development of a discontinuum-based model (UDEC), a continuum-based model is also being developed using FLAC to investigate stress changes with different geo-material properties. The model accounts for different geological conditions including structures and bedding planes by varying the properties and dimensions to simulate the conditions at different mine sites. Figure 2 shows the model configuration under consideration at mine site A. Cable bolts have been installed in both numerical models and different pre-tensions have been applied to examine its influence on strata movements. Details of the cable bolts properties installed at mine site A will be used to correlate with field observations.

Figure 2. Rock types, bedding thickness and orientation of cable bolts incorporated into the discontinuum-based model. Geological structures such as joints and cleating can be integrated into the model as well as changes to rock properties and cable bolt support pattern.

The project team have visited mine sites A and B to identify the potential for a field test. Information on the local geology was collected during the two visits and we also obtained permission from the mine management team to collect more field monitoring data in the future. The geology data, rock properties, and support designs from mine site A have been used in developing the continuum-based numerical models. Information available from public domain relevant to these two sites has also been collected. Two shear strips designed to measure roof shear behaviour were delivered to UNSW in March. Another site visit has been arranged at mine A on 7 May for further discussion of installation of the two shear strips. Field installation is expected to be completed in June/July this year.

Three sets of test samples for double shear tests have been cast in concrete at UoW with cable bolts attached. The test samples have been transported to the engineering laboratory at USQ where they will be tested using its 2500 kN capacity loading frame in early May. Each set contains three blocks with dimensions of 1.0 m (h) x 0.45 m (w) x 0.45 m (l). A pair of cable bolts orientated at 45 degrees are fixed in 42 mm diameter holes using Stratabinder grout each set as shown in Figure 3. All the cable bolts were pretensioned to 40 kN. The cable bolts used in each set include: 15 mm diameter, 25 tonne capacity plain wire bolts; 28 mm diameter, 65 tonne capacity plain SUMO cable bolts; and, 31 mm, 62 tonne capacity MW9S spiral 9 wire cable bolts. Preparation is underway at the UoW for the construction of the next three sets of blocks at UoW with the cable bolts installed at 30 degrees.
**C27045**

**Assessment of Longwall Mining Induced Connective Fracturing: Stage 2**

CSIRO
Deepak Adhikary

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<td>Claire Morton, Paul Buddery, Peter Corbett, Peter Bergin</td>
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**ACARP Contact:** Peter Bergin

The project deliverables 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.

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 ACARP 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 (in C24020 the heights of connected fractures were quantified for Crinum North and Springvale mines only); 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. This discrepancy is being further analysed.

PFC models representing mine site 2 are developed. Detailed modelling work on site 2 has been started.

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

**C27071**

**Intrinsically Safe Digital Networked 3D Roof Bolt**

Holville
Anne Wylie

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<td>Claire Morton, Mick Stadler, Paul Buddery, Roger Byrnes, Peter Bergin</td>
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**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 3D;
- Interface to the Holville handheld terminal (ACARP project C25060), the wireless network of geotechnical sensors ACARP 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 transducers has been completed. A novel low-cost method of measuring strain which also works at very large strains has been chosen for further development.

A prototype analogue multiplexer is being tested. The next stage is to mount the prototype circuitry in a bolt.

The IS handheld data collection terminal to be used for this project is nearing the end of the certification process and has had a draft certificate issued from Ex Testing and Certification.
C27073
Roadway Stability Monitoring System

CSIRO
Chad Hargrave

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

ACARP Contact: Patrick Tyrrell

This project is an extension to 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. Project C27073 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.

The industry monitors have emphasised the relative importance of temporal coverage (continuous monitoring), so the primary goal of the project is to demonstrate this capability in order to deliver a sensor.

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.

The primary current activity for the project is the construction of the new radar sensor system. The radar front end has been completed and extensive testing has commenced. Some mismatch in the antennas has been observed which is compromising the operative bandwidth to a degree, so this may necessitate a modification to the design. If a redesign is required then the delivery for the complete system may slip into Q3 (currently targeted for end of Q2). At this stage the overall project timeframe (reporting in March 2020) should be unaffected, however the project team is currently considering an initial underground test using the current radar hardware in a real-time acquisition mode to validate the fundamental measurement concept in preparation for a more extended trial when the new hardware is delivered.

The project team has successfully negotiated mine site access with the industry monitors for Q3-4 this year, initially targeting a section in the NERZ where ground movement is likely to occur.

Ventilation, Gas Drainage and Monitoring

C25001
Ventilation and Gas Management - Underground Coal Mines: Stage 2

Bruce Robertson
Andy Self
Bruce Robertson

Value: $270,000
Report Expected: May 2019
Industry Monitor/s: Bharath Belle, Brad Elvy, Jim Sandford, John Grieves, Peter Brisbane, Patrick Tyrrell

ACARP Contact: Patrick Tyrrell

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

C25065
Specific Gas Emission Patterns from Different Coal Seams

CSIRO
Rao Balusu

Value: $277,340
Report Expected: May 2019
Industry Monitor/s: Bharath Belle, John Grieves, Paul O’Grady, Patrick Tyrrell

ACARP Contact: Patrick Tyrrell

A draft report is with the industry monitor(s) 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 Grieves, Paul O’Grady, Patrick Tyrrell

ACARP Contact: Patrick Tyrrell

A draft report is with the industry monitor(s) for review.
C25072
New Approaches to Mine Gas Analysis and Ratios
Simtars
Fiona Clarkson

Value: $416,192
Report Expected: February 2021
Industry Monitor/s: Bharath Belle, John Grieves
ACARP Contact: Peter Bergin

The aim of the project is to identify additional gases for the detection and monitoring of spontaneous combustion. This will be achieved through the following objectives:

- Objective One – Using a medium scale reactor, profile the gases evolved from the heating of a Queensland coking coal with a methane / ethane seam gas composition and a New South Wales coal with a carbon dioxide seam gas;
- Objective Two - Compare these gas profiles to the normal carbon dioxide seam gas and methane / ethane seam mine fingerprints identified in the first stage of the C25072 project and ACARP Project C10015;
- Objective Three - Expand the current ‘Fire Ladder’ to include additional alkanes below the ethylene point which can be used to give earlier warning of a developing heating / spontaneous combustion and incorporated into TARP.

The following work is in progress:

- Configuration of the medium scale test apparatus for the heating of a coking coal;
- Development of a revised analytical method for the gas chromatography based on the Stage 1 findings;
- Literature survey and review of relevant reports and papers.

C26055
Control and Management of Outburst Risk
University of Wollongong
Dennis Black, Najdat Aziz

Value: $100,000
Report Expected: May 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: July 2019
Industry Monitor/s: David Webb, Russell Thomas, Sharif Burra
ACARP Contact: Peter Bergin

This project will:

- Define the current status of gas predrainage design and management practices across the industry;
- Establish a benchmark of coal seam permeability and its relationship with stress, cleat, coal rank and type, and assess how permeability measurements are best applied in the gas drainage design process;
- Establish a set of guidelines that will provide -
  - a framework for gas predrainage design, management and validation,
  - a protocol for the acquisition, validation and application of key gas drainage and gas reservoir parameters.

Work completed to date:

- Established a clear understanding of the current status of gas predrainage practices and design methods employed across the industry;
- Set up a database of permeability measurements, use that to benchmark permeability with depth and stress;
- Completed a review of literature related to gas drainage design, performance and permeability; and
- Initial set up for stage 2 studies at Appin and Moranbah North mines.

Work planned for next quarter includes:

- Complete data acquisition and assessment;
- Completion of the permeability benchmarking;
- Detailed assessment of the gas drainage history at Moranbah North mine including -
  - gas reservoir characterisation;
- review mine plan, schedule, lead times and predrainage practices,
- review and assessment of drilling data,
- gas drainage review and assessment,
- gas drainage and optimisation modellings;
- Commence work on gas drainage guidelines.

**C27035**

**Automatic Leak Detection for Tube Bundle Systems**

**Simtars**

Sean Muller
Snezana Bajic

**Value:**  $220,000

**Report Expected:** January 2020

**Industry Monitor/s:** Bharath Belle
John Grievess

**ACARP Contact:** Patrick Tyrrell

The project objective 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.

A project extension was granted due to events which required significant industry support from Simtars. Work will be recommencing shortly 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:** July 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; and
- Gas and water through the drainage boreholes.

During the previous reporting periods, literature review and the modelling work was completed and the validation of the new development work was completed. During this reporting period, different case studies on gas released from overlying and underlying formations to the goaf and working area have been carried out. The effect of stress change and its impact on permeability has been included in the case studies. The next stage involves more simulation case studies and writing up of the final report.

**C27072**

**Intrinsically Safe Borehole Survey Tool**

**Holville**

Anne Wylie

**Value:**  $120,000

**Report Expected:** June 2020

**Industry Monitor/s:** Claire Morton
Mick Stdaler
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.

The electronics used in the survey tool is finalised. Evaluation of lighting and lenses for the camera is ongoing with the objective of maximising the depth of field. Transfer of video from the tool to the receiver has been done successfully. Software for synchronising the positional data with the video feed is being developed. Prototype borehole survey tool modules are now being manufactured and tested.
Effect of Occlusions by Coal and Stone Dust on the Sensitivity and Time Response of Methane Gas Detectors in Underground Coal Mines

Ampcontrol  
Ian Webster

Value: $90,000  
Report Expected: August 2020  
Industry Monitor/s: Bharath Belle, Ken Singer  
ACARP Contact: Peter Bergin

The overall objective of this project is to:
• Verify and quantify the susceptibility of real time methane detectors to occlusion by coal and stone dust by controlled laboratory testing of typical methane sensing devices;
• Establish the existing degrees of occlusion of real time methane sensors in service in underground coal mines by qualitative survey, and hence determine the potential compromise in performance.

The project work is on schedule. Pro-forma has been compiled, reviewed and implemented to ascertain the condition of in-situ fixed gas detectors in underground mines. This survey includes a cross section of sensing technologies, target gases and detector locations.

The conceptual design for a test rig suitable for the synthetic exposure of fixed detectors to ambient coal and stone dusts has been completed. This rig encompasses the principles inherent in IEC 60529 Degrees of protection provided by enclosures (IP Code) to ensure transparency of technique and directly comparable variables.

The particle sizes proposed for use in the synthetic dust exposure experiments has been informed by the technical paper ‘Comparison of Portable, Real-Time Dust Monitors Sampling Activity with Size-Selective Adaptors’ by Andrew Thorpe and Peter Walsh.

Domestic suppliers of fixed detectors used in Australian mining applications have been approached regarding their willingness to provide detectors for use in the synthetic dust exposure experiments. Where detectors cannot be sourced from OEM suppliers, samples will instead be borrowed from mining operations.

The next stages of the project will involve construction and commissioning of the dust exposure test rig, and preliminary evaluations of data obtained from the in-situ surveys.
OPEN CUT

Drilling and Blasting

C27034
Top of Coal Detection Phase 4

University of Queensland
Byron Wicks
Erik Isokangas

Value: $395,310
Report Expected: June 2019
Industry Monitor/s: Max Ayliffe
ACARP Contact: Cam Davidson

Mining3 have developed a novel approach in determining coal seam location while drilling in a rotary air blast (RAB) drill rig. By using a geotechnical measurement technique, the top of coal detection system has been proven to be capable of mapping the location of the coal seam in a rotary air blast drill rig during routine drilling on a hole by hole basis. Furthermore, it has been proven that the system is capable of making measurements of the overburden during the drilling process. This information correlated well to drilling conditions and may prove to be useful for optimising blast design.

The system mechanical, electrical and user interface designs have been optimised and finalised. Validation and verification of the electrical system is currently being performed at the Mining3 test facility. Proposed mechanical changes have been modelled with a finite element stress analysis and validated by chartered professional engineer (image below). Manufacturing of mechanical components to commence in April. Preparation for field trials at mine site 1 occurring, with trial scheduled for May-June and will run for three weeks duration.

Environment

C25031
Closure Criteria for River Diversions: An Alternative to Reference Sites

Edith Cowan University
Melanie Blanchette

Value: $232,293
Report Expected: May 2019
Industry Monitor/s: John Watson
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
ACARP Contact: Patrick Tyrrell

Flooding has impacted on field studies again in this quarter. Additional heavy rain in early March (46mm and 30mm within three days) were ‘added to’ on the weekend 30-31 March when 90mm fell (photo below). The latest rainfall event inundated all experiments at mine 1. Some plant stakes are still emergent, but few plants are visible.

We have replacement plants for many of those that do not survive and additional species to plant once the water has been pumped out and the surface sufficiently dry to allow access according to our safety protocol. As soon as this occurs we will resurvey survival and plan the replacement plant positions to achieve the different leaf area indices in the experimental plan, although plot size may have to be reduced for some species.

Progress is being made with the development of the species baseline models which will allow the rate of transpiration of water to be related to environmental factors. Both individual species (Eucalyptus camaldulensis
and Melaleuca quinquenervia) and environmental conditions at mine 1 that affect plant transpiration are under study. An aim this year being to produce models of species transpiration, to start to apply them to mine environmental conditions, and to measure activity at mine 1 to evaluate failure of site conditions to allow the species models to be fully expressed. That is, resistances that might be related to crust density and nutrient availability.

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: November 2019
Industry Monitor/s: Bill Baxter, Nigel Charnock, Stephen White
ACARP Contact: Patrick Tyrrell

There has been little progress during the quarter due to continued drought but we are now planning to start field work in May/June if conditions remain favourable in the Upper Hunter.

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, Patrick Tyrrell
ACARP Contact: Patrick Tyrrell

The core objectives of the project 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 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. The project has a national context, with a focus on the Hunter Valley.

To date, the project has undertaken comprehensive literature review of the relevant literature, as well as legislation, policies and guidelines. Consultation with NSW OEH is ongoing regarding programs on mine rehabilitation, with liaison with New South Wales OEH assisting with project relevance from a government perspective.

Collection of existing mine rehabilitation data and PCT specific floristic data is complete and is currently subject to analysis. The intensive field work component of the project commenced in March and is expected to conclude in mid-May. Thus far, the field team has visited four mine sites to collect data in rehabilitated areas and remnant bushland. Floristic and biometric data is being collected at each sampling location, in addition to soil samples.

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 (eg 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 (eg 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.

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 in this project 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;
- Liaising with site regarding the acquisition of LiDAR data over the site to capture erosion features;
Liaising with site to collect a representative mine spoil to be sent to UoN for erosion parameter development; and
Laboratory flume constructed and now being commissioned for parameter derivation.

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 ~10pts/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:
Has not been approached for LiDAR data at this stage.

Software development:
Determining (1) what components of the SSSPAM are necessary and (2) 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 been validated on ground at this stage;
Updating of the existing SIBERIA parameter database has commenced and the new parameters are being evaluated for correctness.

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 and natural lakes. Many natural lakes are saline and still host valuable ecosystems. 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.

The first round of pit lake sampling that was undertaken in February was completed successfully.

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 recovery and resilience.

Work undertaken in this quarter includes:
- Field data collection at mine 2 for the six-month post-fire assessment. A team of CMLR staff collected field data in February and monitored six burnt transects and six unburnt transects. This includes ground survey data and associated drone imagery.
- Data analysis and remote sensing analysis for all sites is continuing and progress report is due to be delivered to mine 2 in May.
- Planet satellite imagery of the fires have been downloaded and assessed for fire severity and recovery at mine 2 (see below) and mine 3.
- Proposals have been submitted for fires at three new mines with work proposed in 2019 depending on weather conditions.
- Additional discussions are ongoing with new sites for potential burns in 2019.
- Ongoing discussions with QPWS, QFES and UQ FireLab regarding future works.

Figure 1. Fire recovery 40-hectare burn conducted at mine 2 using NDVI 3m multispectral Planet satellite imagery. Note that the burnt block has recovered and is achieving higher NDVI values compared with the unburnt block (control).

Figure 2. Planet colour infrared imagery of the burn site (red polygon) and control site (green polygons) corresponding to the data presented in Figure 1.

C27061
Open Path Boundary Monitoring for Operational Dust Control

Pacific Environment
Damon Roddis

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

No report received.
C28037  
Local Scale Dispersion Modelling to Refine Emission Factors  
ERM Australia Pacific  
Judith Cox  
Value: $86,344  
Report Expected: March 2020  
Industry Monitor/s: John Watson  
ACARP Contact: Patrick Tyrrell  

This project has very recently commenced.

C28043  
Scale up leaching tests for spoil salinity predictions  
University of Queensland  
Mansour Edraki  
Value: $198,500  
Report Expected: March 2021  
Industry Monitor/s: Jason Fittler, Stephen White  
ACARP Contact: Patrick Tyrrell  

This project has very recently commenced.

C28044  
User Driven Refinement of Decision Support Tools to Inform Final Mined Landform Outcomes  
Tree Crop Technologies  
Glenn Dale  
Value: $250,220  
Report Expected: March 2021  
Industry Monitor/s: Craig Lockhart, Jason Fittler  
ACARP Contact: Patrick Tyrrell  

Previous ACARP project C24033 developed a framework to support practical, cost-effective management of dispersive spoil, including a Bayesian network-based decision support tool to facilitate practical application of project results. This current project aims to facilitate transfer of project C24033 outputs into practice, and to refine the package of decision support tools through a combination of user-driven training and analysis of results from operational mine rehabilitation outcomes. The project will also extend the application of the existing decision support tools to all mined land rehabilitation in order to support improved quality and cost of rehabilitation outcomes, and confidence in meeting regulatory commitments.

An initial training session has been arranged for Brisbane-based mine rehabilitation staff, and a plan has been developed to deliver a series of regional workshops throughout Queensland and New South Wales. The workshops will cover the principles of challenging mine spoil management; the functional basis of management interventions; and use of the Mine Spoil Rehabilitation decision support tools to forecast erosion likelihood.

Throughout the 2019 dry season, detailed site assessments will be undertaken across a range of rehabilitated site conditions, approaches, and performance outcomes to improve parameterisation of the existing Bayesian Decision Support Model and associated Best Management Practices. This will involve application of digital remote and proximal sensing approaches (electromagnetic surveying, multispectral surveying and digital terrain mapping) to characterise fine-scale (5cm resolution) spatial variation in spoil properties, vegetation occurrence, and terrain. These data layers will be used to derive secondary data layers for each pixel across the sites surveyed, including slope, slope length, catchment area, vegetation cover and erosion. The data will generate millions of data points for each site, and will be used to develop probability distributions for the likelihood of any given set of conditions relating to a quantitative measure of erosion.

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  

The main objective of the project is to develop a guideline for downgrading the laboratory properties to the field condition through combining the conventional rock mass classification systems and Synthetic Rock Mass numerical modelling technique. The project had two streams, (i) laboratory and empirical streams, which were carried out by UNSW; and (ii) the numerical simulation stream which was conducted by UQ.
During this quarter the draft final report was submitted to the Industry Monitors and valuable feedback has been received. Following discussions with the Industry Monitors the final report has been divided into two separate reports as parts A and B. UQ has incorporated all suggested changes and submitted their final report. UNSW is currently compiling the final report on their part.

C26023
Borehole Data Standard
GeoCheck
Brett Larkin

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

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

C26029
Controls on Fluorine and Phosphorus Distribution in Bowen Basin Coals
University of Queensland
Joan Esterle

Value: $141,050
Report Expected: November 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 February to April the team continued and completed the microanalysis of the apatite grains to confirm whether the trace and rare earth element and yttrium patterns between volcanic fluorapatite and that occurring as coal matrix attritus, inertinite pore fill and fracture fill could be consistently distinguished. Additional data was obtained from stratigraphic equivalents of the Rangal Coal Measures, and from Early Permian sequences, to test the stratigraphic trends observed in the current data sets. These new data sets are under analysis and are due to be completed early next quarter. A draft report will be submitted next quarter.

C26034
Storage and Time Effects on Coking Properties of Small Coal Samples
McMahon Coal Quality Resources
Chris McMahon

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

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

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: June 2019
Industry Monitor/s: De Nicholls, Gareth Johnson, Mark Laycock
ACARP Contact: Patrick Tyrrell

We are yet to get site access to undertake the trial and therefore the site component of the project work has not yet commenced.

C28033
Raw ash to yield relationships
McMahon Coal Quality Resources
Chris McMahon

Value: $29,120
Report Expected: April 2020
Industry Monitor/s: Hugo Kaag, John Terrill, Rod Doyle
ACARP Contact: Cam Davidson

This project has very recently commenced.
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 C25035 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 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. Tests have been conducted to determine how close the sensor can be to a steel dozer blade whilst keeping noise and interference to a minimum and the effect of a thick non-metallic skid plate. The design of mounting the sensor and additional components for the mini-digger trial are in progress.

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: June 2019
Industry Monitor/s: Gavin Lowing, Leigh Bergin, Shaun Booth
ACARP Contact: Patrick Tyrrell

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

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: May 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
Byron Wicks
Erik Isokangas

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

This project will develop a sensing device to deliver greater certainty about groundwater conditions and stability of any scale of spoil dumps or tailings’ dams. The device will be able to sense the groundwater pressure, which will allow better monitoring of slope stability for spoil dumps, and embankment stability for tailings dams. A monitoring system comprising the new groundwater sensors will likely be scalable; coupling multiple sensors into meshes as opposed to single sensor monitoring; should be able to integrate into autonomous risk management systems in real time; and be low-cost.

Site visit to mine site 1 to inspect application of sensors to specific spoil pile locations has occurred. Partnership between Mining3 and Company 1 created to leverage both companies’ technologies to create a functional prototype and allow for field trials. Modelling and optimisation of transmitter, receiver and transmission path requirements (image below).
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 Keilich
ACARP Contact: Cam Davidson

This project proposes to 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 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 analysis of mine site 1 structural data has now been completed and refined. Options for the partitioning of the data spatially to define domains upon which the random fields can be based have also been explored and this activity is currently ongoing to provide adequate parameters to the statistical analysis. A second set of structural data has been collected from mine site 2 and is currently undergoing detailed analysis.

The team is currently working on extracting and appropriately grouping the parameters upon which the random fields will be defined. In particular, attention is focused on characterising the statistical properties (average, standard deviation, distribution, correlation length) of the geostuctural data (dip, dip direction, persistence and spacing of the different joint sets) and their spatial variation. The objective of this task is to rigorously define the inputs of the random field models.

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 completed using data from mine A. This has included comparison of the algorithm performance using both DSLR data and data acquired with the existing camera system on the radar. The analysis has shown that particularly for oblique angle corrections, high resolution imaging sensors with narrow angle lenses and minimal compression applied will be required for the types of features/textures acquired in coal mine highwalls and low walls. Providing these configurations are used, the algorithm performance can be sub-millimetric to millimetric depending on target range which meets the target sensitivities.

In the next quarter, further analysis of the field data (radar and imagery) provided by radar companies for mine sites A and B will be undertaken to determine the performance of the algorithm against different deformation scenarios.

Health and Safety

C25026
Reducing Risk Taking Among Australian Coal Miners

University of Newcastle
Anna Giacomini
Mark Rubin

Value: $302,235
Report Expected: April 2020
Industry Monitor/s: Bharath Belle, Doug Kennedy, Robyn Masters
ACARP Contact: Patrick Tyrrell

This multi-phased project aims to investigate the cause of risk-taking behaviour in Australian open-cut and underground coal mines as well as develop a practical intervention to reduce dangerous risk-taking. The aim is to improve safety outcomes through reducing 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 the long-term effectiveness of the intervention.

Phase 2 of the project is underway with the development of the project intervention: The Safety Choices Task (SCT). The SCT has been developed based on the results of Phase 1, which showed that perceived poor safety norms predicted an increase in reported risk-taking. The SCT is therefore aimed at improving positive safety norms at the target mine site and ultimately reducing risk-taking. The SCT outlines an experimental procedure designed to 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. Example SCT scenarios (generic issues) have been developed for adaptation (site-specific issues) and implementation at each participating site. The intervention will also involve a pre- and post-test
survey that will identify changes in perceived safety norms as a result of participating in the intervention.

The project team is currently recruiting mine sites to participate in the intervention. Due to time and budget constraints, we are focusing on mine sites within a 350km radius from the project team’s base in Newcastle. This distance represents a viable option for frequent site visits (mines within a 4-hour drive). We are in various stages of discussion with over 30 mine sites throughout the Hunter Valley and the mid- and central-Western regions of New South Wales. We aim to secure 3-6 sites for participation.

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: June 2019
Industry Monitor/s: Occupational Health and Safety Task Group
Tony Egan
ACARP Contact: Patrick Tyrrell

No report received.

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 utilizing 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 nearing completion. These systems will 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 and accessible via web browser. Software is in development to facilitate off-line analysis and integration of accelerometer data with existing equipment health databases. A new staff appointment is underway to accelerate the software development.

A second company has requested to participate in the project and have the RPi modules and accelerometers installed in dozers at site. A meeting with Hexagon took place in March regarding a potential collaboration.

C26028
Proximity Detection System Performance Testing Framework
University of Queensland
Joji Quidim
Rajiv Shekhar
Susan Grandone

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

The second stage of this project has not yet commenced.

C27005
Interface Design for Haul Truck Proximity Advisory Systems
University of Queensland
Danellie Lynas
Robin Burgess-Limerick

Value: $199,296
Report Expected: May 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.

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

C27013  
Evaluating Risk Control Performance

University of Queensland  
Maureen Hassall

Value: $135,000  
Report Expected: June 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 of this research project are as follows:
- 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.

Findings from a literature review, survey of mining industry practitioners and a workshop with cross-industry people involved in critical control management has been collated into a draft report that outlines current practices for measuring control performance across different high hazard industries. The report also describes review options for measuring control effectiveness for different types of controls. Case study examples that demonstrate options for measuring for different control types has been developed. The outcomes will be presented to the industry monitors in the near future.

C27062  
Augmentation to Emissions Factors

Pacific Environment  
Damon Roddis

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

No report received.

C28034  
Mining equipment human factors design for workforce diversity

University of Queensland  
Robin Burgess-Limerick

Value: $187,350  
Report Expected: August 2020  
Industry Monitor/s: Brendan Wilkins, Iain Curran, Skye Searle, Tony Egan  
ACARP Contact: Cam Davidson

The objectives of the project are to:
- Identify and describe design issues with current mining equipment which are a barrier to workforce diversity;
- Document and evaluate remedial control measures currently undertaken at sites; and
- Communicate the results of the investigation to equipment designers and mine sites.

Several planning meetings have been undertaken with the Earth Moving Equipment Safety Round Table advisory committee members, industry monitors and representative of BHP. A series of initial site visits are scheduled for April 29-May 3.

Maintenance and Equipment

C26020  
Preventing Fatigue Cracking Via Proactive Surface Dressing

Bureau Veritas AIRS  
Simon Krismer

Value: $126,940  
Report Expected: January 2020  
Industry Monitor/s: Shane Saunders  
ACARP Contact: Patrick Tyrrell

No report received.
C26021
Verification of Interoperability - Collision Awareness and Avoidance Systems

CSIRO
Jeremy Thompson

Value: $105,844
Report Expected: September 2018
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 project as the ISO standard ratification is still in progress. However, we believe regardless of the status of the standard we will begin work on the project next quarter.

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

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 current 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 research team have developed a prototype system that includes the following:
- A prototype software application for displaying sequential x-ray images and to highlight damaged regions of complete tyres;
- A stepper motor and 10:1 reduction gearbox mounted on a wheel rotator;
- A prototype motor control software application to control the stepper motor.

ALS recently provided new Digital Detector Array (DDA) technology from their Roma Laboratories for acquiring radiographic images of a sample tyre carcass. In particular, a GE DXR250U-W wireless DDA was clamped to an x-ray scanner stand positioned over the tyre wall. An Iridium 192 radiation source was positioned opposite the DDA on the other side of the tyre. The images produced by the GE DXR250U-W DDA provided better cord detection performance than that previously obtained using a RIGARKU INDUSTRIAL RADIOFLEX DDA. The developed automated tyre rotation system enabled a tyre wall radiographic image acquisition to be completed in less than an hour.

Mining and the Community

C28039
Low Frequency Noise Prediction and Validation Study

ERM Australia Pacific
Aaron McKenzie

Value: $89,584
Report Expected: March 2020
Industry Monitor/s: John Watson
ACARP Contact: Patrick Tyrrell

This project has very recently commenced.

C28046
Broader contribution of coal sector employment to Indigenous individuals, families and communities

Myuma
Michael Limerick

Value: $199,472
Report Expected: February 2020
Industry Monitor/s: Anthony Galante, Hayden Leary
ACARP Contact: Patrick Tyrrell

This project has very recently commenced.
Overburden Removal

C26035
Dynacut Fundamental Development: Phase 2

University of Queensland
Dihon Tadic
Erik Isokangas
Isaac Dzakpata

Value: $1,333,000
Report Expected: July 2019
Industry Monitor/s: Andrew Lau, Ivan Heron
ACARP Contact: Cam Davidson

This project directly follows ACARP project C25041 – DynaCut fundamental development and scalability testing for high capacity mining of coal overburden. There are a number of 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.

A number of rock samples for cutting trials with the DynaCut test machine have been procured, and construction of the first test bunker is now being finalised. Core samples from these rocks have been extracted and tested, confirming two distinct rock strength domains (<30 MPa UCS and >30 MPa UCS). The experimental design is also being finalised and cutting trials with this first bunker are scheduled to be completed in May.

Concurrent work on conceptual mining system designs has significantly advanced; work on the project has stopped while the project team is in discussion with project monitors to assist direction with this element, and also to review remaining work scope based on findings and outcomes to date.

C27063
SATS Automated Mission Planning

University of Queensland
Peter Beasley
Ross McAree

Value: $346,046
Report Expected: September 2020
Industry Monitor/s: Brian Neilsen, 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 workstation. Missions are the ‘packages’ of work that the bulldozer completes autonomously with one operator overseeing several bulldozers.

The project aims towards high utilisation of available time by planning plan missions autonomously and choreographing dozers.

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.

Work completed in the last quarter includes:
- Completion of a field trial that has benchmarked the performance of the current SATS technology with results to be used as a basis for quantifying the impact of the project on productivity and to quantify reasons for current utilisation rates under autonomy; and
- The development of algorithms for choreographing multiple dozers in pivot push to maximize the rate of overburden movement to prime.
COAL PREPARATION

Dewatering

C24040
Improving the Dewatering Efficiency of Fine Flotation Concentrates by De-Aerating Froth Products

University of Queensland
Yongjun Peng

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This project extension now focuses on direct plant tests of the deaeration techniques developed in the laboratory. The main objectives of this proposal 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 optimize 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 the pilot-scale deaeration unit has been completed. It includes a froth-slurry separation system to separate froth from the flotation product prior to deaeration and two stages of physical deaeration to achieve a complete froth deaeration. All the components of the trial unit have been tested continuously in laboratory using coal samples collected from participating plants. 80% to 90% froth reduction can be achieved at the stage 1 deaeration, while a complete froth deaeration can be achieved after stage 2 deaeration.

The plant trial in two coal preparation plants is scheduled at late May and June. The connection of the trial unit to the plant has been discussed with the plant process engineers. All the devices are being checked to meet the safety standards of the plant.

C24047
Steam Pressure Filtration Targeting Step Change Reductions in Filtercake Product Moistures

QCC Resources
Andrew Swanson
Bob Drummond

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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 initial pilot testing phase of the project was recently completed. A summary of the pilot testing headline filter cake discharge moistures from site moisture testing is provided below.

The objective of this stage of the 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 ten 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 ten sites that have agreed to contribute a sample towards the research. Sample collection has been completed and all samples
from the contributing sites were delivered to Bokela in Germany during 1st quarter 2019. Preliminary results from the Bokela laboratory testing are expected by the end of May.

It is anticipated that on receipt of the laboratory data that interpretation and reporting of the project outcomes will take a further two months, and that the research will be completed by the end of July.

C25012
Dewatering of Ultrafine Coals and Tailings by Centrifugation: Pilot Scale Studies

University of Queensland
Anh Nguyen

Value: $296,000
Report Expected: June 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.

This report covers the activities and outcomes of the project extension from January to March, 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
• Provide solid recovery by size analysis of the centrifugal dewatering for each type of the samples.

Characterisation of tailings thickener underflow samples (sample A and B) received from two coal preparation plants in Bowen Basin were completed. The ash content of the samples is similar, but sample A and B contain 17% and 16% swelling (smectite-type) clay, respectively. Zeta potentials of particles of samples A and B are -8.7 mV and -45 mV with D90 of 60µ and 37µ, respectively. The results of the process water analysis of the samples show high Ca2+ and Mg2+ ions concentrations for sample A. The dewatering trials using the pilot-scale solid bowl were completed for both samples A and B. A minimum cake moisture of 30% with 0.35% total suspended solids (TSS) in the centrate was obtained for sample A at ~2000 g-force and 14 differential rate with the medium pool depth condition. The same operating condition produced cake moisture of 34% with 0.8% TSS for sample B. The centrate quality was improved with increasing pool depth, but cake moisture increased for both samples. Solid recovery and size analysis show capturing particles larger than 5µ at high pool depth for both samples. However, solid recovery of particles below 5µ for sample B was lower than sample A. Characterisation and pilot-scale centrifugal dewatering trials on the tailings sample C are underway.

C25018
Improving Solids Recovery and Moisture Reduction in Ultrafine Coal Dewatering

University of Queensland
Liguang Wang

Value: $184,000
Report Expected: August 2019
Industry Monitor/s: Rahul Patel
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 pilot-scale SBC test unit constructed at The University of Queensland is ready for pilot scale experiments. The research team just received the SBC feed samples shipped from a participating site in Central Queensland.

In the following quarter, bench-top scale tests will be repeated for the newly arrived samples, followed by pilot scale SBC tests for the reagents selected from bench-top scale tests. A cost-benefit analysis will then be conducted.

C27016
Eriez HydroFloat in Plant Evaluation

Eriez Magnetics
Darren Mathewson
Liam Davis

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

The Eriez HydroFloat is a small footprint, high capacity coarse particle 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 QLD coal processing plants. This testing is to be similar to previous test work conducted in the USA with the emphasis on determining 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.

The following lists some of the 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 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 progressed through initial calibration of the individual relative density particles;
- X-ray sorting of middlings is to progress in mid-May following a laboratory relocation.

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 main objective of the project is to 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.

Multivalent cations (Al3+, Fe2+, Ca2+, and Mg2+) were used to study their effect on settling rate and change in surface charge of pure montmorillonite (a swelling clay mineral) and kaolinite (a non-swelling clay mineral) and to correlate the minerals interaction with ions in process water during the dewatering process. The results showed that multivalent cations could increase kaolinite settling rate by a factor of two. Montmorillonite settling rate was very poor in comparison with kaolinite in DI water. Multivalent cations improved montmorillonite settling rate by a factor of 10, but its rate was still slower than kaolinite. Neutralisation of montmorillonite surface charge was the main reason for its increased settling rate.

Different structure and charge of polyacrylamide (PAM) flocculants (widely used in coal dewatering) were used to study their effect on kaolinite and montmorillonite settling rate. Anionic PAM showed the highest settling rate when compared with cations and non-ionic PAMs for kaolinite. Increasing molecular weight of anionic PAM to 18 m and its charge to 40% significantly improved the kaolinite settling rate. Water salinity showed an adverse effect on kaolinite settling rate with flocculants. The effect of flocculants on montmorillonite settling rate in DI
water or saline water was very poor. Increasing anionic PAM molecular weight and charge increased montmorillonite settling rate, but it was not very significant. Consolidation of the settled montmorillonite in saline water was higher than in DI water. Studies to design a suitable flocculant for montmorillonite are in progress.

Environmental Improvement

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: May 2019
Industry Monitor/s: John Watson, Kevin Rowe
ACARP Contact: Nerrida Scott

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

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%). A pilot scale dewatering flume has been constructed, allowing variable inclination angles and interchangeable flow restriction plates to be tested. Results show that water recovery and slurry velocity are inversely related, whereas flow restrictor plate roughness was negligible.

Furthermore, an open-air channel CFD simulation, consisting of three Eulerian phases for the water, tailings and air has been undertaken of the pilot scale dewatering flume.

The pilot scale testing will provide calibration and validation of the CFD simulation work, which will be used in conjunction with the testing to optimise further flume and flow restrictor plate designs.

C28059
Impact of Water Quality in CHPPs

Basacon Services
Bruce Atkinson

Value: $111,414
Report Expected: February 2021
Industry Monitor/s: Kevin Rowe, Rebecca Fleming
ACARP Contact: Nerrida Scott

This project involves the monitoring of CHPP water quality across eight different CHPPs, every month for an eighteen-month period. During that period, sets of three standard corrosion test coupons will be located at each of three different locations at each CHPP, for a total of twelve months, ranging from background reference locations to regularly wetted locations within the CHPP.

Detailed water quality will be analysed monthly for each of clarified water and ‘fresh’ makeup water.

The project will quantify:
- Degree of concentration of water quality parameters that results in CPP recirculation (difference between clarified water and makeup water);
- Corrosion rates for standard mild steel specimens (coupons) located at each site;
- Any correlations between measured corrosion rates and water quality; and
- Any correlations between site reagent consumption (flotation and dewatering reagents) and water quality.
Fine Coal

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
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 1000 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.

Following the tender process, it was necessary to review the design for trialing the ReFlux Flotation Cell to bring the project into budget. Previously it was assumed that the existing Rixs Creek facility would result in project savings, but that structure has become a liability due to the geotechnical costs, and multilevel refurbishment retrofit cost. 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.

C24049
Performance Enhanced Diesel Collector for Coal Flotation

CSIRO
Shenggen Hu

Value: $148,013
Report Expected: June 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 at another CHPP site 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. Due to the slow dissolution of Naflote 9840 which was used as frother at the site with Jameson cell, the combustibles recovery for all cases were less than 27%. In the ACARP reviewing meeting held in March 2018, it was suggested by the ACARP committee that one more plant-based test should be done on Jameson cells with MIBC as frother. Additional plant-based tests were carried out at a Queensland mine site in September and the analysis of samples has been completed. The final report is being internally reviewed.
C25009
Rapid Extraction of Frothers from Process Water

University of Newcastle
Jamie Dickinson

Value: $122,965
Report Expected: May 2019
Industry Monitor/s: Kevin Rowe, Mario Salazar
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: June 2019
Industry Monitor/s: Mario Salazar, Rahul Patel
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. The viscosity of this frother is an order of magnitude higher than MIBC. The industry monitors expressed preference for the tests to be performed at 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. The industry monitors 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 analyses have been completed and a final project report is the final stages of completion.

C25019
Adaptation of Coal Grain Analysis to Improve Yield Estimation

QCC Resources
Bruce Atkinson

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

Accurate prediction of flotation yield is difficult. Modelling of density separation processes is reasonably straight-forward, 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.

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 been completed for each feed sampled. Detailed CGA data evaluation will be undertaken after CGA data for all sites are available. The CGA data for the remaining two sites is awaited and expected to be completed by May. The draft report for is expected to be submitted by July.
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
- Make recommendations with regard to future R&D on fine coal classification and/or pilot plant trials.

The literature review of NERDDC, ACARP, Australian Coal Preparation conference papers and International Coal Preparation Congress papers is complete. The literature review identified considerable work into cyclones, sieve bends and ultrafine vibrating screens but no new processes for the classification of fine coal. Further research is being carried out to identify if there are fine particle classification technologies currently in use, or development, in other mineral industries that may be of interest to the coal industry. Six fine particle classification OEM’s were surveyed to gather information regarding best practice, common problems or challenges and the direction of the OEM’s research and development in these areas. This information has been collated and is being used as the basis of a survey for plant operators.
The objective of this project 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 maximizing 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 bench mark. Then continuous steady state runs were undertaken, with increasing levels of wash water, creating a strong bias flux. The level of cleaning correlates with the bias flux and washing ratio.

More recently, a new series of experiments was conducted using a higher feed flux. This work suggests that a wash water flux of about 0.9 cm/s will be sufficient for a feed flux of 3 cm/s and also 5 cm/s. Very strong cleaning was observed as a function of the wash water flux taking the separations to well-left of the tree curve. These results show that the rougher-cleaning can be achieved within the one system at very high throughput. We are further examining the issue of recovery and its dependence on the water content reporting with the gas flux to product. There appear to be significant benefits in minimizing the gas flux, provided the flux is sufficient to achieve full recovery. New feed samples are revealing important differences in how best to operate. In a tailings sample, for example, it appears that stronger throughput and washing will be possible because of the opportunity to lower the gas flux.

C27026
Ultralow Ash Coal by 3D Binder Flotation

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. Thus, 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 maximize 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. This new milling arrangement has been successful. However, a number of issues concerning the experimental protocol developed over the past quarter concerning the presence of the salt in the binder, and the methods used to release the salt. In the end a series of experiments at different salt concentrations was conducted. The work involving no salt addition provided an immediate way forward, showing again that this feed does not liberate. We are now starting to receive new coals which should lead to strong prospects for liberation.

**C27033**
**Comprehensive Flotation Model using CGA Particle Surface Composition**

Basacon Services  
Bruce Atkinson  

**Value:** $74,527  
**Report Expected:** May 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 JK modelling method uses the concentrate and tail CGA data to calculate flotation rate constants for each of the ‘pure’ maceral particles: vitrite, inertite etc. Overall recovery (yield) and grade (quality) are then predicted based on the surface coverage of each particle (in flotation feed) by each pure maceral or mineral, and the flotation rate constant for each.

The approach has been found to work well for two coal types, but the project has identified that further development work is required for the perimeter identification aspect of CGA, in order to overcome polished surface topography (relief and subsequent shadowing) in the resulting images. This only affects the particle perimeter pixels, and not the routine volumetric CGA composition data.

A final draft report is scheduled to be submitted in May.

**C28060**
**Measuring and correlating CGA data at particle topsize**

Basacon Services  
Bruce Atkinson  

**Value:** $55,444  
**Report Expected:** November 2019  
**Industry Monitor/s:** Chris Urzaa, Tim Manton  
**ACARP Contact:** Nerrida Scott

This project involves sizing a coal sample into separate size fractions (-31.5 +16, -16 +8, -8 +4, -4 +2, -2 +1 and -1 mm) to allow CGA to be determined on each size fraction individually, in the as-received sample state. In addition, a composite sample will be carefully prepared from the individual size fractions, and the composite will be crushed, subdivided and ground to –1 mm for a routine raw sample CGA.

The specific objective is to determine whether the CGA data mathematically recombined from analysis of the individual size fractions ‘at top-size’ retains the same correlation to a ground raw sample CGA as if the raw sample had first been crushed, subdivided and ground to –1 mm.

In addition, a single lump of coal will be analysed by CGA as progressive slices, and compared to its bulk composition after grinding to minus 1 mm.

The coal sample has been received, sized and subdivided ready for preparation of all of the CGA specimen blocks.
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: May 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: August 2019
Industry Monitor/s: Clinton Vanderkruk
Rod Fox
ACARP Contact: Nerrida Scott

No report received.

C26011
CSIRO Instruments at Multiple Plants

CSIRO
Mike O’Brien

Value: $427,798
Report Expected: February 2020
Industry Monitor/s: Naomi Pritchard
Rebecca Fleming
ACARP Contact: Nerrida Scott

No report received.

C26012
Improved Flotation Recovery Via Controlling Froth Behaviour - Stage 2

University of Queensland
Liguang Wang

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

The objectives of this project are:
- 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 trials for the froth monitoring systems was carried out for two weeks in early April. Compared with the previous round of the plant trial, more data were collected at various operational conditions, facilitated by adjusting frother dosage, aeration, and froth depth. Analysis of the collected samples and data (i.e., the outputs of the froth monitoring systems) are underway.

Coal slurry and process water samples were collected across the participating CHPP. The frother concentrations of the collected samples will be obtained using the newly built prototype of the frother concentration measurement system.

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

University of Newcastle
Peter Stepień
Rohan Stanger

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

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

C26016
Benefits of Online Thickener Underflow Rheology Measurements

Clean Process Technologies
Noel Lambert

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

This project will 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; and
- Provide a means for maintaining more consistent operation of all the above systems.

The Thickener Underflow Monitor and Power Supplies have undergone some rewiring and identification of wiring to conform with site standards.

**C27004**

**Improving Coal Flotation with Oscillatory Air Supply**

University of Queensland  
Liguang Wang

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The objectives of this project are to:

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

Sample preparation for pilot scale flotation test has been done and the pilot scale flotation tests have been commenced. Preliminary results showed that higher combustible recovery was achieved with oscillatory air supply compared with steady air supply. In the following quarter, more pilot scale flotation experiments will be carried out at various experimental conditions.

Additional work has been carried out to test a new concept of using oscillatory air supply to improve the flotation recovery. Five different aeration systems (i.e., diffuser and oscillatory air supply) were built and evaluated at the laboratory to find the most appropriate aeration system for the pilot scale and industrial scale system. In the following quarter, the new concept will be tested using the pilot scale flotation column prior to the on-site evaluation.

**C27028**

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

McMahon Coal Quality Resources  
Chris McMahon

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The 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. Presentation to industry monitors of trends to date has been performed and formal reporting of outcomes is due for commencement.

**C27032**

**Methodologies for Applications of CGA: Handbook**

Basacon Services  
Bruce Atkinson, Graham O'Brien

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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 outcome will be a Handbook of applications.

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 on schedule. A full Handbook Draft has been prepared and is now under editing. Completion of a full complete draft ready for submission is scheduled for May.

C27050
Detection of Non-Ferrous Broken Pick Tips and Clay Balls in the DMC

CSIRO
Mike O'Brien

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

No report received.

C28061
Quantitative Based Structural Integrity Evaluations Using Modal Parameters Estimation

Mincka Engineering
Fidel Gonzalez

Value: $363,651
Report Expected: April 2020
Industry Monitor/s: Kevin Rowe, Peter Shumack, Phillip Enderby
ACARP Contact: Nerrida Scott

Project work will commence in the next quarter.

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: June 2019
Industry Monitor/s: Clinton Vanderkruk, Rahul Patel
ACARP Contact: Nerrida Scott

No report received.

C24051
Effect of Particle Crowding at the Vortex Finder and Spigot on Cyclone Operation

CSIRO
Mike O'Brien

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

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

C25015
Pilot Plant Scale Testing of Modified Downcomer in Jameson Cell

CSIRO
Shenggen Hu

Value: $184,149
Report Expected: June 2019
Industry Monitor/s: Clinton Vanderkruk, Rahul Patel
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 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 2018. 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: June 2019
Industry Monitor/s: Clinton Vanderkruk
ACARP Contact: Nerrida Scott

No report received.

Major Projects

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: May 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 organisations 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.

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 ACARP committee has accepted the interim summary. The removal of the facility from the site is now underway.

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: June 2019
Industry Monitor/s: Clinton Vanderkruk, Rebecca Fleming
ACARP Contact: Nerrida Scott

The aim of this project is to expand on previous project C25011. 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. Previous flotation experiments using an artificial salt water showed that the water recovery increases with water salinity as well as frother dosage. The subsequent Gieseler plastometer test
results suggested that MIBC might improve the maximum fluidity of the coal, however, this improvement can be offset by increasing dodecane dosage. The thermoplastic behaviour of coal was found to be related to the presence of salt. Coal recovered by flotation using water with higher salt concentration resulted in shortened plastic range and reduced maximum fluidity of the coal product. Surface analysis by using scanning electron microscope was conducted to examine the change in coal surface after flotation using salt water. Elemental analysis confirmed the precipitation of NaCl on the surface of coal product. Furthermore, coal recovered from salt water flotation seemed to cause more clay particles on the coal surface, which might be attributed by the increased froth stability in salt water.

Upcoming investigations will be focusing on the effect of flotation using salt water on clay entrainment and the subsequent effect on coal thermoplastic properties. In addition, the surface of the semi-coke retrieved from Gieseler plastometer tests will be analysed in order to provide insights on the changes in coal chemistry when salt and clay are present during the coking process.
**TECHNICAL MARKET SUPPORT**

**Future Technologies**

**C28068**
Utilisation of CHPP Waste in Value-Added Products

CSIRO
Philip Ofori

Value: $250,000
Report Expected: July 2020
Industry Monitor/s: Morgan Blake
Tim Manton

ACARP Contact: Ashley Conroy

Nothing to report this quarter as this project has very recently commenced.

**General**

**C25053**
Coal Sample Bank

CSIRO
Keith Vining
Lauren Williamson

Value: $282,011
Report Expected: October 2021
Industry Monitor/s: Graeme Harris
Kim Hockings
Technical Market Support Committee

ACARP Contact: Ashley Conroy

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.

To date, 36 coal samples have been delivered, stored at -18°C and their details recorded in a database. Of the 36 samples stored coal quality data has been provided by coal producers for 30 of the samples. The following coal samples are missing their analysis.

<table>
<thead>
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A new project leader (Lauren Williamson) was on boarded by CSIRO in February. A small number of new samples have been added to the sample bank (as detailed below) to replace depleted samples or to meet the needs of research projects that have commenced in the first quarter of the 2019 calendar year.

Samples banked since January 2019

- C03-C-001
- C04-C-002
- C03-C-003

*Samples have been requested and are in transit to QCAT

Coal and/or coke samples have been requested for the following ACARP projects in 2019:
- C20866 and C28069.

**C26003**
Management of SA and ISO Coal Technical Committees Work Programs

Carbon Connections
Barry Isherwood

Value: $185,550
Report Expected: June 2020
Industry Monitor/s: Graeme Harris
Kevin Rowe
Kim Hockings

ACARP Contact: Anne Mabardi

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.

SA Committee MN/1/1, Coal Analysis held a meeting in March and discussed the latest round of systematic reviews for specific ISO Standards, which will be the basis for further discussions at the October ISO meeting in Tokyo, Japan, during the period of October 6 to 11. The Conveners’ Manual prepared by the ISO SC5 mirror committee is now sufficiently matured to allow its rollout to other committees under TC27.

The Australian Standard on Density Tracers, a world’s first in assessing the efficiency of coal preparation plants has now been published and will be presented at the forthcoming ISO meeting, for consideration and adoption as an ISO Standard. This two-step process follows a proven process for innovative new procedures developed within Australia.

Similarly, a SA Handbook on Sampling in Coal Preparation Plants has recently been published and will also be presented for consideration for adoption at the ISO meeting.

The preparations for the ISO meetings are progressing well, with the dates and venue finalised, and formal invitations issued to all countries. Continuing dialogue is underway with a number of countries, who either have not attended in the past, or only on an occasional basis and these include Indonesia, Egypt, India and Tanzania.

The schedule for the week of meetings has been agreed, along with the agenda for each of the Subcommittee and Working Group meetings.
Discussions are also underway with the ISO Central Secretariat for a Technical Program Manager to attend the meeting, to bring us up to date on the latest ISO editing rules as well as to provide background on the ASTM/ISO partnership models used by other committees such as in the Manufacturing and Nuclear sectors, to allow better and increased collaboration with ASTM for development of some necessary joint Standards, where either party does not have the expertise or interest to develop individual Standards.

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

Standards Australia  
Simona Tomevska  

- **Value:** $191,493  
- **Report Expected:** February 2020  
- **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: Mr Barry Isherwood  
Next meeting: 11th July 2019, Brisbane (BHP Office)

MN-001-01 (Coal analysis) —Mirror Committee for ISO/TC27/SC3 and SC5  
Chairman: Mr Barry Isherwood  
Last meeting: 14th March 2019, SA Office, Sydney  
Next meeting: 11th July 2019, Brisbane (BHP Office)  
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: Dr Dave Osborne  
Last meeting: 12th March 2019, CSIRO, Pullenvale  
Next meeting: Newcastle. 22nd November 2018, NIER, Newcastle.  

MN-001-02 Subcommittee has three active projects to develop Australian Standards:  
AS 4156.1.1 Coal preparation, Part 1.1: Higher rank coal-Float and sink testing, Drafting Leader: Michael Campbell—Published Dec 2018.

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—Published, March 2019.

MN-001-05 (Coal Mining and Geology)  
Chairman: Dr 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.

C28069  
How inertinite concentrates in blends affect coke strength

University of Newcastle  
Wei Xie  

- **Value:** $99,500  
- **Report Expected:** April 2020  
- **Industry Monitor/s:** Jay Zheng, Sean Flanagan  
- **ACARP Contact:** Ashley Conroy

This project will:  
- Evaluate the fusibility of inertinite/semi-inertinites in different proportional blends with other coking coals and investigate their impact on metaplast phase formation (swelling, permeability and fluidity) and volatile release;  
- Characterise coke strength of the blends, and identify the impact of inertinite/semi-inertinite on coke structure development relating to coke strength;  
- Use the knowledge gained to provide suggestions on how to optimise the utilisation of inertinite rich coking coals in blends for improving coke strength.

To achieve these goals, this project uses reflux classifier to concentrate inertinite particles, CATA for swelling and permeability, DETA for volatiles evolution, Pearson Coal Petrography for coke fusibility analysis, Sole Heated Oven for preparing coke samples and Drop Shatter for coke strength analysis.

Work on this project recently started in April. We have contacted coal sample suppliers and the ACARP Coal Bank for coal samples. To date, we have received one sample from an industry monitor, we are expecting to receive other coal samples within this quarter and start the experimental tests.
**Major Projects**

**C27001**  
Maritime Regulation Project: Self Heating and Corrosivity Test Evaluation

Goodwin Port Solutions  
Ash Goodwin

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<td>Maritime Regulation Task Group</td>
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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 2019.

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

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| 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 draft final report is being internally reviewed by the project team. It has been agreed that the draft final report will be submitted to industry monitors by the 15th of May.

**C25045**  
In Situ High Temperature Strength of Low CSR Cokes

University of New South Wales  
Pramod Koshy

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| Industry Monitor/s: | Kim Hockings  
Nick Andriopoulos |
| ACARP Contact: | Ashley Conroy |

This project is a joint collaboration between UNSW, ANSTO, and UoN. From Stages I and II, the strength at high temperatures was seen to not have a clear correlation with the CSR values. The high-temperature strengths were generally higher for the low CSR cokes. Moreover, the strengths increased generally with increase in temperature and showed high 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 high-CSR and low-CSR coke were supplied by the industry monitors. 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.

Cylindrical coke samples (~21 mm height, ~19 mm diameter) were cored and then end-polished and subjected to reactivity tests using temperatures and atmosphere profiles simulating a blast furnace. Then the high CSR samples were tested at 1400°C and 1550°C at ANSTO. Fractography analysis showed that the extensive crack propagation had taken place in both samples with increased propagation through the RMDC in both cases compared to the IMDC. Higher numbers of transgranular cracks through the IMDC were seen at the higher temperature. Moreover, the sample tested at 1550°C was more brittle owing possibly to higher concentrations of voids and porosity (from ash-carbon reactions) compared to the sample tested at 1400°C.
C25049
Fusibility of Coal Blends and Behaviours of Minerals in Coking
CSIRO
Merrick Mahoney
Priyanthi Hapugoda

Value: $193,020
Report Expected: May 2019
Industry Monitor/s: Kim Hockings
Stephen Brant
ACARP Contact: Anne Mabardi

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

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: July 2019
Industry Monitor/s: Nick Andriopoulos
Oliver Scholes
ACARP Contact: Anne Mabardi

The project is an extends on previous 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 project. This project 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.

C26039
Nanoporosity in Cokes: Their Origin and Influence on CO2 Reactivity
CSIRO
Mihaela Grigore

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

A recent ACARP 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 draft final report will be submitted soon.

C26040
Fusible Content of Individual Coal Grains and its Application in Cokemaking
CSIRO
Karryn Warren
Merrick Mahoney

Value: $161,640
Report Expected: August 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;
- Help to confirm new insights obtained from C24057 into the links between the size distribution of fusible and infusible macerals and minerals, associations of macerals 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.

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

A delay occurred in the 3D image analysis of the microstructure of the cokes using reconstructed CT images of coke lumps. Further assistance has been sought and secured within CSIRO to use Geodict to determine 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.

Fractographic analysis of cokes from the remaining two iRF grinds for both coals D and E has now been completed, with the results for all ten cokes collated and compared with the results for cokes A, B and C. Interpretation of these results, and further analysis of the rotational tribology and scratch test data will be completed in the next quarter.

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: June 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 (C26041), the single Australian PCI coals were evaluated using a 3D PCI model. In the stage 2 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.

Model improvement and test. Significant effort has been made to further develop the PCI model of coal blend injection under industry-scale conditions at Bluescope. NB: 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 the interactions between the component coals in the blends are considered explicitly. In this industry scale PCI model, the computational domain includes coal lance, blowpipe, tuyere, raceway and surrounding coke bed.

Parametric study of industry-scale PCI model of coal blends has been conducted in aspects of some key PCI operational variables under industry-scale test rig conditions. Some blending fractions have been studied for the three blends. In addition, some other key PCI operational variables have also been studied, including blast temperature, oxygen enrichment, particle size and PCI rate for the three blends. Over 100 simulations have been conducted. Significant computational effort has been requested in this stage. The simulation results have been analysed in terms of flow pattern, temperature field, concentration of gas and solid species and coal combustion. NB. The overall performance and individual behaviour of each component coals are both studied.

Research team. Shen and his two associates visited ACARP office and gave a presentation of progress of this project and also introduced potential future projects. Shen visited Baosteel of China in March and confirmed the use of Baosteel BF data in developing a Baosteel-version Australian PCI coal simulator. This may be studied in Stage 3 of this project. The team also contacted Tata steel for developing an India-BF PCI simulator in the future.

C26042
Coal Swelling in PCI Lance Conditions

University of Newcastle
Liza Elliot

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

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

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 to develop a more comprehensive understanding of the degradation of cokes from coal blends under the blast furnace (BF) conditions, and the methodologies for characterisation of cokes under the simulated BF conditions. Specific objectives of this project include:

- Understanding effect of high/low rank coking coal addition on coke performance under BF conditions;
- Further development of investigative methods to simulate more realistic BF operating conditions; and
Further elucidation of the 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;
- Gasification and annealing of all the cokes and cokes made from single coal constituents were completed;
- Comparison of BF performance of cokes produced in the pilot oven and the commercial coke battery was completed; and
- Characterisation of four-compartment charge cokes under the simulated BF conditions was completed.

The inclusion of H2O in the gasification atmosphere significantly increased the coke reactivity and caused more severe degradation on the coke lump surface. However, such degradation did not penetrate to the core of the coke lump. The addition of H2O promoted the ordering of cokes carbon during gasification due to the more effective consumption of the amorphous carbon, which had higher reactivity than the ordered carbon.

The comparison of weight averaged values of single coal cokes and the measured values of cokes from blends provided the opportunity to understand the potential interactions between coal constituents in the blends and their effects on the coke properties upon simulated BF conditions. The measured micro- and macro-strengths of cokes was equalled to the calculated values from cokes made of single coals. However, the interactions between coal constituents in the blends promoted the development of graphitisation of the cokes and resulted in higher measured values than the calculated values.

Next quarter work:
- Inspection of degradation on the different coke microtextures; and
- Preparation of the final report and publications.

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: May 2019
Industry Monitor/s: Ashley Conroy
Nick Andriopoulos
Oliver Scholes
ACARP Contact: Anne Mabardi

This project follows 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 most of the analysis/interpretation is complete. We are now writing the final report.

C26045
Mineralogy Effects on the 3D Porosity of Coke

University of Wollongong
Brian Monaghan
Richard Sakurovs

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

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

C26046
Relevance of Maceral Concentrates to Whole Coal Coking Predictions

University of Newcastle
Wei Xie

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

The aim of project is to:
- Clarify how to concentrate maceral components from coke oven feed particles combining the reflux classifier and Coal Grain Analysis (CGA);
- Examine what maceral concentrates represent in whole coal and the extent of the concentrates and the blends modify industrial fluidity of whole coal; and
- Establish the relevance of coal maceral concentrates on whole coal coking prediction.

To achieve these goals, this project uses CGA for analysing coal maceral populations and compositions of whole coal, Reflux Classifier (RC) feed and products; RC for concentrating coal maceral; and Gieseler plastometer for evaluating the fluidity of the concentrated maceral particles and the blends.

This project has been delayed, the two main reasons for this are:
- We did not receive our coal samples until the end of 2017; and
- The external tests for coal macerals were delayed.
We have communicated the above to the industry monitors. To date, we have completed all maceral separation based on the CGA results of the raw coals, received the results for three quarters of the CGA and fluidity tests for coals macerals and the blends. We are expecting to receive all results for external tests by the end of May. Therefore, we are expecting to submit a draft report by the end of June.

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 cokemaking 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 has used new coal samples and coals left over from previous project to carry out some preliminary experiments. 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 FTIR and the C13 NMR data have shown that the blending may have significant influence on the plastic layer chemistry. The research team has also been working on 3D image analysis on the micro-CT images using trial license of the software GeoDict.

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
ACARP Contact: 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.

Last year, we conducted trial tribological tests at temperatures of up to 400°C, which demonstrated our successful development of a suitable, novel sample preparation method to allow tribological testing of coke samples at elevated temperatures in the absence of a mounting medium. The absence of a mounting medium allows the results of the tribological tests to be related exclusively to the properties of the coke, and thus the properties of the parent coal(s).

The design of the tribometer upgrade to allow tribological testing at temperatures of up to 950°C and in gas-controlled atmospheres has now been finalised, and will meet the requirements for this project. The upgrade will take place in the next quarter, with trial tribological tests using the new system expected to take place at the end of July, and the bulk of the tests the following month. The sample dimensions for the upgraded design have also been finalised and we have started the sample preparation for both the pilot oven coke lumps and the matched blast furnace feed and bosh coke lumps, which were retrieved from a Port Kembla blast furnace. Further progress on this project has been delayed due to CI Lomas taking six months’ maternity leave in the second half of 2018. We now expect to submit the draft final report for this project in early 2020.
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: July 2019
Industry Monitor/s: Kim Hockings
Sean Flanagan
ACARP Contact: Ashley Conroy

This project follows projects 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 prepared three coke cubes that are 1.5 x 1.5 x 1.5 cm³ and fissure-free. These samples have been taken from a coke sample that was adjacent to the wall and the cubes are at various points in a line that extends from the wall. We have carried out CT Scanning and are currently using GeoDict to examine the pore properties and see if the permeability is different in the direction towards the wall compared to the up and sideways directions. We have also prepared coke samples in the rheometer under various loads to examine pore distortion and the influence of force on pore properties. These samples are awaiting CT and GeoDict analysis.

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
ACARP Contact: Ashley Conroy

The project addresses:
• Fundamental and applied understanding to relate properties of cokes to those of the coals from which they are made; and
• 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;

The project is nearing completion.

Deep Learning - The supervised deep learning work has been completed for one of the cokes being examined (AC204). The approach has been able to generate an approximation of the cracked region and produce heatmaps that highlight the areas in the coke used by the algorithm to learn where the crack occurs. This approach is now being repeated on two further cokes (AC204, AC155) to generate further heatmaps. 3D interactive visualisations have been created and are ready for further examination with experts (due in early May).

Isomapping - An additional approach to cluster different types of structure in the three cokes has also been implemented on AC210. This approach clusters similar structural regions (50x50x50 blocks) in the coke. (For example, areas with large number of pores). Once complete the process will be repeated on AC204 and AC155. Visualisations have been created and are ready for further examination with experts (due in early May).

Stress modelling - Further 3D visualisations have been generated for the AC155 coke. These visualisations incorporate stress modelling of this coke. These models highlight areas of stress (and potential breakage) in this coke.

Statistical Characterisation - The final element of the project is to use structural points of interest identified (with the help of experts) and the three approaches (deep learning, isomapping, stress modelling) into the statistical characterisation. It has been decided to use Ripley’s K calculations which will generate 3D distribution relationships for the different types of identified points. These will be compared against traditional attributes of the coke (CSR, CRI) to identify any correlations.

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 Urzua
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?

The Fourier Transformed Infra-Red (FTIR) data is currently being processed, but there have been slight delays due to the presence of an unavoidable variable interference (sinusoidal wave) as a result of the nature of the sample (Figure 1). The team from CSIRO is currently developing a method to process the large amount of IR data collected at the synchrotron without losing the subtle variations expected along the maceral gradient (as seen in Figure 2) that will be used to determine the aliphatic/aromatic ratios.

Figure 1. FTIR spectra collected for a region of vitrinite in Coal J. The pink line is the raw spectra, the blue line is the spectra after preliminary processing.

Figure 2. Area of coal analysed showing vitrinite collection site (optical image left, characterised image right (vitrinite green, fusible inertinite yellow, infusible inertinite pink, mineral red).
C28064
Carbon Structure Transformation in the Plastic Layer and Coke of Australian Coking Coals: Better Understanding of Coke Strength and Reactivity

University of Newcastle
Jianglong Yu

Value: $144,900
Report Expected: April 2020
Industry Monitor/s: Kim Hockings, Morgan Blake, Nick Andriopoulos
ACARP Contact: Ashley Conroy

The main objectives of the project are to systematically investigate the carbon structure formation and transformation in the plastic layer during coking using a suite of Australian coking coals from the ACARP coal bank and to achieve a better understanding of the impacts of carbon structure of coke on coke quality. The project is focused on the characterisation of the chemical structure transition of the plastic layers formed during coking and the evolution and transformation of carbon structure during the coking process, establishing a methodology of quantitatively linking the characteristics of carbon structures of coke and semi-coke to the strength and reactivity of coke, and understanding the influence of coal rank, maceral composition, and heating conditions during coking on the order and structure of carbon and subsequently on the quality of coke.

Single and blends of ACARP coking coals have been used on coking tests on the 4kg lab-scale coke oven at the NIER site of the University of Newcastle. A number of plastic layer samples have been produced with different ranks and vitrinite contents. The plastic layer samples have been analysed using the Synchrotron Micro-CT, ATR-FTIR and C13NMR. Particular attentions have been paid to the sample sectioned from the resolidified portion of the plastic layer samples. The focus of the analysis is to investigate the roles of aliphatic structure elimination during the formation of carbon-carbon bond formation during the thermoplastic stage and the roles of the elimination of C-H bonds during the later stage of the plastic layers on the carbon-carbon bond formation. Synchrotron FT-IR will be used in the next stage to investigate the chemical structure transition inside the plastic layer samples from different coals.

C28065
Effect of Blend Characteristics on the High-Temperature Strength Evolution and Relevant Mechanisms in Cokes

University of New South Wales
Pramod Koshy, Xing Xing

Value: $309,800
Report Expected: September 2020
Industry Monitor/s: Jay Zheng, Nick Andriopoulos, Stephen Brant
ACARP Contact: Ashley Conroy

This project has very recently commenced.

C28071
Improving Understandings of IMDC–RMDC Interfaces

University of Newcastle
Hannah Lomas

Value: $161,076
Report Expected: July 2020
Industry Monitor/s: Kim Hockings, Morgan Blake, Stephen Brant
ACARP Contact: Ashley Conroy

This project will investigate the principal mechanisms involved in determining the microtextural interface properties of metallurgical cokes, using an inertinite analogue to elucidate the influence of particular inertinite attributes. Specifically, this project aims to:

- Develop an inertinite analogue, capable of controlled oxidation and tunable size and shape, to investigate the link between inertinite properties and the properties of the IMDC–RMDC interface and other coke microstructural features using fractographic analysis techniques;
- Establish the link between coal properties and coke IMDC–RMDC interface properties using different metallurgical coals and blends to produce different types of interfaces;
- Establish the link between coal properties and coke IMDC–RMDC interface properties using blends of vitrinite-rich coal and analogue inertinites with controlled attributes to produce different types of interfaces; and
- Examine the impact of maceral associations on laboratory carbonising tests as part of improving predictions of coking performance from these tests.

Two coals have been selected by the team for this project, with the third coal to be confirmed pending its availability. Following approval of the selection by industry monitors, we intend to prepare coal maceral concentrates using a bench-scale washery at UoN in next quarter.
A literature review into suitable materials and methods for preparing the inertinite analogue has commenced, with the results to be discussed with the monitors before finalising the selection within the next month.

### Thermal Coal

#### C27022
**Slagging and Fouling During Co-Combustion in HELE Boilers**

**University of Newcastle**
Liza Elliot

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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. One set of deposits were extremely hard. 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. Effort to transport the samples to Australia is ongoing.

Significant electrical issues with the TMA have been overcome and it is now operational. Burnout achievable in The University of Newcastle’s small drop tube furnace with the samples was poor and the residence time could not be extended further in this furnace to overcome this issue. The larger drop tube furnace is now being trialled. Blowback experienced with the vibrating tray feeder has meant that an alternate feeder will need to be used. A syringe feeder is currently being trialled.

#### C27029
**High Tech Testing Facility for Evaluating Combustion Performance of Thermal Coals and Establishment of Testing Methodology**

**University of Newcastle**
Jianglong Yu

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The project objective is to develop a high-tech combustion testing facility at UoN 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 design of the combustion rig and the manufacturer has completed the engineering designs. 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 to. 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 industry monitors and manufactures during the course of the project. NIER has assigned a new lab area of 110m² to allow sufficient space for the combustion rig operation.
C27047
Combustion Characteristics of Australian Export Thermal Coals using Advanced Imaging Techniques

CSIRO
Chad Hargrave
Ed Lester
Silvie Koval

Value: $60,644
Report Expected: July 2019
Industry Monitor/s: Graeme Harris
Greg Wickman
ACARP Contact: Ashley Conroy

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 (i.e. pure components and composite particles) to specific char types to gain a better understanding of combustion performance. For selected samples these 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 residence 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 2018, 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 has arranged for Silvie to be granted a CGA license so that she can complete her technical tasks and work with the University of Nottingham and CSIRO researchers to prepare the final report.

Silvie was provided with the CGA software licence in March, and she is currently finalising the analysis stage of the project:

- All coal samples have been analysed using CGA;
- Australian char sample CGA completed mid-April;
- International char sample CGA completed end of April;
- SEM MLA analysis of coal and char from sample 052-T-001 completed end of April.

Next quarter:
- Completion of the analysis as noted above, followed by evaluation of results and preparation of the draft final report;
- It is anticipated that the draft final report will be submitted in June.

C28067
Characterisation of Complex Coal Blends, and Methodology to Investigate Thermal Coals Based on Compositional Analysis

CSIRO
Priyanthi Hapugoda

Value: $104,008
Report Expected: October 2020
Industry Monitor/s: Graeme Harris
Greg Wickman
Stephen Brant
ACARP Contact: Ashley Conroy

The main objectives of this project are to:

- Validate enhancements to the capability of CSIRO’s Coal Grain Analysis system (CGA) that enable the characterisation of complex coking and thermal coal blends; and to
- Test a methodology to characterise thermal coals and blends using complementary CGA and SEM analyses to obtain maceral and mineral information in order to improve the understanding of coal used in the combustion process.

To date the sample selection strategies were discussed in the start up meeting with industry monitors. In parallel CGA software strategies were discussed with CSIRO software engineers to enhance the CGA system to characterise complex coal blends.

In the next quarter the sample selection of coals will be completed. In parallel CGA software strategies will be improved using standard samples with known reflectance values to test the system capability.

C28072
Mineral Redistribution from PF Coal to Ash in Commercial Power Stations

University of Newcastle
Rohan Stanger

Value: $153,270
Report Expected: April 2020
Industry Monitor/s: Chris Spero
Kay Palmer
ACARP Contact: Ashley Conroy

Work on this project has not yet started.
Fabrication of the skid-mounted pilot-plant has been completed and delivered to The University of Newcastle. Cold commissioning has been completed. Hot commissioning is expected to be completed in May and field trials are expected to be completed by end of June.

C26004  
**CFD Modelling of Reverse Thermal Oxidisers for VAM Abatement**

University of Newcastle  
Victoria University  
Behdad Moghtaderi  
Vasily Novozhilov

Value: $381,520  
Report Expected: August 2019  
Industry Monitor/s: Donna Dryden  
Jim Sandford

ACARP Contact: Patrick Tyrrell

The project outlined in this submission 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 project was completed in early 2018 and a final report was sent to ACARP on 17 April 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 Q1 2019 of Phase-II project are:

- Milestone Task V – Perform simulations using the same fuel load as in milestone task IV which was completed in Q1 (100% Completed).
The focus of research activities until 30 June 2019 is on completion of milestone task VI as well as milestone task VII (please refer to the long version of the project proposal for details):

- Milestone Task VI – Provide a write-up of these cases for peer review and independent assessment (80% Completed).
- Milestone Task VII – Complete additional simulations that are specified as a result of item (vi) (60% Completed).

Despite the efforts we made towards the on-time completion of the milestone tasks, the CFD modelling scheduled in milestone task VII is computationally demanding and time consuming. This, in turn, holds off the analysis of the modelling results. However, we are aiming to submit the final report covering the entire project by the end of June.

C27054
Optimisation of a Thermal Flow Reversal Reactor for VAM Mitigation

CSIRO
Jon Yin

Value: $190,173
Report Expected: January 2020
Industry Monitor/s: Ben Klaassen, Trevor Stay
ACARP Contact: Patrick Tyrrell

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 (ie 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 (20.2%). 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;
- Investigation of safety management associated with VAMMIT.

A 3D and transient Fluent model were established and validated against experimental results. Then the model was operated under various conditions to optimise the honeycomb bed structure and operating parameters. The first two milestones have been successfully completed. The project had an issue before with the long computing time as a result of large mesh numbers. The project team managed to solve this issue by modifying the model being able to change the flow direction automatically, running the model with high performance computers, etc. As a consequence, the project is progressing on time and schedule. The project team will start working on the third milestone shortly.

C27058
Technological Assessment of a Recycle Reactor for VAM Abatement

University of Newcastle
Michael Stockenhuber

Value: $264,672
Report Expected: May 2019
Industry Monitor/s: Jim Sandford, Trevor Stay
ACARP Contact: Patrick Tyrrell

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