FEBRUARY 2024

CURRENT PROJECTS

This report is a summary of current projects for the months November, December 2023 and January 2024

ACARP

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UNDERGROUND

Coal Burst

C27020
Management of Coal Bursts and Pillar Burst in Deep Mines

University of Adelaide
Giang Nguyen
Murat Karakus

Value:	$380,240
Report Expected:	February 2024
Industry Monitor/s:	Coal Burst Task Group
ACARP Contact:	Peter Bergin

The draft final report has been submitted to the Industry Monitors for review.

C28012
Microfracture Analysis as a Trigger for Coal Bursts

SCT Operations
Winton Gale
Yvette Heritage

Value:	$498,000
Report Expected:	August 2024
Industry Monitor/s:	Coal Burst Task Group
ACARP Contact:	Peter Bergin

The project aims to identify the nature of micro fabric in coal around structures such as dykes and faults relative to "normal" unstructured coal and the role of 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.

The overall objective of extension work is to define the zones around dykes and faults in which the coal is structurally modified and capable of generating sufficient gas related energy to initiate a coal burst, achieved by:
- Digital CT scanning of coal block samples which have been selected at various distances from dykes and faults mapped in coal mines;
- Collation of results from project C28012 (characterising the volumetric porosity) with those from this micro fracture geometry study;
- Assessment of the burst potential for the various geometries noted close and distant to dyke and fault structures.

The majority of the bulk scanning has been conducted. A fracture distribution analysis technique has been finalised and is being applied to the CT scanned samples. The deliverables of this technique include measuring fracture surface area, fracture volume and fracture spacing for three fracture sets. This data is provided as both individual fractures and presented as a statistical distribution to allow for both statistical and oriented assessment of fracture networks.

C29010
In-situ Stress Measurements using Cored Coal/Rocks for Coal Burst Management

University of Adelaide
Giang Nguyen
Murat Karakus

Value:	$228,600
Report Expected:	February 2024
Industry Monitor/s:	Coal Burst Task Group
ACARP Contact:	Peter Bergin

The draft final report has been submitted to the Industry Monitors for review.

C33014
Coal Burst Research Findings

SCT Operations
Winton Gale
Yvette Heritage

Value:	$388,000
Report Expected:	March 2024
Industry Monitor/s:	Coal Burst Task Group
ACARP Contact:	Peter Bergin

The aim of this project is to examine and summarise the energy required to cause a coal burst in a range of seams. The energy may be derived from stored strain, seismic transmission and expansion of desorbed gas.

The project objectives are to:
- Examine the threshold energy requirement to cause a coal burst for a number of coal seams cases based on a range of generic mined seams;
- Provide guidance as to the factors to be considered in a risk analysis; and to
- Provide an estimate of the threshold values associated with dynamic bursts for a range of coal.

Modelling of both strain and gas induced bursts within a roadway has been assessed to determine the seismic signature of such an occurrence. The strain tensor of the seismic waveforms and energy of events has been determined. In general strain induced bursts are well reflected in the seismic transmission however gas related bursts are not well reflected.

Modelling and theoretical assessment of strain bursts has been undertaken. One of the key findings has been that the upper bound velocity of a strain burst associated with shear slip and overstressing can be defined. This allows burst severity and risk levels to be determined on the basis of stress conditions about the excavation.

Simulations of bursts in a range of seam thickness and banding has been undertaken. The main control is the rib resistance to a burst event. This is being assessed and known to be related to seam height, clay bands, structure and degree of rib fracture during development. This has been completed and indicates that rib strength is reduced by:

- An increase in rib height from 3m to 5m reduced rib strength;
- The occurrence of weak clay rich bands reduced the strength ,
- The occurrence of two clay rich bands did not change the results markedly from that of only one band. However, it did significantly increase the velocity of ejection.

One of the key outcomes is that most instances of seismic event recordings record a combination of modes of failure. This is due to the fact that one form of failure (say shear slip on bedding) allows additional failure in the surrounding area due to reduced confinement. In that way the overall strain tensor is one which reflects both events and associated displacement.

A definition of the change in strength of the ribside caused by claystone bands and rib height has been determined. The effect of gas pressure, gas volume and gas desorption rate has been assessed for a range of extraction heights and claystone bands.

It has been found that the use of energy as a criteria for understanding of bursts allows a simple assessment of the risks of bursts irrespective of the cause. The energy required is constant although the generation of the energy is different albeit gas ,strain or seismic.

A review of the strength of the coal ribside has been undertaken to define energy levels required to move the coal under the confining conditions which occur.

This approach provides a clear view of the likelihood and risk of various types of bursts on the basis of the energy available to the system.

The project is in the late stage of reporting and is on schedule.

C35014

Investigation of Pre-Installation of Optic Fibre Cable in Exploration Holes for Longwall Weighting and Coal Burst Monitoring

CSIRO
Baotang Shen
Joey Duan
Matt van de Werken

Value:	$258,473
Report Expected:	June 2025
Industry Monitor/s:	Coal Burst Task Group
ACARP Contact:	Peter Bergin

The project goal is to provide a new and more cost effective approach for assessing the longwall caving progress and coal burst risk. The objectives are to:

- Trial optic fiber cables pre-installed in geo-exploration holes for high accurate and cost efficiency longwall weighting and coal burst monitoring; and
- Conduct a field demonstration using both distributed fiber optic sensors (DFOS) and geophones and investigate the optimal monitoring configuration, data processing and interpretation methods for the DFOS system.

During the quarter, the main activities have been focused on testing of the borehole splicing hardware prototype and numerical modeling of the seismic response registered by the DFOS system. The test of the borehole splicing hardware has been completed in the lab and it demonstrated the borehole splicing hardware can be securely used for the field installation. An invention disclosure on the borehole splicing hardware design and methodology has been submitted for a potential patent application. The numerical modeling of the DFOS response suggests that the DFOS system can achieve better location accuracy for seismic monitoring than conventional geophones. A more comprehensive comparative study will be conducted during the field monitoring.

Mine A has advised that the monitoring is likely to proceed in April or May for a new longwall panel. The final arrangement and actual date of the field monitoring installation at Mine A are yet to be finalised.

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
Alaster Wylie
Clive Hanrahan
Dave McLean

Value:	$392,500
Report Expected:	April 2024
Industry Monitor/s:	David Webb
	Owen Salisbury
	Paul Wild
	Peter Baker
	Sharif Burra
ACARP Contact:	Patrick Tyrrell

The project aims to provide an additional spontaneous combustion control technique for use by industry and to:
- Procure a full system ready for deployment;
- Deploy the system in at least one underground longwall panel(s); and to
- Evaluate the cost and effectiveness of using CAFs to alter goaf 'micro ventilation circuits'.

The system will be retained by NSW Mines Rescue and maintained similarly to the Mine Shield for use by the New South Wales and Queensland industry as a tool to assist manage accelerated oxidation of coal.

A CAF unit was deployed at a New South Wales underground mine in mid-2021 to provide assistance in controlling a spontaneous combustion event in an active longwall panel. Preliminary findings from the initial mine site trial suggested that CAF, when injected into the goaf acted as an effective 'dam', stopping the ingress of oxygen into the goaf and allowing the mines seam gas to fill the void and no air ingress was possible. Since the initial mine site trial, the unit has been deployed to address other spontaneous combustion events at the same mine and one other. On both occasions the injection of foam and Nitrogen into the goaf has reduced oxygen ingress.

During the quarter, there has been no further testing undertaken. The CAF unit is currently located at Hunter Valley Mines Rescue Station.

A draft project report is being prepared in consultation with subject matter experts and the test underground mine. A peer review was completed by the second subject matter expert and received by Mines Rescue in January. It is envisaged that this peer review report will be reviewed and included into the final draft report for ACARP review early in the next quarter.

C29026
Investigation into the Thermal Ignition Caused by IS Power Supplies

Resources Safety & Health Queensland
Andre De Kock
Gareth Kennedy

Value:	$153,700
Report Expected:	May 2024
Industry Monitor/s:	Brad Lucke
ACARP Contact:	Patrick Tyrrell

The objectives of the project are to:
- Determine the fault conditions arising in an intrinsically safe electrical circuit that could ignite combustible material on a mining machine;
- Determine the role and extent that combustible material accumulation can cause or contribute to the risk of equipment fires, when ignited by intrinsically safe power supplies; and to
- Determine the parameters to be considered in installing an intrinsically safe circuit in an area where they could be an accumulation of flammable materials.

The testing requirement and methodology are planned to be finalised in the second quarter of 2024, followed by testing and analysis. The project is expected to be completed in 2024.

Environment - Subsidence and Mine Water

C28004
Monitoring Hydrological Status of Complex Upland Heath Communities Using Canopy Conductance and Thermal Imaging

Queensland University of Technology
Andrew Fletcher

Value:	$230,964
Report Expected:	April 2024
Industry Monitor/s:	Gary Brassington
	Peter Corbett
ACARP Contact:	Patrick Tyrrell

Regulators are concerned about the loss of listed communities in complex shrub swamp systems due to modified hydrology. Existing technology can detect dramatic changes in vegetation health, however new methods are needed to detect subtle, long term spatial and temporal changes to moisture patterns. This project aims to identify remote sensible signals for plant stress in these communities. Researchers will use calibrated thermal imaging on board small unmanned aerial service platforms to assess canopy water use through the day. Foliage is usually cooler than the ambient air temperature when soil water is readily available, so higher temperatures indicate change in moisture patterns.

The field work at the sponsor site was completed in December and imagery processing is proceeding. Patchy cloud cover throughout the field week has introduced errors in thermal imagery and spectral reflectance products that require manual assessment. Classification of vegetation is supported by high resolution imagery visible imagery and Lidar captured during the field trip. Report completion will proceed as soon as thermal products are completed.

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
Nathan Emery

Value:	$444,055
Report Expected:	March 2024
Industry Monitor/s:	David Gregory
	Gary Brassington
	Peter Corbett
ACARP Contact:	Patrick Tyrrell

The overarching objective of the project is to successfully translocate and monitor multiple populations of Persoonia hirsuta and Persoonia hindii in mining offset and rehabilitation areas. Scientific research has been conducted in parallel with the translocation work, with a strong focus on understanding the seed biology and reproductive system of both species.

Data analysis and writing for the final report is expected to be completed by the end of February.

C33021
Pilot Scale Membrane Distillation Crystalliser (MDC) with Renewable Heat Source for Mine Water Brine Management

CSIRO
Ramesh Thiruvenkatachari

Value:	$969,195
Report Expected:	December 2025
Industry Monitor/s:	Michael Holzapfel
	Paul O'Grady
	Tim Kendrick
ACARP Contact:	Patrick Tyrrell

This project aims to undertake a mine site demonstration of the MDC system for treating saline and acid mine drainage mine impacted water under actual mine site conditions. The main objectives are to develop a modular MDC water treatment plant to mine site specifications, install at the mine site by integrating with onsite infrastructure and to demonstrate the mine impacted water treatment performance. Through this study optimum operating process parameters for AMD treatment will be obtained in maximising reusable water recovery with reduced volume of saturated concentrate.

Design of the mine site pilot test unit is being carried out and is expected to be completed in the next quarter. Design of the major components of the membrane units have been completed. Upon completion of the design, procurement and fabrication is expected to commence in the next quarter.

Preparation are being made for onsite infrastructure development for the pilot setup. Mine water intake and storage tanks have been installed. Other infrastructure such as compacting of site location where the test unit is to be installed, pipeworks, power supply etc will further be developed. Suitable data and communication network management system is evaluated.

C33028
Fire Resilience of Temperate Highland Peat Swamps on Sandstone

University of Queensland
Mandana Shaygan

Value:	$279,450
Report Expected:	February 2024
Industry Monitor/s:	Gary Brassington
	Peter Corbett
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C35016
Rehabilitation Options for Ponded Areas Due to Longwall Coal Mining

University of Queensland
Louisa Rochford

Value:	$397,200
Report Expected:	May 2026
Industry Monitor/s:	Jason Fittler
	Ned Stephenson
	Raymond Howard
ACARP Contact:	Patrick Tyrrell

There has been limited research on the most appropriate options for rehabilitating land subsided by longwall mining in Australia. This project is investigating the implications of retaining ponded areas from longwall mining, including their contribution to environmental values. The approach is to select a study site and conduct the research at that location over a three year period, providing a template for the assessments that are required to make decisions on rehabilitation options for ponded areas at other mines.

Following selection of a representative study site, an initial round of fieldwork was completed in November. The fieldwork involved collection of water, sediment and

soil samples for assessment of physical and chemical properties, establishment of plots for ecological monitoring, bird surveys and camera trapping within the plots, bird surveys around the ponds, and installation of staff gauges in two ponds to facilitate manual reading of pond water levels.

Laboratory analysis of water and sediment samples has been completed and data analysis is underway. Laboratory analysis of soil samples is underway and due for completion in March. Bird survey data has been digitised. The images captured by the camera trapping are under review using a machine learning algorithm developed to filter the large number of images collected. Mine site representatives are recording pond water levels following rainfall events and approximately weekly. Work is underway to develop a methodology for a water balance of the ponds using remote sensing, LiDAR, survey, and pond water level data.

The next round of fieldwork scheduled for April will involve collection of water and sediment samples, and assessment of vegetation and fauna (bird surveys and camera trapping) within the plots. Installation of additional staff gauges will be considered. Additional soil sampling may be undertaken depending on the results of the laboratory analysis.

Maintenance and Equipment

C25063
Photocatalytic Destruction of Diesel Particulate Matter

CSIRO
Yonggang Jin

Value:	$527,192
Report Expected:	February 2024
Industry Monitor/s:	Brad Lucke
	Dave Young
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

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

University of New South Wales
Francois Ladouceur
Lucy Chen

Value:	$704,974
Report Expected:	March 2024
Industry Monitor/s:	Ben McCamley
	Dave Young
	Ernest Baafi
ACARP Contact:	Peter Bergin

The current project work is a continuation of an earlier stage of work where the participants have completed the design of an optically powered, intrinsically safe gas monitoring station (CH4, CO, CO2, O2). This certified system has been successfully deployed in situ and reliably collected data over a period of two months. The current project seeks to:
- Fix identified technical issues with the current system and proceed with its testing;
- Develop an improved system design, focussing on design for manufacture; and
- Provide the resources needed for its deployment and testing.

Work undertaken in the quarter includes:
- Improvement has been made on the gas station main PCB and a small battery board is added to further enhance battery safety;
- New components added to RTU PCB for better signal processing and display;
- Updated PCB designs above have passed the final assessment of intrinsic safety;
- Progress made in firmware development for the PCBs; and
- Compose progress has been made on Android APP for Bluetooth communication.

Work planned for the next quarter:
- Android APP development and firmware development;
- Ingress test (part of Intrinsic safety test) on the prototype enclosure;
- Fabrication of the final version of enclosures based on the test result of the prototype;
- System assembly and testing; and
- Final report prepared.

We foresee no important technical holdups but the final stage (fabrication and testing) may take longer than expected and field trial decision needs to be made.

C29009

Control of Touch Potential Transients During Switching

ResTech
Peter Stepien

Value:	$114,000
Report Expected:	March 2024
Industry Monitor/s:	Barrie Alley
ACARP Contact:	Patrick Tyrrell

During a number of investigations into electric shock incidences in the past, machine frames measured touch voltage transients when switchgear closed or opened. There were no faults present in the equipment of the earth fault limited supply, yet touch voltages occurred. The aim of this project is to understand the method by which these touch voltages occur and determine a method to eliminate them to improve mine safety. An ELV hardware equivalent model has been developed for convenient experimentation. Solutions to eliminate touch voltage will be demonstrated on typical mining equipment at normal system voltage as a find proof of concept.

The results from the ELV hardware simulator have provided results that are consistent with that observed during investigations into several electric shock instances undertaken in the past where the electric shock coincided with the operation of switchgear:
- Occurrence is very infrequent;
- More likely to occur when opening switchgear.

The assessment for perception of a touch voltage has been simplified to use the peak measurement, given that the dynamics of the system is constant. Apart from possible variability in switchgear contact arcing, the only other variables that change is the timing of the switchgear closing and opening.

Installation of the solution to control touch voltages during switching on the ELV hardware simulator reduced the touch voltage transients significantly. The solution, with suitable voltage rating, will be installed on typical mining equipment to assess its performance.

C33009

Ceramic Wall Flow Filter Commercialisation

PPK Mining Equipment
Bradley Drury
Greg Briggs

Value:	$888,778
Report Expected:	April 2024
Industry Monitor/s:	Andrew Esdaile
	Steve Coffee
	Trevor Hartley
ACARP Contact:	Patrick Tyrrell

The purpose of this project is to develop a commercially available improved diesel particulate filter (DPF) for widespread use in underground coal mines.

This project builds on work undertaken in projects C25073 and C26070. An industrialised filter was developed under C26070 and requires the following to be commercially available:
- Technical refinements to allow retro-fit to existing Diesel Engine Systems;
- Testing against certification and regulatory requirements – emissions and Ex-protection.

The focus during the quarter has been on finalisation of documentation for submission to the NSW Resources Regulator for Design Registration. Plant Design Registration has now been received. A trial vehicle has been fitted with the registered CWFF system and site trials are scheduled for February following Plant Item Registration.

C33017

Specialised Instrumentation and Data Processing for Real Time FEA Condition Monitoring of AFC Chain

Vayeron
Ryan Norris

Value:	$185,000
Report Expected:	March 2024
Industry Monitor/s:	Brad Lucke
	Jarrod Sampson
ACARP Contact:	Patrick Tyrrell

Armoured face conveyor (AFC) chain failure causes serious production delays and associated costs for longwall operators, accounting for up to 27% of longwall failures. This project will develop a closed loop quasi real time prototype AFC chain link to model real time stress and strain monitoring.

Progress over the last quarter is as follows:
- Units fully certified and assembled;
- Initial preliminary testing completed on AFC mini build at workshop;
- Data gathered.

Results of preliminary testing at workshop mini-build are shown as follows.

| AFC_1	AFC_2	AFC_3	AFC_4
Non-Functional	Functional	Non-Functional	Functional
Loose Lid screw	Used for demo	Fuse blown	Not installed
When returned, old fuse board screwed, but no contact was made	During test, long idle time was configured (10mins of no motion for it to go back to stationary mode) This was accidentally set before test scenario	Not certified to be used in the field	Was not assembled in trial run as it had no matching pair which would have been AFC_3.
Using fuse-less test board, it was functional	Radio transmission worked at the furthest distance	Using fuse-less test board, it was functional	Fused lid board works.
Conclusion was to manually solder a small blob onto positive terminal which compresses onto the spring terminal	Tonnage formula not entirely accurate	Recertification process to replace fuse being investigated. Use of PPTC fuse as an option considered	Radio broadcast worked when motion was detected.

No. 2 connector is the only connector used in this test that gathered information.

The major obstacle throughout this process has been the lid alignment.

Default settings of 10 min idle (AFC not being in motion, switching it from normal mode to stationary mode) was set and was not reconfigured until the last phase of the process.

Data from radio was uncalibrated due to incorrectly setting serial number to their corresponding strain gauge lookup table. Each Connector has its own strain gauge lookup table that has been hardcoded to measure up to 70 tonnes. We then linearly extrapolate the values to achieve higher than 70 tonne values. This is going to be implemented in the later addition of the software update.

Strain gauge look-up plot:
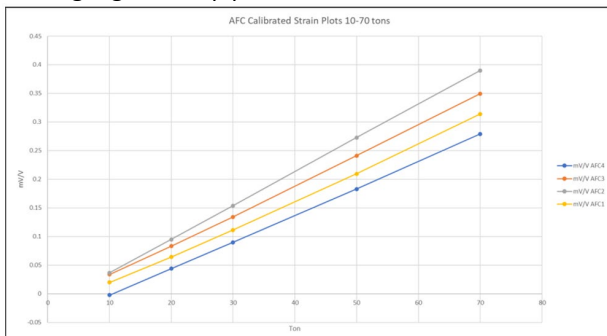
Measured acceleration plots (X, Y, Z):
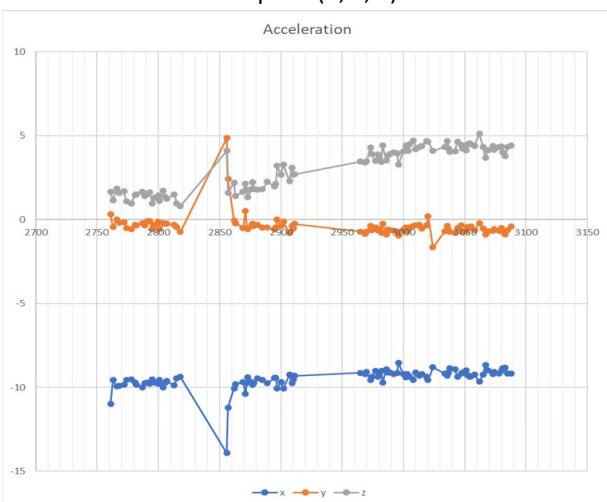
C33026
Prototype Battery Electric Load Haul Dump

3ME Technology
Justin Bain
Lewis Grainger
Martin Kime

Value:	$1,431,295
Report Expected:	July 2024
Industry Monitor/s:	Brad Lucke
	Dave Young
	Paul Wyatt
	Sharif Burra
ACARP Contact:	Patrick Tyrrell

The objective of this project is to design, build, and certify a high-performance battery for use in an Electric Vehicle (EV) system that meets Australian Hazardous Area requirements, achieve Hazardous Area certification of a Ex battery and then integrate into an underground rubber tyred vehicle to operate in a hazardous area of an underground coal mine.

Key activities conducted to date:
- Fully functional battery sent to Certifying Body;
- Continued discussions with OEM;
- Testing continued on two x scaled enclosures; and
- Operating instructions and test procedures sent to Certifying Body.

Key Tasks to be conducted next quarter include:
- Completion of testing process at Certifying Body;
- Commence detailed platform integration planning;
- Finalise layout of large scale battery system to suit platform.

Mining Technology and Production

C20033
Development of a Safer Underground Explosive

University of New South Wales
Andres Castro
Duncan Chalmers

Value:	$468,000
Report Expected:	March 2024
Industry Monitor/s:	Brad Elvy
	Paul Wild
	Russell Thomas
ACARP Contact:	Patrick Tyrrell

Discussions have been held with the supplier to resolve the issue, after an incident in the plant facility that has changed the priorities.

Work has resumed by the explosives manufacturer to produce some new formulations.

Discussion with the team at CIMFR Dhanbad will be held in February to program the testing of the new formulations.

Further test work was scheduled to be conducted in Gore with several higher density formulations based around the composition of the currently available Indian packaged explosive. Unfortunately, inclement weather prohibited this activity and will be rescheduled.

C28018
Longwall Floor Horizon Sensing

CSIRO
Andrew Strange
Zak Jecny

Value:	$269,680
Report Expected:	April 2024
Industry Monitor/s:	Jarod Chadwick
ACARP Contact:	Patrick Tyrrell

Effective horizon control is essential for both safety and productivity in underground longwall mining. The key to achieving this outcome is a reliable means of actively sensing the geological strata of the seam floor. This project will develop a ground penetrating radar sensor for installation on a production longwall and long-term trial as a floor horizon sensor.

Further to the report in the previous quarter about the damaged skid base, the entire system (i.e. LW GPR system, skid base and bracket) is ready for installation. The host mine site waiting for an appropriate opportunity to install the system for the long term production trial.

C29033
Alternative Flameproof Enclosure Protection Techniques

CSIRO
Peter Reid

Value:	$272,000
Report Expected:	April 2024
Industry Monitor/s:	Brad Lucke
	Colin Hoyle
ACARP Contact:	Patrick Tyrrell

The primary objective of this extension stage of the project is to design and produce a certified pressure sensing module capable of achieving Ex ia/ib certification. This module is intended to automatically and safely de-energize the payload promptly if the enclosure's internal atmosphere is compromised. The integration of this module into various existing enclosures aims to facilitate their certification as Ex P, elevating their protection levels.

The key project goals are:

- Semiconductor Independence - reduce reliance on specific, currently challenging to procure semiconductors;
- Consolidation of Pressure Switches - integrate the functionality of two separate pressure switches into a single board;
- Compliance with Standards - address all necessary modifications to ensure compliance with 60079.2 and 60079.11 requirements;
- Design Optimisation - redesign the module with a focus on enhancing manufacturability and cost-effectiveness;
- Manufacturer Selection - identify and choose a suitable manufacturer for the production of these certified modules;
- Differential Pressure Sensing - implement a differential pressure sensing configuration for enhanced functionality.

The design and project have progressed significantly, culminating in the completion of Revision 2.0 PCBs and Schematics, which are currently in draft form. These critical documents have been formally submitted for review to Ex Testing and Certification, marking a pivotal phase in our project timeline. The certification process, anticipated to span several months, adopts a phased approach to ensure comprehensive evaluation and validation the design.

Upon achieving a favourable outcome from the ongoing certification, a small production run of the PCBs is being prepared. The manufactured PCBs from this production run will be returned for additional certification and testing, and to ensure regulatory compliance.

This iterative process of testing, certification, and refinement is instrumental in paving the way for the final production of the design.

C29037
Intrinsically Safe RFID Sensors for Underground Coal Mining

CSIRO
Lance Munday

Value:	$136,050
Report Expected:	February 2024
Industry Monitor/s:	Brad Lucke
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34003

Self-Drilling Bolt Automation: Bolt Design and Manufacture Method, and Chemical Canister Concept Development

OKA Rock Bolt Technologies
Mark Levey

Value:	$1,857,744
Report Expected:	February 2024
Industry Monitor/s:	Roadway Development Task Group
ACARP Contact:	Patrick Tyrrell

The project objectives are:
- Complete development of the Chemicals, Capsule and Self Drill Bolt;
- Complete the development of the Adaptor/modified drill-head, headplate and software such that an underground trial can take place;
- Carry out an underground Trial.

Progress during the quarter is as follows.

The Chemicals:
- Have locked in the chemical formulae for use in the capsule.

The Adaptor:
- The adaptor IFC drawings had final dimensioning applied, along with other design refinements. The lid and body of the adaptor were 3D printed in metal and machined to tolerance at the end of this quarter;
- The segmented piston was manufactured, as was a second version of the sequence valve;
- The adaptor will be assembled early February and commissioned soon after.

The Capsule:
- 250 sets of the capsule body and nozzle were made overseas and sent to Australia. The molds were also shipped to Australia;
- All four components used within the capsule are manufactured in Australia. Three of the components have been manufactured for the workshop trial. The fourth component, the water valve (cup) includes a temporary membrane, which has taken months to refine and complete. The water cups will now be manufactured at the beginning of the next quarter.

The Bolt:
- 250 hollow bars are complete and ready for trial;
- 125 x 6' and 125 x 7' bolts have been prepared for the workshop trial;
- The drill rig support frame and drill rig have been installed, however the drill rig hydraulic control unit took most of the quarter to carry out repairs required. It is now running correctly and ready for the workshop trial.

Headplate:
- The modified headplate is prepared for the workshop trial.

The next steps are:
- The capsules and components will be gaseous treated, assembled and filled with chemicals in preparation for the workshop trial;
- Once the adaptor is assembled and tested, the complete system can be tested in the drilling rig in the workshop;
- FRAS and EMF studies on the final plastic type and magnets used in the system will then be carried out.

C34015

Assistive Shuttle Car: Development of an Industry Ready Guidance System: Stage 3

CSIRO
Andrew Strange
Mark Dunn

Value:	$205,395
Report Expected:	April 2024
Industry Monitor/s:	Roadway Development Task Group
ACARP Contact:	Patrick Tyrrell

Most development operations in Australia utilise manual line-of-sight radio controlled miners to cut roadways, and operator driven shuttle cars to transfer coal from the working face. These levels of technology are not able to achieve the goal of safe remote operation of roadway development. Two issues have been identified that inhibit progress in the domain of remote development:
- Continuous miner self-steering technology to maintain desired roadway headings has not yet reached the required level of performance required for sustained remote operation.
- No automated options currently exist to guide shuttle cars while tramming through roadway systems and whilst avoiding ribs, cut-through corners and other infrastructure.

A system based on CSIRO's ExScan technology along with SLAM techniques has been developed to address these issues. A bracket that mounts two ExScans on the shuttle car operator cab has been designed such the ExScans provide both forward and reverse view along with distance to the ribs during operation. The bracket is currently being fabricated. The system electronics has also been operated for several days inside an enclosure to ensure the system doesn't overheat when running in production conditions, which was successful.

Once the mounting bracket and components have been fabricated, the system will be assembled and tested at CSIRO to confirm the ExScan mounting configuration is stable. Once that is deemed suitable, the system will be transported to the host site for installation on a shuttle car so that a production trial can be conducted with UPEE approvals.

C34019
Longwall Bretby Cable Handling Monitoring with Fibre Optics

Mining3
David John
Erik Isokangas
Karsten Hoehn

Value:	$237,940
Report Expected:	February 2024
Industry Monitor/s:	Brad Lucke
	Nick Belton
	Shane McDowall
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34024
Effects of Rock Weathering on Life-of-mine Roadway Stability

University of Queensland
Zhongwei Chen

Value:	$312,534
Report Expected:	September 2024
Industry Monitor/s:	Brian Vorster
	Matt Tsang
ACARP Contact:	Patrick Tyrrell

The main objectives are to:
- Identify the relevant weathering testing standards for assessing the process of rock degradation;
- Experimentally characterise and quantify the responses of rock properties to the weathering; and to
- Apply the laboratory results to assess the weathering impact on CMRR de-rating and its implications to support design practices.

In this quarter, the following tasks have been carried out:
- The sample preparation for the mechanical and microstructure characteristics has been completed.
- Classification of 270 samples into four distinct rock types based on geological logging data.
- The weathering tests have been running for two months using environmental chambers.
- Weekly characterisation of rock mechanical and physical properties (e.g. sonic velocity, porosity, UCS, BTS, water absorption, etc.) along the establishment of weathering timelines.
- Quantification of the evolution and correlations of these properties in response to varying heat and humidity conditions, which is different to the conventional weathering sensitivity testing (e.g., immersion or slake durability testing).

The following activities are planned for next quarter:
- The rock weathering tests will be carried out for another ten months, and the evolution and correlations of rock properties will be recorded periodically, aiming to provide a more comprehensive understanding of the long-term effects of weathering.
- Detailed characterisation of rock microstructure evolution in response to different weathering conditions using various techniques, such as micro-CT, optical microscope, and SEM-EDS.

C35004
Advancing Remote and Automated Capability for Longwall and Roadway Development

CSIRO
Andrew Strange
Jonathon Ralston

Value:	$2,517,000
Report Expected:	May 2025
Industry Monitor/s:	Roadway Development Task Group
ACARP Contact:	Patrick Tyrrell

This project responds to the industry need to accelerate remote and automated longwall and roadway development capability. The project utilises the flexible industry directed project model to deliver research impacts to industry through well scoped work packages.

The second work package, entitled "Longwall Gate End Face Alignment", has progressed over the past quarter. A gate end face alignment system was developed that utilises an ExScan mounted close to the CME at pan 5 and measures the position of a reflective marker attached to equipment connected to pan 1 to generate an estimate of the main gate end alignment state.

Software has been developed that fuses this gate end lead/lag measurement with a corresponding LASC shearer face profile. The software uses this information to generate a new face correction profile that incorporates both the classic shearer face profile and new gate end alignment state.

Before integrating this software into the LASC production environment, a trial needs to be conducted at the host site to validate the lead/lag measurements generated using this approach, which requires ground truth validation information from operators. Unfortunately the host site reached the end of a panel before the validation information could be sufficiently captured. This ground truth trial will resume once full production at the host site (after panel move) has recommenced. Once the functional validation test has been completed, further development will be conducted to integrate the system into LASC to achieve automatic gate end face alignment.

In order to continue progress in this project, the scope for WP3 has been proposed and is currently being finalised where the topic is "Automated BSL Steering". The goal is to extend LASC such that a creep

measurement from a nominal creep sensor can be input into LASC at which point a new face profile can be generated which integrates both a wedge cut and a face correction profile. An initial trial will be conducted for this package. If deemed successful, this will be extended to form a system which automatically steers the BSL through the roadway as the longwall retreats.

C35009
Longwall Remote Operations – Face Mapping Robot – Phase 1

Quantum Engineering and Consulting Group
Luke Dyer

Value:	$170,000
Report Expected:	March 2024
Industry Monitor/s:	Mick Condie
ACARP Contact:	Patrick Tyrrell

This project aims to create a significant improvement to remote operations in underground mining by designing and executing a mobile face scanning system (the "Face Mapping Robot"). The robot would contain inertial navigation hardware, forward (coal face), rear-facing (goaf), and traverse (walkway) cameras and laser scanners. The robot would be mounted onto the rear of the AFC pans and be able to move up and down the face independently of the shearer.

The primary objectives of the robot are to:
- Enable face-wide visual images of the coal face and roof supports;
- Enable face-wide 3D laser scans of the coal face and roof supports; and to
- Enable a fast remap of the position of the AFC panline at any time, particularly at a point in time after the AFC push has occurred.

Phase 1 of this project aims to design, build, and perform on-face tests with a manually propelled prototype robot to determine if the data captured is suitable for the various automation systems currently in use.

Discussions and work that has been undertaken includes:
- Trolley base received minor repairs to remove rust and has been powder coated for better longevity of frame for use in underground environments;
- All brackets and gears machined and fitted to trolley to allow for the addition of an encoder to the platform;
- Belt for encoder assembly sourced and ordered;
- Camera model determined, sourced and order.

The following tasks are scheduled for the next quarter.
- Installation and testing of various mounted technologies in workshop environment; and
- Second trial at mine site 1 to assess data capturing via various technologies mounted to trolley base, on surface and underground longwall zone.

Health and Safety

C24010
Proximity Detection Systems Specification for Underground Coal Mining Machines

Resources Safety & Health Queensland
Andre De Kock
Gareth Kennedy

Value:	$565,988
Report Expected:	March 2024
Industry Monitor/s:	Brad Lucke
ACARP Contact:	Patrick Tyrrell

The objectives of the project are to:
- 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; and to
- Determine if future developments by the proximity detection manufacturers will address the specification from the coal mining industry.

All interviews have been completed and transcribed. During the next reporting period the analysis of all the interviews will be carried out and a draft final report will be prepared.

C27049
Mine Rescue Vehicle Radar Sensing Integration

CSIRO
Eleonora Widzyk-Capehart
Gareth Kennedy
Lance Munday

Value:	$254,405
Report Expected:	March 2024
Industry Monitor/s:	Brad Lucke
ACARP Contact:	Patrick Tyrrell

The project objectives are to:
- Develop an integrated radar sensor and user interface that is applicable to a wide range of fixed and mobile sensing applications underground;
- Provide robust ranging and mapping that is tolerant of both airborne and sensor-surface contamination caused by dust, smoke and water vapour; and to
- 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. The key benefits of the system are:
- Improved health and safety, whereby persons in any part of a mine, who are subject to disorientation or

severely impaired visibility, are able to find their way out of the mine; and

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

A final report is nearing completion and will be submitted soon.

C28029

Personal Real Time Dust/Particulate Monitor (Direct Mass Based Measurement)

Lear Siegler Australasia
Peter Phaedonos

Value:	$152,1730
Report Expected:	June 2024
Industry Monitor/s:	Brad Lucke
	Glenn Owens
	Ian Marshall
ACARP Contact:	Patrick Tyrrell

The PDM Real time dust monitor is a safety tool and a safety companion to the miner. At any point in the miner's working shift the PDM will display the 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, the PDM will provide the miner with the means to monitor and manage such exposer. 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.

Project status:
- Vast progress this quarter with all the required redesign of the various PCBs completed and submitted to SIMTARS for evaluation, to allow us to move to the prototype stage. All required drawings are with SIMTARS waiting for their final desk review/approval and go ahead to next stage.
  o This has now been fully completed with a positive outcome. (Jan,2024)
- Most of the components for the manufacture of the PCBAs have been purchased and on hand.
  o LSA is progressing to the purchase of all the various components to complete the first lot of prototypes.
- A revised set of batteries/battery pack is being currently retested to IECEx to ensure compliance. This was required to eliminate any cause for concern for end of life components.
  o This is still ongoing and progressing well. Battery type and brand already identified.
- Having had the WiFi re-evaluated by SIMTARS, the PDM will be built with WiFi as an option to ensure initial batch receives an easier/clearer path to IECEx certification in its current development.
- The prototypes for the Certification process need to be as the final manufactured and ready for field use

PDM instrument. LSA is working towards finalising the mould supplier/manufacturer.
  o Ongoing, but getting close to finalising the ordering of these moulds.
- It is anticipated that over the next two months a clearer end point of the project and final certification of the PDM will be seen.
  o Well down the track of sourcing/preparing prototypes and modules which will enable SIMTARS the carry out physical testing that will lead to the IECex certification and completion of this AWARP project.

C33001

Methodology Development of Free Silica Analysis of Dust on PDM Filters: Phases 1A&B

CSIRO
Hsin Wei Wu
Yonggang Jin

Value:	$249,200
Report Expected:	February 2024
Industry Monitor/s:	Andrew Lau
	Brad Lucke
	Kevin Rowe
	Sharif Burra
	Tony Egan
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C33006

Breathing Zone Exposure Quantification and Respirators Performance – Review of Exposure Control Strategies

CSIRO
Rao Balusu

Value:	$329,450
Report Expected:	March 2024
Industry Monitor/s:	Andrew Lau
	Brad Lucke
	Kevin Rowe
	Sharif Burra
	Tony Egan
ACARP Contact:	Patrick Tyrrell

The project objective is to investigate the spatial variability of dust concentration levels in the breathing zone and the impact of current dust monitoring strategies on personal dust exposure levels. The project also aims to evaluate the effectiveness of respirators, such as various types of powered air-purifying respirators (PAPRs), on personal dust exposure levels. The project work will involve extensive laboratory investigations and some field studies. Studies will provide a better understanding of the effectiveness of respirators and integrated unit performance of full-face PAPRs in protecting workers working under high dust

concentration zones as well as the actual personal dust exposure levels of workers wearing full face PAPRs.

All the project studies including laboratory investigations and field monitoring studies are complete. In the quarter, work focused on data analysis of the results of laboratory and field studies and drafting of the final report. This report will be submitted for review in the next quarter.

C33012
Respirable Dust Reference Testing Method and Dust Chamber Facility

Resources Safety & Health Queensland
Gareth Kennedy

Value:	$215,950
Report Expected:	December 2024
Industry Monitor/s:	Andrew Lau
	Brad Lucke
	Kevin Rowe
	Sharif Burra
	Tony Egan
ACARP Contact:	Patrick Tyrrell

The aim of this project is to establish the methodology for the respirable dust chamber as a reference tool for cyclones and devices used in the coal mining industry. This will be achieved through three objectives:
- Establish that the respirable dust chamber conforms to international testing methodology and accuracy;
- Verify the methodology utilising a selection of respirable dust cyclones and impactor plate devices currently used in underground coal mines; and
- Compare the accuracy of the devices when using a different dust types and dust mixtures (stone dust, coal dust, silica).

The visit by NIOSH to Simtars took place in December 2023. Simtars visit to NIOSH is planned in March to undertake training and conduct representative testing using the NIOSH chamber.

The final commissioning including installation of the control system for the chamber is still progressing with expected completion around April. It is expected that the report will be completed by November.

The next steps are:
- Complete the commissioning;
- Develop the testing requirements during the visit to NIOSH;
- Purchase the cyclone dust samplers; and
- Obtain coal samples from an Australian mine site for testing, including sample preparation.

C33069
New PDM filter for Direct-on-Filter Silica Analysis of Coal Mine Dust

CSIRO
Yonggang Jin

Value:	$298,240
Report Expected:	March 2024
Industry Monitor/s:	Andrew Lau
	Brad Lucke
	Kevin Rowe
	Sharif Burra
	Tony Egan
ACARP Contact:	Patrick Tyrrell

The main objective of this project is to develop a new type of Personal Dust Monitor (PDM) filter with a non-silica filter material and a novel filter assembly structure to enable the direct-on-filter silica analysis of the PDM collected dust sample with a field-based FTIR method. The project work will involve extensive laboratory studies for development, evaluation and prototyping of the new PDM filter. Expected outcomes from this project include a novel type of filter for use in PDM to achieve both real-time respirable dust monitoring throughout the sampling shift and silica content measurement at the end of the sampling shift, and a rapid reliable field-based approach to be developed for optimal monitoring of personal exposure levels of respirable coal dust and respirable crystalline silica with one single PDM unit.

In the quarter, work focused on data analysis of experimental results of parallel sampling tests and FTIR silica analysis and drafting of the final report. The draft report should be submitted to the Industry Monitors for review shortly.

C34006
Resilience and Mental Health in Mining Pilot Program

Macquarie University
Rebecca Mitchell

Value:	$476,099
Report Expected:	March 2025
Industry Monitor/s:	Sharif Burra
ACARP Contact:	Patrick Tyrrell

This project is currently on hold.

C34007

Evaluating Toxicity of Different Types of Respirable Crystalline Silica Particles to Lung Cells and Tissues

University of Queensland
Gordon Xu

Value:	$207,950
Report Expected:	May 2024
Industry Monitor/s:	Andrew Lau
	Brad Lucke
	Kevin Rowe
	Sharif Burra
	Tony Egan
ACARP Contact:	Patrick Tyrrell

The project aim is to evaluate the toxicity and potential hazards of respirable crystalline silica (RCS) particles to lung cells and tissues. By developing three typical RCS particles (freshly generated, hydrated and aged) that the coal mine workers are typically exposed to, their biological impact on lung cells and tissues in vitro are investigated and their toxicity and potential hazards to lung tissues in a mouse model is examined. Outcomes will provide a comprehensive understanding of the varying levels of toxicity and risk posed by different RCS particle types to mine workers and help inform and direct health and safety strategies to reduce exposure to the most dangerous RCS particle types.

During this quarter, significant progress has been made in the following areas:

- Assessing the penetration and diffusion of RCS through cell monolayers made of intestine and lung cell lines using Transepithelial-Transendothelial Electrical Resistance (TEER) assay. In 24-h culture, some RCS particles were adhered on the cell monolayer, but no significant diffusion and penetration were observed.
- Developing an air-liquid interface model to evaluate the cytotoxicity of three RCS particles on dense lung and intestinal monolayers. The MTT results have demonstrated no significant cytotoxicity of fresh, hydrated, and aged RCS at the low-to-moderate concentration for 24 hour exposure time.
- Investigating inflammation profiles of three RCS particles on monolayers using ELISA assay. Dense lung and intestinal monolayer models have been developed on Patri dishes for studying their inflammation profiles upon exposure of RCS particles for 24 hour treatment.

C34023

Advanced Breathing Apparatus with Gas Membrane Modules

Monash University
Victor Chang

Value:	$298,436
Report Expected:	January 2025
Industry Monitor/s:	Ken Singer
	Lee Earnshaw
	Paul Wild
ACARP Contact:	Peter Bergin

The main project objective is to develop a prototype for breathing apparatus which will replace the CO2 adsorption module with a light weight gas separation module.

The commissioning of the new hollow fiber spinning machine has been completed for the membrane prototype development and first five batches of trial membranes has been generated. The quality of the membrane met the expected separation efficiency, but the surface homogeneity can be further improved by optimising the recipe. Several potential approaches have been identified and finalisation of the SOP in the first half of 2024 is hopeful. In addition, designing the membrane housing module to be integrated into the Drager's BG4 has started.

C35017

Is Exposure to Illite Dust Linked to Pneumoconiosis?

University of Tasmania
Basil Beamish
Graeme Zosky

Value:	$302,428
Report Expected:	October 2024
Industry Monitor/s:	Andrew Lau
	Brad Lucke
	Frank Fulham
	Kevin Rowe
	Shane Apps
	Sharif Burra
	Tony Egan
ACARP Contact:	Patrick Tyrrell

Previous projects conducted by our group have identified illite in coal dusts as a potential driver of lung cell toxicity, which may be related to the risk of developing Coal Workers' Pneumoconiosis (CWP). The overarching aim of this project is to explore this relationship in more detail.

A systematic review has been completed of more than 4000 articles and identified a significant gap in knowledge regarding the comparative health effects of dusts generated by potassium rich minerals in mining operations. The review for publication in a peer-reviewed Journal will be submitted shortly. Cell studies

have been commenced using 44 coal samples obtained from operating coal mines in New South Wales and Queensland that cover a range of mineral constituents from low to high potassium alumino-silicates. Samples of muscovite, orthoclase (K-feldspar) and illite (confirmed analytically) have been obtained for comparison and for blending with low-potassium coal samples.

Roadway Development

C27076
Underground Coal Mine Gateroad Development Continuous Haulage System

Premron
Mick Whelan

Value:	$9,773,528
Report Expected:	December 2024
Industry Monitor/s:	Roadway Development Task Group
ACARP Contact:	Patrick Tyrrell

This project aims to develop a Continuous Haulage System for mine gateroad development, utilising the closed conveyor system of the "Premron CHS" ©.

The project encompass the following key objectives:
- Perform modifications to the Premron CHS to allow a more compact machine operating window, allowing additional components to be fitted to the machine (Ventilation) – completed.
- Provide a customised fully onboard Services and Ventilation System within the Premron CHS – completed.
- Perform modifications to the Sizer Feeder machine, to reduce width and height allowing clearance for LHD and other equipment – completed.
- Perform a FAT mini build to test functionality of the modifications provided on both Premron CHS and Sizer Feeder machines - completed.
- Installation and trial in a fully operational underground panel.

Premron have completed successfully key objectives 1 – 4 inclusive, with the final objective, being an underground trial at the host mine site. Due to mine plan movements with the host mine, delays are expected until 2025.

In 2024, Premron will carry out the following work scope:
- Modify existing Test Track Structure to suit new Premron CHS loading;
- Install Monorail Test Track and Premron CHS; and
- Commission and surface test Premron CHS.

C33020
Floor Horizon Control for Roadway Development

CSIRO
Andrew Strange

Value:	$80,000
Report Expected:	March 2024
Industry Monitor/s:	Roadway Development Task Group
ACARP Contact:	Patrick Tyrrell

The overarching objective of this project is to develop a floor horizon control sensor suitable for installation on a production miner-bolter. The key outcome of this project is to install an enclosure that is capable of housing a floor horizon sensor (ground penetrating radar) on a production miner-bolter to ascertain how well a new non-metallic enclosure, along with the corresponding mounting bracket, can survive the roadway environment. The enclosure will not require certification because it will not contain a sensing payload.

The technical activities for this project have been completed. The draft report is currently in preparation and will be provided to the Industry Monitors shortly.

Strata Control and Windblasts

C28011
Prevention Techniques for Stress Corrosion Cracking Failures of Rock and Cable Bolts

University of New South Wales
Serkan Saydam

Value:	$298,380
Report Expected:	February 2024
Industry Monitor/s:	Lesley Munsamy
	Patrycja Sheffield
	Peter Corbett
ACARP Contact:	Peter Bergin

The draft final report has been submitted to the Industry Monitors for review.

C28020
Optimising the Cablebolt Pre-Tensioning Practice to Control Roadway Roof Failure Using Advanced Combined Axial and Shear Testing Facility

Monash University
Hossein Masoumi

Value:	$165,000
Report Expected:	March 2024
Industry Monitor/s:	Brian Vorster
	Patrycja Sheffield
	Peter Corbett
ACARP Contact:	Peter Bergin

The objective of this project is to investigate the cable bolt pre-tensioning practice as followed by Australian coal industry through large-scale testing. The selected level of pre-tensioning and the technical reasons associated with such a selection are to be further studied.

Numerical study and report writing are ongoing and expected to finish in next quarter. The numerical work completed up to now entails axial performance of the cable bolt system (relative joint separation), and model development for the shear case (relative joint shear sliding). Report writing work completed up to now entails the details on the conducted experiments and results, key details from the collected mining sites data regarding pretension practice, and details on the numerical study regarding the relative joint separation case.

C29014
Definition and Quantification of Long Term Stability of Coal Pillar Systems

University of New South Wales
Ismet Canbulat
John Watson

Value:	$230,000
Report Expected:	March 2024
Industry Monitor/s:	Peter Corbett
	Russell Thomas
ACARP Contact:	Peter Bergin

This project aims to define and quantify the long-term stability of coal pillar systems.

The work undertaken this quarter includes:
- During the review of the final report, it is suggested that rectangular pillars should be included in all models, which was not the case previously. This has now been completed.
- The final report has been compiled and is currently being internally reviewed.

C29019
Mechanical Assessment of Time Dependent (Creep) Behaviour of Coal and Coal Measure Rocks Under Uniaxial and Triaxial Conditions Based on Experimental and Analytical Methodologies

Monash University
Amin Heidarpour

Value:	$205,000
Report Expected:	March 2024
Industry Monitor/s:	Brian Vorster
	Elliot Tembo
ACARP Contact:	Peter Bergin

The project objective is to investigate the time dependent behaviour of coal and coal measure rocks by conducting experiments under various timeframes ranging from a month to a year or more. Researchers will use creep loading frames in temperature and humidity-controlled conditions which replicate the underground mining environment.

The project has made significant progress this quarter, with substantial achievements in various phases of research. A comprehensive literature review has been conducted and will continue to be a crucial project aspect in the upcoming period. The experimental design phases have been successfully completed, ensuring a robust testing program. Adequate sandstone samples have been acquired from three different sites to facilitate the testing program.

Notably, short term uniaxial compressive tests have been conducted on sandstone, marble, granite and coal, providing valuable insights into the different rock type mechanical behaviour. Additionally, short term triaxial compressive tests have been performed on sandstone, allowing for the determination of key mechanical properties under different confining pressures.

Significant advancements in the setup and operation of creep rigs equipped with precise extensometers have been made. All ten creep rigs are now operational, enabling both conventional and multistage creep experiments at various stress levels. Uniaxial and triaxial creep testing has commenced, facilitated by the successful modification of the temperature control system to maintain a constant room temperature during tests. In conjunction with these significant achievements, a predictive model has been developed based on the comprehensive set of experimental results. This model aims to predict the time-to-failure under various loading conditions.

Investigation into the influence of the specimens' slenderness ratio and sample diameter on their time dependent properties has been successfully completed. Creep experiments on coal and marble samples are currently underway, reflecting the project's breadth and depth in exploring the time dependent behaviour of different materials.

C29022

Mechanical Investigation of Two Critical Standing Support Systems (Timber Chock and Pumpable Crib) in Underground Coal Mines

Monash University
Hossein Masoumi
Javad Hashemi

Value:	$295,000
Report Expected:	March 2024
Industry Monitor/s:	Bob Coutts
	Brian Vorster
	Dan Payne
	Patrycja Sheffield
ACARP Contact:	Peter Bergin

The main objective of the project is to characterise the mechanical behaviour of two standing support systems including timber chock and pumpable crib which are commonly utilised in underground coal mines in Australia.

To investigate the mechanical behaviour of timber chock structures, the project has been divided into three levels: component, contact, and global levels. For the contact level tests, based on the design of experiments, more than 30 tests have been conducted using a compression test loading frame which is capable of accommodating a vertical force of about 3.5 MN. To study the strain field variation of contacts between timber-timber and timber-steel for the connection of timber and steel loading platens, Digital Image Correlation (DIC) recording has been utilised. After organising all obtained results from the compression tests, numerical simulation has been applied to model the real behaviour of timber chocks at contact levels. To reflect the real behaviour of timber components engaged in the tests, DIC data has illustrated the process clearly, and the data has been utilised to calibrate numerical simulation, particularly in the contact of timber-timber components. Based on reviewed papers associated with the modelling of contact timber components, it was found that the soft contact, which models the contact based on the real overclosure behaviour and frictional behaviour, has been applied to show actual behaviour in contacts. Moreover, thanks to a sophisticated UMAT, the simulation can provide real failure modes, which are practical for comparing experimental and numerical results.

C29025

Effectiveness of Shotcrete in Underground Coal Mines

University of New South Wales
Chengguo Zhang
Joung Oh

Value:	$185,000
Report Expected:	February 2024
Industry Monitor/s:	Ben Forrest
	Brian Vorster
	Julian Potten
ACARP Contact:	Peter Bergin

The draft final report has been submitted to the Industry Monitors for review.

C33019

Monitoring While Drilling Concept on Characterising Coal Mine Roof

CSIRO
Manoj Khanal

Value:	$279,989
Report Expected:	February 2024
Industry Monitor/s:	Brian Vorster
	Dan Payne
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C33024

Improved Model Upscaling of Overburden Hydraulic Conductivity for Input into Groundwater Models

SCT Operations
Yvette Heritage

Value:	$230,000
Report Expected:	November 2024
Industry Monitor/s:	Agi Burra
	Bob Coutts
	Gary Brassington
	Peter Corbett
ACARP Contact:	Peter Bergin

The key objective for the project is to determine an upscaling method that bridges the gap of geotechnical model fracture conductivity at longwall panel detail, to groundwater model bulk conductivity input requirements. It has so far been a challenge across the geotechnical and hydrological disciplines to upscale these detailed fracture flow conductivity results to the groundwater models, whilst resulting in flows that are consistent with experience.

Collaboration with groundwater modelling consultants has allowed understanding of groundwater model inputs and limitations. This project aims to understand the differences and limitations of the geotechnical and groundwater modelling to improve the disconnect between the approaches.

Initial investigations into upscaling methodologies has shown similar results between local and non-local upscaling techniques. Investigation into other potential causes of variation in overburden conductivity between geotechnical conductivity and groundwater balanced overburden conductivity are being investigated.

C34012

User Friendly Computer Program for Modelling Fracture Induced Instabilities in Underground Mining Environments

University of Newcastle
Anna Giacomini

Value:	$197,350
Report Expected:	February 2024
Industry Monitor/s:	John Grieves
	Matt Tsang
	Paul O'Grady
ACARP Contact:	Peter Bergin

The draft final report has been submitted to the Industry Monitors for review.

C34018

Carbolt – Pre Commercial Fixed Length Carbolt Prototype

Mining3
David John

Value:	$360,088
Report Expected:	September 2024
Industry Monitor/s:	Alex Wright
	Bob Coutts
	Peter Quinn
ACARP Contact:	Patrick Tyrrell

The project objectives are to:
- Develop a pre-commercial fixed-length carbon-fibre based roof bolt to provide tensile and shear strata support. The Fixed-Length Carbolt will be designed to be installed in a manner similar to a standard rebar rock bolts and provide a non-corroding alternative to existing rebar roof bolts, which includes the ability to be re-tensioned.
- Develop a locking mechanism that locks the carbon fibre braid without damaging them.
- Characterise and statistically analyse the shear and tension load capacity of the Fixed Length Carbolt through a series of trials. Achieve comparable load performance to a steel rebar roof bolt.

The creation of longer Carbolts require the design and development of a specialised mould equipped with heating, to facilitate the resin setting process, and to achieve the necessary rib and thread patterns akin to conventional metal rockbolts. This custom mould serves as an interim solution, with the plan being to eventually replace it with a pultrusion machine once the manufacturing process is fully established.

The inner components of the custom built mould for the Carbolt prototype have been finished and tested. The initial curing of the Carbolt core with this new mould has also been successfully achieved, demonstrating even distribution, improving upon the previous version. The team will now proceed to braid and cure the 1.75-meter ribbed section, which will be subjected to shear and pull-out tests. The following photo shows the custom built mould and temperature controller.

Figure 1. Custom-built Carbolt curing and heating mould with a temperature controller.

C34021
Roof Beam Support Assessment Tool

Resource Geotechnical
Terry Medhurst

Value:	$150,000
Report Expected:	April 2024
Industry Monitor/s:	Brian Vorster
	Roger Byrnes
ACARP Contact:	Patrick Tyrrell

Previous projects C22008 and C24015 funded the development of a roof support design approach that takes account of differing roof conditions, effect of support type and stiffness that can be used for mine design and in the strata management process. An analytical framework was developed for roadway development that provides a measure of both support load and roof convergence which can be matched and updated against roof monitoring data. It is based on beam-column principles and incorporates bending, immediate roof failure and shear. The model relies upon inputs from the Geophysical Strata Rating (GSR), roof bolt characteristics including pull-out stiffness/load, in-situ stress ratio and unconfined compressive strength (UCS). The current proposal is to now convert this

method into a practical site-based software tool to accompany existing design methods.

A windows based version has been developed that can be used to assess both development and longwall abutment loads. The beta version and user guide has been developed and shared with the project monitor for initial evaluation. Error checking is nearing completion. A meeting was held with project monitors regarding delivery model of which several options were identified going forward. Work on this aspect is underway.

C34022
Risk Based Model for Forecasting Longwall Face Cavity Development

University of New South Wales
Chengguo Zhang
Ismet Canbulat

Value:	$173,200
Report Expected:	June 2024
Industry Monitor/s:	Bob Coutts
	Matt Martin
ACARP Contact:	Peter Bergin

Cavity development across the longwall face can cause substantial production losses and pose significant safety risks to mine workers during recovery operations. Previous research into longwall roof cavities has primarily focused on individual causes, such as equipment, shield pressures, geology, in situ stresses and geotechnical setting. In this project, researchers will adopt a holistic assessment of all causes that, in combination, can result in the formation of a roof cavity. The project aims to produce a risk based approach for assessing the likelihood of cavity development; a set of predetermined controls to mitigate the risk of cavity development; and a proposed hierarchy of longwall fall-of-ground severity linked to these controls, based on the escalating level of risk.

The main progress in the quarter was the cavity prediction for the next cut. The results are encouraging with stable performance and relatively high level of accuracy.

In addition, various methods were explored to predict the cavity location (i.e. chock number). Current results did not give a great accuracy level and over-fitting was observed. Other most recent ML methods were examined trying to introduce extra control parameters to optimise the analysis.

Further data collection for the numerical modelling has been confirmed and the setup of parametric analysis scenarios is being worked on.

C35008
Optimum Design of Pillars with Various Sizes and Shapes at Increasing Stress Environment

University of Queensland
Mehdi Serati
Paul Buddery

Value:	$172,000
Report Expected:	April 2025
Industry Monitor/s:	Brian Vorster
	John Grieves
	Peter Corbett
ACARP Contact:	Patrick Tyrrell

This project aims to establish a modified pillar load estimation methodology for the optimum design of pillars of various sizes and shapes in increasing stress environments. The project's ultimate goal is to provide a more accurate pillar stability assessment at increased mining depths. The project will verify the design of main pillars based on a load less than the tributary area load, which will potentially have considerable financial and operational benefits.

The dimensional analyses and factorial design parts of the Project's physical modelling component are now completed and verified using the available pillar design methods and several benchmark numerical validations. A half-size model made from a customised synthetic material was prepared and tested using a 1 MN hydro-controlled testing platform and a 5 Mega-pixel stereo-DIC (digital image correlation) system – see also the figure below. The displacement tensor induced around the "roadway" and within the "solid pillar" was successfully obtained to determine the pillar stress at varying normal loads. In the next stage, full-size moulds of synthetic materials will be prepared and manufactured, and new physical models will be tested under different pillar arrangements to investigate the pillar load distribution at varying mining depths.

Test setup with DIC for half size sample
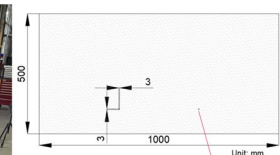
Schematic diagram of half size sample
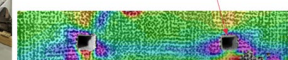
DIC contour of vertical displacement

C35010

Causes for Swelling and/or Bearing Capacity Floor Failures in a Pillar System Under Varying Geological and Geotechnical Environments

University of New South Wales
Serkan Saydam

Value:	$298,300
Report Expected:	June 2025
Industry Monitor/s:	Brian Vorster
	Peter Corbett
ACARP Contact:	Peter Bergin

This project aims to investigate the conditions to swelling and bearing capacity floor failures through an experimental program, in-situ monitoring program, and analytical and numerical approaches and determine timing of failure. Based on the learning from C26064 and C29041, an analytical model will be developed to evaluating the bearing capacity of soft floor strata in underground coal mines. The cutting edge numerical modelling framework will be developed that will enable us to better understand the swelling failure mechanisms. The research team will develop a framework for assessment and prediction of floor heave. This approach will provide comprehensive guidelines to assess and predict floor heave failures.

The finite difference modelling approach (FLAC2D) was utilised to assess the floor heave mechanism of the soft floor in an underground coal mine. The preliminary modelling results have been validated based on the field measurements in the previous studies. The factors influencing the load bearing capacity have been assessed (see Fig.1). The deformation mechanism of floor heave in a roadway has been revealed. Based on this modelling work, a parametric study has been conducted on the rock unit underlying the soft floor to evaluate its impact on the floor heave behaviour. These results can offer an effective perspective and new methods for controlling floor heave in mining operations. This work has been sent and accepted by the 6th Itasca Symposium to be held in Toronto in 2024. With the arrival of the requested rock samples from the coal mines, the swelling testing will be undertaken.
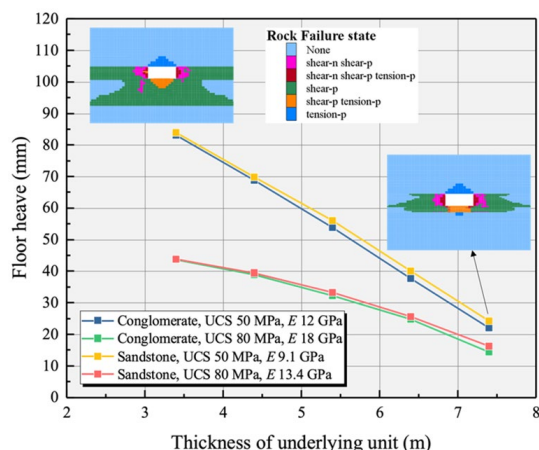

Fig 1. Floor heave measurements for various thickness, strength and lithology.

C35011

Revolutionising the In-Situ Stress Measurement Using a New Generation of Downhole Tools: DilaStress

University of New South Wales
Hamid Roshan
Ismet Canbulat

Value:	$184,500
Report Expected:	April 2025
Industry Monitor/s:	Brian Vorster
	Patrycja Sheffield
ACARP Contact:	Peter Bergin

This project is dedicated to creating an innovative downhole tool (DilaStress) built upon the concept of borehole deformation analysis for precise in-situ stress measurements. In the past quarter, significant progress has been made with the design and fabrication of the mechanical structure of the tool. Additionally, we have successfully designed and produced displacement sensors, pressure sensors, and positioning sensors. The ongoing process involves integrating these sensors into the tool body, and we have also initiated the design of the communication system recently.

Ventilation, Gas Drainage and Monitoring

C25072
New Approaches to Mine Gas Analysis and Ratios

Resources Safety & Health Queensland
Andre De Kock
Gareth Kennedy

Value:	$416,192
Report Expected:	March 2024
Industry Monitor/s:	John Grieves
ACARP Contact:	Peter Bergin

The project aim is to identify additional gases for the detection and monitoring of spontaneous combustion. This will be achieved through three objectives:
- 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;
- Compare these gas profiles to the normal carbon dioxide seam gas and methane/ethane seam mine fingerprints identified in the first stage of project C25072 and C10015; and
- 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 TARPs.

The work status is as follows:
- Aldehyde data has been graphed/processed;

- Preliminary validation work has started on the X-Pid, targeting the identified aldehydes from the HPLC analysis;
- Literature review specifically targeting aldehydes evolved during coal spontaneous combustion is being revisited;
- Preparations for the second test have commenced with an anticipated start date in early May.

The following steps will be addressed in the next reporting period:
- Graph/Process the VOC data from the GC-MS data;
- Continue the preparation of the interim report, with tentative date for submission to ACARP by the end of March;
- Install and commission the PID controller to better control the flange temperatures by early April; and
- Finalise preparations for the second test: update testing regime, engage with the mine site to secure coal samples.

C27035
Automatic Leak Detection for Tube Bundle Systems

Resources Safety & Health Queensland
Sean Muller

Value:	$220,000
Report Expected:	April 2024
Industry Monitor/s:	John Grieves
ACARP Contact:	Patrick Tyrrell

The objective of this project is to develop a fully automated prototype integrity testing system, based on information of the flow rates and pressures on tubes. 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 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 used in underground coal mines. During the second phase the specifications for automatic system prototype will be developed. The final phase will be to test the prototype using the Simtars Mobile Gas Laboratory (MGL) and then retrofit the prototype to a tube bundle system for a trial at the mine site.

Simtars will conduct comprehensive testing using the Mobile Gas Laboratory (MGL), and adequate lengths of tube-bundle tubing to represent an actual scale of a mine site. The aim of these tests are to evaluate the following:
- Effectiveness of the prototype to undertake leak testing according to AS 2290.3 2018; and
- Ability and accuracy of the prototype to detect leaks and changes in tube integrity.

All components are functional and fit for purpose. The oxygen analyser has been re-calibrated. Settings for the variable speed drive pump have been determined for the

testing. The leak testing prototype is operational, and testing has commenced.

Lengths of tubing are currently being tested. Tests undertaken to date include 5/8 tubing at 200m and ½ tubing at 1000m and 2000m. Tube infrastructure has been procured for the next round of testing. Testing will continue throughout February.

C28016
Ventsim Goaf Model Development - Stage 2: Goaf Flow – Ventilation Interactions

CSIRO
Martin Griffith
Qingdong Qu

Value:	$319,465
Report Expected:	February 2024
Industry Monitor/s:	Paul Wild
	Peter Baker
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C28027
Effect of Occlusions by Coal and Stone Dust on the Sensitivity and Time Response of Methane Gas Detectors in Underground Coal Mines

Ampcontrol
Gareth Kennedy
Ian Webster

Value:	$90,000
Report Expected:	March 2024
Industry Monitor/s:	John Grieves
	Ken Singer
	Patrick Tyrrell
ACARP Contact:	Peter Bergin

The overall objectives of this project are to:
1. 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; and
2. 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.

During the quarter the following tasks were undertaken or completed by Simtars, related to objective 2.

Equipment modifications: Test rig completed and commissioned to undertake comparison of Calibration Cups (OEMs and Simtars' designed) and occlusion using tape, as agreed with the Project Leader.

Measurement:

- 350 tests were completed on the gas detectors, comparing the gas detectors' accuracy and response times when using OEM specific Calibration Cups or Simtars designed Calibration Cups.
- 559 tests were completed to verifying the effect of blockage applied to the detectors' inlets on the detectors' accuracy and time response.

Next steps:

- Finalise a report for the comparison of Calibration Cups with respect to the detectors' response time and accuracy;
- Finalise a report for the effects of blockages on the gas detector's response time and accuracy;
- Commence dust occlusion testing within the purpose-build chamber towards completion of the laboratory testing at Simtars by mid-2024.

C29018
Evaluation of Explosion Resistant Ventilation Control Devices and Determining Explosion Risk Exclusion Zones

University of Wollongong
Alex Remennikov
Andre De Kock
David Carey
Gareth Kennedy
Timothy Jackson

Value:	$562,560
Report Expected:	June 2025
Industry Monitor/s:	David Webb
	John Grieves
	Ken Singer
	Paul Wild
	Russell Thomas
	Tim Huston
ACARP Contact:	Peter Bergin

This second stage of this project aims to properly characterise the threat of projectiles from mine entrances through a systematic experimental and numerical approach. Since the start in June, the following project tasks have been undertaken:

- Small-scale Advanced Blast Simulator (ABS) – Additional modifications were completed to enable the initiation of the methane-air cloud within the ABS with a booster. Preliminary tests with the new initiation system show that objects placed inside the ABS could be ejected out the back from the explosion. Additionally, engineering design work was performed on a platform to allow control of the gradient of the ABS to more realistically simulate an inclined drift. Fabrication of the platform is planned to begin in February.
- Determination of the effects of scaling – Fluid-structure interaction modelling was performed using LS-DYNA (FEA) and Viper::Blast (CFD) to determine the effects of scaling down from full-scale (actual) to small-scale (1:10 experimental). Properties such as

projectile launch velocity, trajectory, and others were explored. This is important for experimental planning and for appropriately calibrating the masses of the projectiles for the experiments.

- Development of an experimental program for studying projectiles ejected from drifts.
- Comprehensive literature review – Review was continued on relevant research on debris ejected from the adit of underground installations in the open literature and military documents: previous experimental/numerical studies of projectiles from tunnels, relevant empirical equations, mathematical models, existing guidelines against projectiles from adits (AASTP-4, DDESB, etc) and damage/injury criteria.

C33018
Strata Gas Content using Geophysical Logs and Laboratory Measurements

University of New South Wales
Guangyao Si
Joung Oh
Peyman Mostaghimi

Value:	$128,560
Report Expected:	February 2024
Industry Monitor/s:	Agi Burra
	Mark Laycock
	Russell Thomas
ACARP Contact:	David Drakeley

The draft final report has been submitted to the Industry Monitors for review.

C33029
Review Longwall Face Ventilation to Mitigate Goaf Gas Emissions onto Walkways and Tailgate End

University of Wollongong
Ting Ren

Value:	$146,500
Report Expected:	February 2024
Industry Monitor/s:	Ventilation Task Group
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34010

Time Lapse In-Seam Seismic and Resistivity Measurements as an Integrated Component of a Smart Coal Seam Gas Pre-Drainage Practice: Literature Review

University of New South Wales
Hamid Roshan

Value:	$60,000
Report Expected:	February 2024
Industry Monitor/s:	Ventilation Task Group
ACARP Contact:	Peter Bergin

The draft final report has been submitted to the Industry Monitors for review.

C34011

Appraisal of Gas Indicators from Goaf Drainage Holes for Spontaneous Combustion and Explosion Risk Management: Stage 2

University of New South Wales
Guangyao Si

Value:	$223,254
Report Expected:	June 2024
Industry Monitor/s:	David Webb
	John Grieves
	Ken Singer
	Paul Wild
ACARP Contact:	Peter Bergin

The project objectives are to:

- Develop CFD models to simulate intensive goaf drainage impact and interaction with longwall ventilation airflow. This will be calibrated and validated by a large amount of goaf gas drainage data collected from the Stage 1 project;
- Understand the migration pathways of leaked air from the face to individual goaf holes; and
- Evaluate the effect of goaf holes on pulling oxygen back and goaf fringe size, at various goaf drainage scenarios (completion depth, position, layout, suction pressure) and goaf natural characteristics.

In the last quarter, further models were developed on the spontaneous combustion of coal in the goaf, building upon previous studies. This CFD model employs the Arrhenius Equation to simulate the rate of oxidation reaction of coal at low temperatures in the goaf area. Additionally, this model utilises the concentrations of the oxidation reaction products, CO and CO_2, as gas indicators for assessing spontaneous combustion risks in the goaf. As depicted in Figure 1, the contours of O_2, CH_4, CO, and CO_2 at 0m above the seam were analysed. Furthermore, various factors affecting spontaneous combustion risks in the goaf were examined, including the oxidation rate, oxygen concentration, gas flow rate, and others. Consequently, under the influence of intensive goaf gas drainage, the spontaneous combustion risks in the goaf can be assessed.
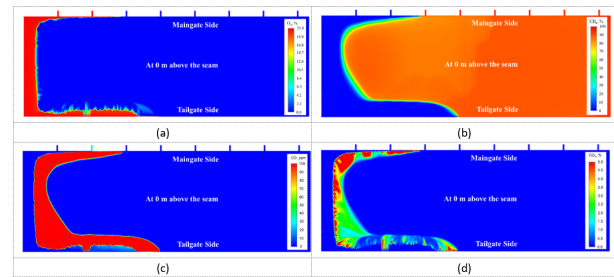

Figure 1. (a) O_2 concentration contour (unit: %), (b) CH_4 concentration contour (unit: %), (c) CO concentration contour (unit: ppm), and (d) CO_2 concentration contour (unit: %) at 0m above the seam in the goaf.

C34014

Borehole Tools to Deal with Outbursting, Coal Bursting and Gas Drainage: Stages 1 and 2

Sigra
Ian Gray

Value:	$1,678,320
Report Expected:	May 2024
Industry Monitor/s:	Brad Lucke
	Ventilation Task Group
ACARP Contact:	Patrick Tyrrell

The aim of this project is to produce a survey system for drilling, including a rock recognition system and a packer system to enable coal seam permeability and pressures to be determined. The project is multi-facetted as it involves drilling hardware, sensing equipment, downhole and at the drill rigs sensing and electronics. This is in both IS and flameproof form and it also involves a lot of software development.

Part of this project involves the modification of a drilling rig to record the operation of the chuck, rod gripper, drilling fluid flow, drill head position etc. The mine has a requirement that all such equipment shall form part of the drill rig manufacturers design. However, the rig manufacturer does not wish to incorporate any modifications, which has brought the project to an impasse. Some solution has to be found that may involve changing drilling rig manufacturer and trial mine.

On other aspects the project is progressing steadily. Internal trials on Sigra's drill rig have been satisfactory. The downhole and most of the uphole equipment is proceeding to IS certification.

Software development is proceeding reasonably and will be complete by the time IS achieved.

C35012
Optimising Gas Management

CSIRO
Rao Balusu

Value:	$100,000
Report Expected:	March 2024
Industry Monitor/s:	Ventilation Task Group
ACARP Contact:	Patrick Tyrrell

Looking solely at inertisation may not be a true reflection on the best management strategies, therefore this project will initially look at current management systems and strategies used throughout the industry including areas where high gas drainage rates in goaf holes influence high oxygen concentration levels that may create a significantly increased risk of spontaneous combustion. The main objective of this project was to work with industry on a scoping study for research to implement the development of optimum inertisation strategies to reduce oxygen levels in goaf holes and to minimise oxygen ingress on both maingate and tailgate sides of the longwall goaf.

Base-case CFD model of longwall goaf has been developed incorporating various features to carry out extensive investigations. Preliminary modelling simulations and calibration studies are continuing to obtain goaf gas distribution patterns in the longwall goaf under base-case mining conditions and different operational scenarios.

C35015
Studies of Coal Toughness and Gas Sorption Dynamics for Outburst Risk Management

University of Wollongong
Ting Ren

Value:	$275,000
Report Expected:	June 2025
Industry Monitor/s:	Ventilation Task Group
ACARP Contact:	Patrick Tyrrell

The objective of this project is to improve industry knowledge and management of potential outburst risks by conducting systematic studies of coal toughness, geo-mechanical properties and gas sorption dynamics with different coals sourced from underground coal mines in New South Wales and Queensland.

The project has completed the following tasks:
- Laboratory sorption testing, including adsorption/desorption isotherms, sorption hysteresis and rapid desorption based on fixed gas content, has been completed on eight different intact coal samples by using both CH4 and CO2;
- Direct evidence of gas fast desorption induced damage to coal structure has been studied by using CT scanning, and quantitative characterisation of coal structure changes and damage was achieved by assessing void volume measurement before and after the rapid desorption, with initial results presented in Fig. 1(a) and (b);
- A number of coal toughness tests have been conducted for a comprehensive database of the coal toughness test index (f) in collaboration with participating labs;
- Further mechanical property testing of coal and coal measure rocks, including UCS, uniaxial cyclic loading, and Brazilian tensile test, with some testing results presented in Fig 1. (c);
- Intact coal samples delivered to University of Queensland have been prepared for comprehensive geomechanical testing, including triaxial, uniaxial compressive strength (UCS) and Brazilian tensile testing.
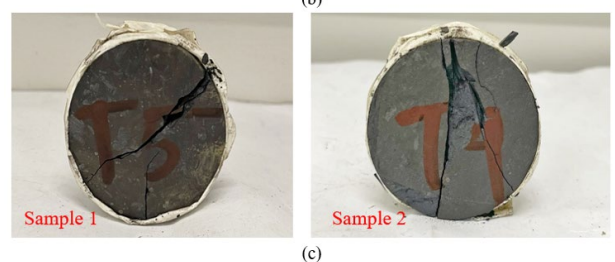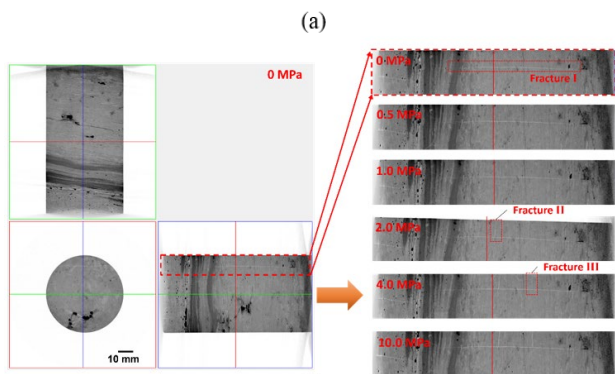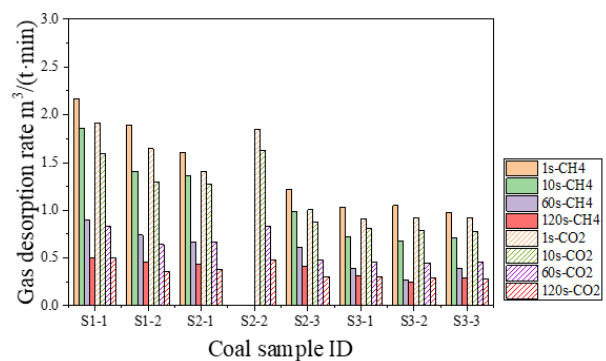

Fig 1. (a) Fast desorption rate comparison of CH4 and CO2 at 10m³/t; (b) CT scanning results of intact coal samples under different sorption pressure, (c) Brazilian tensile testing of intact specimen

C36003

Practical Implications of Oxygen Deficiency on the Determination of Graham's Ratio in Longwall Goafs

Simtars
Gareth Kennedy
Sean Muller

Value:	$64,350
Report Expected:	November 2024
Industry Monitor/s:	David Webb
	John Grieves
ACARP Contact:	Patrick Tyrrell

Graham's ratio is a commonly used indicator for measuring the intensity of the oxidation of coal in underground mine atmospheres. The basis of Graham's ratio is the conversion efficiency of oxygen to carbon monoxide. Graham's ratio uses the nitrogen from a sample for the calculation of oxygen deficiency. This allows for dilution by methane and carbon dioxide seam gases. This calculation is made on the basis that nitrogen is an inert gas which is not consumed or created.

This project will investigate the practical implications for the interpretation of Graham's ratio and other indicators in the presence of an oxygen deficient atmosphere (due to natural processes and both added nitrogen or exhaust gases via inertisation).

Request for mine data has commenced and is currently being acquired for data review.

C36005

Optimisation of Goaf Management Strategies

CSIRO
Rao Balusu

Value:	$1,443,557
Report Expected:	November 2027
Industry Monitor/s:	Ventilation Task Group
ACARP Contact:	Patrick Tyrrell

The objective of this recently commenced project is to develop optimum goaf management strategies to maximise goaf gas drainage, reduce oxygen ingress into the longwall goaf, and minimise fugitive emissions. The main focus of the project are to:

- Obtain a fundamental understanding of goaf gas distribution; obtain an understanding of the impact of various geological, mining and operations parameters;
- Investigate the feasibility of various goaf gas drainage designs and strategies to maximise gas drainage and minimise oxygen ingress;
- Develop optimum inertisation strategies to minimise oxygen ingress on both maingate and tailgate sides of the longwall goaf;
- Examine the impact of various additional goaf management strategies; and develop optimum adjacent goaf gas drainage strategies to minimise greenhouse gas emissions into the main return airways.
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OPEN CUT

Geology

C34016
Elements in Coal – A Start-to-End Analysis

CSIRO
Jane Hodgkinson

Value:	$119,035
Report Expected:	February 2024
Industry Monitor/s:	Raymond Howard
	Shaun Booth
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34020
Guideline for Standardising Structure Interpretation in ATV/OTV Logs

University of Queensland
Mojtaba Rajabi

Value:	$163,415
Report Expected:	April 2024
Industry Monitor/s:	Brian Vorster
	Euan Macaulay
	Matt Tsang
ACARP Contact:	Cam Davidson

This project aims to develop a guideline for processing, analysis, and interpretation of geological features in image logs. Such guideline will significantly reduce the inconsistencies and misinterpretations through image log interpretations. To achieve this goal, a wide variety of data including core, ATV/OTV and company experts' knowledge to develop a guideline for standardisation of image log interpretation and nomenclature will be combined.

Progress during this quarter:
- The data analysis (including >1100 ATV logs) have been completed;
- The library of features in image logs (such as fault, fractures, sedimentary features, cleats, breakouts, induced fractures) is still in progress completion is anticipated in this quarter;
- Dictionary of features and flow chart of ATV analysis have been almost finalised;
- The project report writing has commenced.

C34029
Laser Induced Breakdown Spectroscopy (LIBS) as a Rapidly Deployable Field Technology to Estimate Coal Quality

CSIRO
Joe Perkins

Value:	$135,510
Report Expected:	March 2024
Industry Monitor/s:	Mark Laycock
ACARP Contact:	Patrick Tyrrell

This project aims to validate Laser Induced Breakdown Spectroscopy (LIBS) as a rapidly deployable field technology to assess coal quality.

The project will:
- Calibrate a rapidly deployable handheld LIBS device using mine site samples and established traditional testing with the aim of obtaining comparable analysis results for fixed carbon, moisture, volatiles, ash and Sulphur.
- Develop experimental protocol to enable the rapid field assessment and estimation of coal quality to enable informed decisions regarding further laboratory testing and exploration strategies.
- Lay the foundation for future adaptation of this hardware that would enable LIBS to be utilised as a non-destructive method for assessing the numerous geophysical survey downholes, thereby greatly enhancing the characterisation of a targeted resource.

A draft project report has been completed and is currently under review at CSIRO. It is expected that this will be sent to the industry monitors shortly.

C34037
Statistical Analysis of Methods for selecting Lithology Boundaries from Density and Natural Gamma logs and assessing their ability to select Lithology Boundaries in Blast Holes

GeoCheck
Brett Larkin

Value:	$76,000
Report Expected:	March 2024
Industry Monitor/s:	Mark Laycock
ACARP Contact:	Patrick Tyrrell

This project has the following objectives:
- Compare the current methods for selecting the points on the downhole geophysical density and natural gamma curves that indicate lithology boundary depths.
- Assess statistically which method is the most accurate and whether this depends on the geological environment and/or make of the geophysical tool that collected the data.

- Most current methods make an additional adjustment on the selected boundary depths for thin coal bands and thin partings within coal seams, which is related to tool resolution. The study will compare these adjustments.
- Assess which adjustment method is the most accurate and determine if a better method can be developed. Again, the most suitable method may depend on the geological environments and/or make of the geophysical tool that collected the data.
- Assess if the lithology boundary methods can be applied to blast holes, primarily using density logs from the holes but also natural gamma and drilling penetration rates.

Work to date has focused on the optimal degree of noise filtering of the natural gamma and density logs. Too little filtering and geologically meaningful features are hidden in the noise and too much and they are lost. A method has been developed to determine automatically, the optimal filtering for each variable in each borehole. Work has also focused on applying the techniques for automatically selecting boundaries from density logs to gamma logs but there are some doubts as to its usefulness.

Current work has continued on interviewing senior geologists regarding the degree of filtering that they believe is optimal and their methodologies for selecting tops and bottoms of seams and partings from the geophysical logs.

C35023
Recovery of Critical Minerals from Coal and Coal Production Waste

CSIRO
Clint McNally
Jamie Hodgkinson
Nerrida Scott
Philip Ofori

Value:	$154,000
Report Expected:	April 2024
Industry Monitor/s:	Andrew Lau
	Caroline Lang
	Shaun Booth
ACARP Contact:	Patrick Tyrrell

The objective of this project is to identify potential sources of rare earth elements in coal and production waste. The work considers possible pathways for characterisation, reprocessing and repurposing of wastes that may have critical minerals value in a coal resource.

Early work considered the potential for presence of rare earths in tailings, however, in the samples provided, the levels of rare earths were not significant. This may have been due exclusively to the source of these particular samples. Further work has since identified that there are some locations within the selected test mine that suggest the existence of rare earths exceeding crustal averages.

While characterisation and analysis of samples continue, what remains is to determine potential economically sound methods to extract rare earths from these sources. A range of tests will be done to determine this. Depending on where the rare earths exist, it may be possible to stockpile material for later processing or to process through existing processing pathways.

C35025
CSR Predictions and Correlations Definition

McMahon Coal Quality Resources
Chris McMahon

Value:	$35,880
Report Expected:	November 2024
Industry Monitor/s:	Alison Burke
	Maurizio Tonelli
	Tomoaki Nagata
ACARP Contact:	Patrick Tyrrell

This project seeks to take the published equations, chart data (that can be converted to formulas), and data attained from MCQR's ACARP work, multiple projects and estimators produced in those projects, and industry supplied data to compare against each other and define the effectiveness of each CSR predictor for product coals of varying coal quality characteristics. Several deposits/coal types will be evaluated.

In order to minimise standard error of outcomes (the chosen metric for precision/variability assessment), MCQR plans to test both historical data and MCQR attained data via a "proportional" coal quality approach. The "proportional" approach will allocate percentage contribution to each coal quality test from an optimisation engine process with the goal of minimising standard error outcomes. This approach is in contrast to almost all prior predictive models which were largely based on polynomial equations constructed to give the highest correlation coefficient for the coal quality tests examined.

A request for information memorandum issued in November with receipt of information and commencement of data processing and review is scheduled for February. One borecore database received to date, two others and three shipping databases are due.

The outcomes of this project will be the definition of accuracy (precision and bias) information for varying CSR Estimators (both published and MCQR developed) with differing coal types. This will benefit the industry by providing predictive formulae and ranges of CSR outcomes for a range of coal types, and potentially add to correct resource representation and/or lower analysis costs.

C35047

Real Time Prediction of Coal Top Through Guided Borehole Radar Wave Imaging for Open Cut Blast Hole Drilling Phase III

CSIRO
Matt van de Werken
Wayne Stasinowsky

Value:	$396,792
Report Expected:	April 2025
Industry Monitor/s:	Jack Woollett
	Troy O'Reilly
ACARP Contact:	David Drakeley

The project objectives are to:
- Extend and mature the technology and engineering developed in Phase II;
- Develop a fully functional real time coal top guidance system prototype suitable for field demonstration trials where it is fitted to a blast rig drilling production holes;
- Develop a prototype to the stage that the technology is ready to engage a commercial partner.

Progress during the quarter:
- The main focus since the last report has been on the electronics. The electronics boards are now fabricated after a few minor issues and a test rig for the boards has been built. Firmware programming is underway for the various controller chips with testing scheduled for this month.
- Integration into the mechanical housing has been tested with integration and testing also scheduled for this month.
- Discussion is underway with a mine for a suitable date for the next phase of field testing.

Drilling and Blasting

C27024

Evaluation of Production Trials of HP Explosives

Mining3
Andrew Kettle

Value:	$477,920
Report Expected:	March 2024
Industry Monitor/s:	Andrew Lau
	Brett Domrow
ACARP Contact:	Cam Davidson

The objective of this project is to demonstrate the manufacture and delivery of Hydrogen peroxide (H2O2)/oil-based emulsion-style explosive using a specialised Mobile Processing Unit (MPU) and evaluate blast performance in surface mine-site operations with increasing scales of production. This project progresses the research plan for H_2O_2-based explosives from confirmation of first viable formulations meeting sleep-time and detonation performance towards

implementation and adoption by focussing on manufacture and delivery procedures to meet mine-site operational requirements with a central focus on safety.

Work undertaken during the quarter:
- A blasting company partnership is being negotiated and Mining3's commercialisation roadmap is being explored. Discussions were delayed due to an IP challenge that was successfully overcome and have been resumed.
- The Elquip prototype mixing platform has been temporarily deployed into project C35028 to enable resource sharing, reduce asset duplication, and reduce project costs.

C33041

Production Trials in Two States of HP Explosives with Custom MMU

Mining3
Ewan Sellers

Value:	$342,034
Report Expected:	August 2024
Industry Monitor/s:	Andrew Lau
ACARP Contact:	Cam Davidson

This project is currently on hold while C27024 is completed; due to shared use of equipment.

C35018

Reactive Ground Testing

QMR Blasting Analysis
Alastair Torrance
Gary Cavanough

Value:	$250,000
Report Expected:	January 2025
Industry Monitor/s:	Andrew Micallef
	Mark Laycock
ACARP Contact:	David Drakeley

The objective of this project is to evaluate and introduce a new testing method for assessing reactive ground in coal mining.

Acid has been identified as the key driver for the reaction of sulphide and nitrates. Literature was reviewed on acid mine drainage and it was identified that the formation of hydrous sulfate minerals in coal spoils can be significant sources of 'stored acidity' (Alpers et al., 1994). Experiments were conducted and identified that white crystals formed on pyrite when it was wet and then left to air dry. The crystals were concentrated on the edges indicating that the water was washing off surface oxidation of the pyrite particles with crystals forming as the water naturally evaporated. The white crystals have a pH of 2 and pyrite containing white crystal reacted with nitrates whereas pyrite with no surface crystals has a pH of 4 and does not react with nitrates. Testing confirmed

that coal was able to inhibit a reaction of pyrite containing white crystals and nitrates.

Pyrite was milled to sizes of 250 um and 75um passing mixed with pH8 and pH6.5 ground that contained no carbonates. The samples were tested with the new test method, the AEISG screening test method and the AEISG screening test method with water substituted for weathering agent.

The new test method was unaffected by particles size. No reaction was observed for samples tested as per the AEISG screening test with water substituted for acidic weathering agent. In the case of the AEISG test the finer particle sample reacted on heating and the other sample had a small initial temperature rise and then a much larger temperature rise than the finer sample after five hours. This test further confirms that acid is the driver of the reaction of sulphide and nitrates and highlights the randomness of AEISG test results.

C35028
Mining Explosive Sensitisation using Chemical Free Methods

Mining3
Andrew Kettle

Value:	$297,256
Report Expected:	March 2024
Industry Monitor/s:	Andrew Lau
	Brett Domrow
ACARP Contact:	Cam Davidson

The objective of this project is to further enable and improve bulk hydrogen peroxide (H_2O_2)-based emulsion mixtures. This project investigates unique sensitisation methods of H_2O_2-based emulsion mixtures. Success of this project will lead to improved H_2O_2-based explosive performance, reduced material costs, and an in-line reactor for an on-bench emulsion manufacture process within a mobile production unit (MPU).

Progress during the quarter:
- In the Sydney-based Elquip workshop, the first prototype research mixing platform (see photographs) was built. This unit has temporarily utilised the framework from the C27024 prototype mixer, and reused components of the C25005 mixer. This decision has enabled resource sharing across the projects, reduced asset and legacy equipment duplication, and reduced project costs for C35028.
- The final reactor component, is on-route from Germany, which is needed to complete our first prototype. The critical component is anticipated to arrive in late February. This delivery was delayed so exceeded the expected eight to ten weeks supply window.
- Initial mock testing has commenced, with two preliminary design approaches resolved and rejected. The design of the prototype platform enables rapid modification for design changes to test multiple design modifications inherent in the research approach.
- Due to accumulation of mock (water-based) emulsion waste from prototype testing in both this project and C27024, a waste reduction method was determined and tested. The mock emulsion produced from trials is essentially ~90% water, so the opportunity to remove this water greatly reduces the volume of waste from testing. After consultation with suppliers, searching literature, and laboratory trials, it has been determined that the easiest and most cost effective process to destabilise the rugged emulsifier was freezing using dry ice pellets that deliver an immediate sub-zero temperature source around -78°C. Following mixing of the pellets into the mock emulsion, the predominately water emulsion freezes solid with water crystals destroying the emulsion structure. Upon thawing most of the water can be removed by a density separation, as the remnant fuel phase floats on the surface. This on-site simple waste processing has reduced disposal costs by substantially reducing the waste volume.

Figure 2. A & B. Elquip's rapid modification prototype test mixer platform completed. This unit has temporarily utilised the framework from the C27024 prototype mixer, and reused components of the C25005 mixer. [Image acknowledgement: Otto Lambe, Elquip]

Environment

C29047
Reducing Uncertainty in Long Term Water Quality Predictions for Final Void Management

University of Queensland
Sue Vink

Value:	$245,600
Report Expected:	February 2024
Industry Monitor/s:	Andrew Lau
	Jason Fittler
	Steve Downes
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C29049

Saline Pit Lakes as Aquatic Ecosystems: A Design Manual for Closure

Edith Cowan University
Mark Lund

Value:	$1,089,226
Report Expected:	May 2024
Industry Monitor/s:	Andrew Lau
	John Watson
ACARP Contact:	David Drakeley

Pit lakes are one of the greatest legacies of open cut mining, but they are not well understood. The broad aim of this extension project is to produce a state-of-the-art design manual for saline pit lakes to assist companies prepare for closure. Researchers will continue to broaden the current biophysical monitoring program to include new pit lakes. They will document the range of interannual variability in the biophysical data and long term trends in lake ecosystem development. They will also investigate how the use of floating vegetated islands could enhance riparian development at closure and during lake fill.

The overall project approach has two main components:
- In situ component: Continuing the monitoring of four saline pit lakes (Hunter Valley and Bowen Basin) for a broad range of water chemistry, physical and biological parameters from C27043. Based on findings from the C27043 monitoring program, some refinements have been introduced that include improved replication of water quality data, and consistent numbers of macroinvertebrate and diatom samples between sites. Each lake will be sampled twice yearly. Using instrument chains, installed in all lakes we collect hourly data on stratification and salinity levels.
- Experimental component to examine rehabilitation options: Carbon (in the form of terrestrial organic matter) determines the nature of the aquatic food web and creates important habitat. In C27043, using tank mesocosms (1000 L) on site, the effects of adding coarse, low-cost organic matter on lake water and sediments on biophysical and chemical endpoints (as measured in the lake) were tested. Based on the positive improvements recorded, the mesocosms and test both organic matter phosphorus additions will be reset in this project. Low phosphorus concentrations were recorded in all the pit lakes studies in C27043, and additions should stimulate primary production, creating more food for macroinvertebrates.

Quarter activities:
- Littoral areas are currently being assessed as a part of the experimental design for 2c. Further experimentation is being planned;
- Four pit lakes across the Hunter Valley and Bowen Basin are being used for an experiment to test the effectiveness of different types of organic matter on

macroinvertebrate communities. Additionally an experiment to measure organic matter breakdown rates in situ was piloted. Based on the successful pilot this experiment at these four lakes has commenced;
- Floating islands (three with plants and three without as controls) have been installed and sampled at two pit lakes in the Bowen Basin;
- A database of all pit lake papers available was been completed and will be used to investigate the current state of the art in pit lake science.
- The final sampling trip was completed in November.

C33035

High Water Recovery, Low Cost Desalination using PV-Powered Membrane Capacitive Deionisation (mCDI)

University of New South Wales
Boyue Lian
David Waite
John Fletcher
Yuan Wang

Value:	$334,340
Report Expected:	March 2024
Industry Monitor/s:	Kane Eskola
	Nash Hancock
	Nick Cook
ACARP Contact:	David Drakeley

The draft final report has been submitted to the Industry Monitors for review.

C33043

Best Practice Management and Performance Assessment of Biodiversity Offset Areas

Eco Logical Australia
May-Le Ng
Rachel Murray

Value:	$335,540
Report Expected:	May 2024
Industry Monitor/s:	Mark Nolan
	Nigel Charnock
ACARP Contact:	David Drakeley

The project objectives are to:
- Develop evidence based decision support tools to assist environmental managers to select the best BOA management practices for site conditions, optimise resourcing and maximise biodiversity outcomes;
- Provide managers with appropriate performance indicators and reference benchmarks that better reflect important changes in BOA condition or ecological function as a result of management actions;
- Review current monitoring and data assessment methods and examine approaches to trend analysis that can better account for data variability caused by external factors (for example, rainfall patterns);

- Develop a guide for environmental managers on BOA monitoring, data collection and data evaluation methods to support performance and compliance assessment, and adaptive management;
- Assess any emerging bushfire risks associated with BOAs and identify options for management; and to
- Identify research priorities to address outstanding information gaps.

The fauna monitoring data are informing development of the monitoring and analysis guide. Survey for faunal groups such as bats and birds provide an opportunity to use economic, repeatable and defensible methods (acoustic surveys). Typical survey methods used for other faunal groups are not easily comparable between monitoring events (active search and meander methods are hard to standardise) and therefore good data is hard to obtain without substantial effort. Therefore, we are working to review typically employed techniques and where methods used can be improved to provide data required to understand change through time. This directly contributes to identification of monitoring and data analysis methods for the monitoring and analysis guide. The rehabilitation guide continues to be developed, with technical inputs provided to date being converted into a guide. Results of the data analysis and literature review are being added informing the guides to the technical report.

C33046

Rationale for the use of Paired Continuous Real Time Noise Monitors to Reduce Uncertainty in the Quantification of Noise from Open Cut Coal Mines

Umwelt (Australia)
Steve Lyons
Tim Procter

Value:	$125,000
Report Expected:	March 2024
Industry Monitor/s:	Ned Stephenson
	Ngaire Baker
ACARP Contact:	Patrick Tyrrell

The installation of continuous noise monitors either individually or as part of a continuous noise monitoring network has been a prescriptive requirement of the regulatory authorities since the mid-2000s. The systems are cumbersome and the data overwhelming. While the SMART phone application has improved information accessibility, quantitative source identification can still be difficult to achieve. This project aims to build on previous work to develop a rationale for using the relationship between various data metrics collected by paired acoustic monitors to reduce uncertainty in the quantification of noise from open cut coal mines in complex acoustic environments. This rationale could then be used across the mining industry to provide more accurate noise source quantification.

Preparation of the draft report has been undertaken during this quarter.

C33047

Best Method for Determining Atmospheric Stability for the Assessment of the Acoustic Environment in the NSW Coal Mining Industry

Umwelt (Australia)
Steve Lyons
Tim Procter

Value:	$276,000
Report Expected:	March 2024
Industry Monitor/s:	Ned Stephenson
	Ngaire Baker
ACARP Contact:	Patrick Tyrrell

The prime objective of the project is to determine which method (Pasquill-Gifford sigma-theta method or temperature lapse rate method) is the most appropriate for the assessment of noise enhancing conditions, design of noise control strategies and the establishment of performance-based noise licence conditions within the NSW coal mining industry. This would include the identification of the most appropriate bin structure for the lapse rate analysis.

During this quarter, further consolidation of the analysis of the noise and meteorological data was undertaken along with preparation of the final report.

C34025

New Landscape Evolution Model for Assessing Rehabilitation Designs

University of Newcastle
Greg Hancock

Value:	$875,391
Report Expected:	March 2025
Industry Monitor/s:	Chris Quinn
	Jason Fittler
ACARP Contact:	Patrick Tyrrell

The objectives of this project are to:
- Test and develop the newly developed SSSPAM landscape evolution model (LEM) so that it can be used easily to evaluate both constructed and proposed post-mining landforms. The model will be tested and calibrated across a range of sites in Queensland and New South Wales.
- Develop a database of parameters that can be used by the industry across a range of sites, materials and climates.

Model input parameters have been developed for a site in Queensland and the Hunter Valley. For both sites updated (LiDAR) survey data together with additional site history has been requested. Data from a former Queensland trial has also been supplied with additional information sourced from previous ACARP projects and literature. This has now been processed and while valuable, is not sufficiently reliable for parameter determination and results appear limited in regards to

developing a set of LEM parameters. A second site in an agricultural environment is now being also examined for both SSSPAM and SIBERIA.

C34027

Microalgae Cultivation as a Low Cost Method for Desalinating Void Water and Generator of Post Mining Bioeconomic Activity from Final Voids

University of Queensland
Ben Hankamer
Leigh Trevaskis

Value:	$2,159,848
Report Expected:	March 2025
Industry Monitor/s:	Andrew Lau
	Jason Fittler
	John Watson
	Trudy Mazucco
ACARP Contact:	Patrick Tyrrell

The second stage project objectives are to:
- Confirm pilot scale microalgae production and desalination performance;
- Assess effective microalgae harvesting, determine biomass composition and processing methods;
- Validate and characterise pilot scale salt extraction;
- Optimise process control based on pilot scale system performance;
- Refine technoeconomic simulations for guiding pre-commercial cultivation and biorefinery process delivery for an anticipated pre-commercial stage; and
- Develop a valid commercialisation pathway and value chain to market.

This quarter, the following work has been conducted.

Microalgae cultivation: A floating photobioreactor (Gen-1) was installed and tested. Based on this photobioreactor, a Gen-2 version was built and installed. Control, harvesting and water recycling facilities have been installed for summer, spring/autumn and winter production and desalination trials.

Microalgae strains: 11 strains were isolated in Stage 1 and identified to the genus level. The three most promising strains were subjected to further nutrient screens and desalination trials to fast-track optimisation of pilot scale cultivation outcomes. Microalgae were effectively harvested. Biomass composition analysis methods are underway (e.g. protein and oil content).

Desalination: Pilot scale salt extraction will be conducted as part of the above pilot trails. The systems and analytical methods for this work are in place.

Process control: Robust process control strategies have been put in place.

Technoeconomic simulations: The pilot scale performance data will be integrated into these to enhance their quality.

Commercialisation pathway: The project evaluated a range of operating regulatory framework for a void-based microalgae operation (e.g. pre- and post-mining lease relinquishment) for feedback from mining partners, Government departments, and other stakeholders. Opportunities for testing of harvested biomass to clarify downstream target products have been identified.

C34028

Guidelines for Assessment of Geotechnically Safe and Post Mining Landforms

Sherwood Geotechnical and Research Services
John Simmons

Value:	$120,000
Report Expected:	March 2024
Industry Monitor/s:	Andrew Lau
	Brian Vorster
	Trudy Mazucco
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34030

Optimising Plant Growth and Flood Preconditioning for Tailings Dams

CSER Research
Carmen Castor
Mike Cole

Value:	$294,583
Report Expected:	May 2024
Industry Monitor/s:	Andrew Lau
	Shaun Booth
	Trent Cini
ACARP Contact:	Patrick Tyrrell

This project has the primary objective of optimising plant survival on tailings dams by assessing pre-conditioning to flooding, growth medium mixes and pot size. It also aims to expand the number of primary species appropriate for coalfields in New South Wales and Queensland. Outcomes will be published via C35048.

Short term access has been granted at the site of the parent projects (C27009 and C29041) of this program. Metrics of the surviving plants will be developed in the next few months to provide a preliminary assessment of the impact of plant density on transpiration loss of water from the dam.

A short term experiment to evaluate the use of matting to enable establishment of seedlings directly on tailings to be assessed (below), emergence responses will be assessed in the next couple of months.

C34035
High Interest Native Plant Pittosporum Angustifolium for Mine Rehabilitation: Key Strain Identification and Germplasm Propagation Investigation

RNA Environmental Services
Ryan Anderson

Value:	$197,401
Report Expected:	July 2024
Industry Monitor/s:	Andrew Lau
	Andrew Micallef
ACARP Contact:	Patrick Tyrrell

Hardy native ethnopharmaceutical plant species on locations relevant to Queensland coal sites with potential, via successful vegetative propagation (cloning), for integration into closure goals.

The objectives of the project are to:
- Develop closure beneficial land use opportunity with hardy local high interest native species;
- Document benefits of reference population including 'local knowledge' and prior scientific research;
- Develop geodatabase of CQ phenotypic populations relevant to mine operators to facilitate utilisation of the species distribution best suited for site implementation;
- Genomic characterisation by Australian Genome Research Facility (AGRF) to facilitate sub-species utilisation. Contribute to national knowledge of Australian native plant genomic mapping;
- Tailored phytochemical extraction methodology developed by University of Newcastle specialists;
- Assay anti-cancer properties of phytochemical active ingredients by Bill Walsh Centre Kolling Institute;
- Develop robust practical methodology for successful vegetative propagation not previously achieved;
- Deliver P.angustifolium tubestock suitable for field implementation by interested operators; and
- Prepare Final Report and deliver Workshop to engage with operators and facilitate tech transfer.

Project progress overall:
- Good progress made with Prostate Cancer Cell Line testing of phytochemical extracts.

- Very dry Spring. Plant populations sampling delayed until early December after rainfall. Focus on Genomics investigations and material for Tissue Culture Program. Soil profile sampling undertaken for multi-elemental analysis, physical and chemical characterisation.
- Fieldwork completed.
- Final Reporting underway, awaiting results from some service providers.

Soil Sampling:
- Soil sampling completed December 2023, analytical interpretations underway and ongoing.

Propagation:
- Prior vegetative propagation attempts has lacked success, typical of hardy Native Plant Species and significant plant pathogen issues.
- Plant material collection December with hand delivery by RNA Team to laboratory in Victoria.
- January results show again unfortunate issues with infection resulting. One sample showing promise.

Genetics:
- Final representative plant material collection completed in December, to facilitate stable shipping, local provider for freeze drying was identified and engaged (CQU), freeze drying completed in January and dispatched to laboratory.
- Discussions ongoing with laboratory regarding timing of analysis and finalisation of results.

Cancer Cell Testing:
- Promising results from significant amount of laboratory work completed to end December 2023.
- IC50s (Efficacy) for all 25 phytochemical extracts re-tested using MTT (cancer cell proliferation) utilising DU145 cell line.
- Five most potent extracts identified had MTTs performed (repeat experiments n=4) on all three cell lines (DU145, PC3 and LNCAP) and compounds of interest narrowed to four.
- Preliminary experiments to optimize conditions (cell numbers, plating times, and extract concentrations) for Annexin V Muse Assays and Scratch Wound Assays conducted on all three cell lines.
- LNCAP cell line not viable for Scratch Wound Assays: no formation of uniform cell layer to be scratched. Hence assays to be performed with DU145 and PC3 cell lines only.
- Final Work planned:
  o Finish optimising Annexin V and Scratch Wound Assays and perform three repeat experiments on all cell lines with the four most potent extracts.
  o Optimise Cell Cycle Assays and perform three repeat experiments on all cell lines with the four most potent extracts.

C35021
Delineating Water Tables and Flow Pathways Inside Spoil Piles to Support Water Quality Predictions

University of Queensland
Mansour Edraki
Neil McIntyre
Thierry Bore

Value:	$297,420
Report Expected:	August 2025
Industry Monitor/s:	Andrew Lau
	Steve Downes
ACARP Contact:	David Drakeley

The aim of the project is to detect the spatial and temporal distribution of major flow pathways and water table(s) inside spoil piles with the level of confidence required for the progressive rehabilitation of spoil piles and prediction of water balance and water quality of final voids, in particular predictions of spoil seepage quality.

During the quarter, the focus was on reviewing and identifying a site with suitable attributes as the case study for this project. The selected site is in the Gloucester Basin. The site is preparing to finish coal extraction in 2024 and will transition to closure upon completion of mining operations. As such, it is ideal for this project because it has a range of spoil piles at various stages of closure and rehabilitation and an extensive in-situ monitoring program. It is also located in an area with relatively evenly distributed rainfall throughout the year. Currently, the research team is planning a geophysical survey of selected spoil piles.

C35026
Management Strategies for Invasive Leucaena on Coal Mine Sites

University of Queensland
Shane Campbell

Value:	$531,528
Report Expected:	January 2027
Industry Monitor/s:	Andrew Lau
	Cian Morgan
	Dominique Taylor
	Morné van Zyl
ACARP Contact:	Patrick Tyrrell

The primary objective of this project is to develop strategies to effectively manage the invasive species leucaena (Leucaena leucocephala) in rehabilitation on coal mine sites in Queensland. Leucaena is a leguminous tree introduced to Australia for use as a forage for livestock production, but it has also become an environmental weed in sub-tropical and tropical regions, including on several coal mine sites in central Queensland.

Over the last three months, a residual herbicide trial has commenced at the University of Queensland's Gatton campus. This pot-based trial is evaluating the effectiveness of ten herbicides to prevent seedling recruitment of leucaena from the soil seed bank, with an untreated control included for comparison. As part of this trial, the influence of soil type on residual activity is also being investigated with each herbicide treatment applied to three different soil mediums (field reference soil, stockpiled topsoil, waste rock). These findings will be used to identify the most promising herbicides for follow-up field testing on mine rehabilitation. A suitable site near Rockhampton has been found to undertake an insitu fire trial on leucaena. Planning is underway in conjunction with the land manager (Department of Environment and Science) to evaluate the effect of single and repeat burns on leucaena populations, as a follow up to a lab-based trial on leucaena that investigated the effect of high temperature and exposure duration combinations on seed dormancy/viability, as reported previously. A second PhD student has joined the project team and will initially focus on testing foliar herbicide options for control of leucaena. Through consultation with herbicide experts a range of potential herbicides will be identified for testing at several rates.

C35029
Renewable Energy as Post Mining Land Use

University of Queensland
Claire Cote

Value:	$186,628
Report Expected:	May 2024
Industry Monitor/s:	Jason Fittler
	Ned Stephenson
	Raymond Howard
ACARP Contact:	Patrick Tyrrell

A baseline assessment of post mining land use in Queensland concluded that in the Bowen Basin and Surat Basin, renewable energy produced by solar and wind had vast potential. However, the pathway to implementation is not clear as regulatory barriers and planning constraints are not fully understood. This project aims at examining how renewable energy projects can be set up on a mining lease and be accepted as post mining land use by regulators and stakeholders.

The review of legal acts and planning approval processes is complete and has led to the identification of three potential regulatory pathways. This has been further refined and four pathways are now defined: two are relatively straight forward, one is more complex and one potentially very challenging. The nature of the tenure for the underlying land will dictate which pathway needs to be followed.

Explanatory diagrams have been prepared for each pathway: they outline the assessments that must be undertaken, requiring the compilation of data and site specific information. This is now being tested using the

case study sites. Data sets include two major and two ancillary spatial datasets: mine site land use, land tenure conditions (major), existing grid infrastructure and site specific factors (ancillary), as well as proximity to agricultural land. Land tenure for mines in the Bowen Basin is generally freehold or a Lands Act lease, with minor occurrences of easements, reserves and state land. Mine site land use data is provided using the PRCP spatial data submission schema via the "Activity Type" field and is used to identify suitable locations for renewable energy installations. This data will also be used to estimate the cost to build and maintain different renewable energy technology on different land uses (e.g. waste dumps, laydown yards, undisturbed land, industrial area). Ancillary criteria that will be integrated into the analysis are distance to the electrical grid and local site-specific factors (e.g. subsidence areas).

Parallel to this, a review of large scale renewable energy projects set up near or on mine sites is progressing. This provides baseline information to support the cost-benefit analyses of such projects and identifies key operational considerations.

C35030
Erosion and Sediment Control Framework for Queensland Mines – Calibration and Validation

University of Queensland
Robynne Chrystal

Value:	$347,196
Report Expected:	April 2026
Industry Monitor/s:	Andrew Lau
	Jason Fittler
	Steve Downes
	Tim Kendrick
ACARP Contact:	Patrick Tyrrell

A framework for Erosion and Sediment Control Plans (ESCP) for Queensland coal mine sites was developed during project C29046. The ESCP Framework uses a GIS-based RUSLE tool that was developed to quantify soil loss on site, assist with identifying erosion risks and with selecting, designing, and implementing controls on site. This work also provided guidance on the key steps for sediment basin design. This project aims to verify that the soil loss rates calculated using the GIS-based RUSLE tool accurately represent site conditions at different catchment scales and land uses and that the guidance provided in C29046 is applicable and reflects approaches that ensure compliance.

Three study sites have been selected and the available data have been assessed following data submission from all industry partners. Following an updated RUSLE model for hundreds of subcatchments of ~ 1 ha size, sediment fences and height markers were installed on mine site 1.

Based on data analysis and preliminary catchment based RUSLE models, discussions are currently underway with industry representatives from mine site 2 to implement sediment monitoring set-ups to be implemented by site personnel/contractors.

Initial data submission from mine site 3 is completed and discussion regarding trial areas have been scheduled within the next week. Site 1 will be revisited in Q2 of 2024 to install additional sediment fences in a catchment with recently finished dump reshaping.

Site visits to these two sites are planned for the next two months to conduct final site selection for sediment fence locations and height markers.

Geotech

C29005
System for Rock Fall Analysis Field Trial

CSIRO
Marc Elmouttie
Peter Dean

Value:	$321,268
Report Expected:	March 2024
Industry Monitor/s:	Matt Tsang
ACARP Contact:	Cam Davidson

Systems to detect, monitor and analyse rock falls in open pit mining operations have the potential to improve operational safety, improve calibration of rock fall simulators (restitution coefficients), and importantly provide quantitative data to justify current standoff designs. A monitoring system that can accumulate a large database of rock fall events across the full strike length of highwalls is required. The use of existing monitoring systems (radar, vision, lidar) as well as knowledge of the wall geometry, geology (rock mass types) and structural characteristics (defect orientations and intensities) has potential to support detection of events (potentially in real-time) and detect rock fall movements accurately enough for determination of trajectories (bounce kinematics), impact locations and final resting positions. This project will field trial a prototype system which will consist of software and computing hardware to integrate data from radar, vision and microseismic monitoring systems.

In response to industry monitor recommendations regarding site support constraints (in particular, difficulty in securing infrastructure on-site for housing the monitoring equipment), and after discussions, the project work plan was modified to support development of a trailer based solution. The team successfully sought internal funding to design and commission the construction of a trailer to house, power and cool the geophone and interrogator systems needed for the seismic monitoring system.

In the previous quarter, further CSIRO based testing was undertaken to confirm both robustness and performance of the system. This is currently ongoing and certain issues regarding the environment enclosure are being rectified. Site trials are currently being organised and it is planned that a site investigation will occur in the next quarter in preparation for field deployment.

C29048
Image Based Automated Characterisation of Waste Materials

University of New South Wales
Klaus Thoeni
Simit Raval

Value:	$279,540
Report Expected:	March 2024
Industry Monitor/s:	Adrienna Robotham
	Ned Stephenson
ACARP Contact:	Patrick Tyrrell

This project aims to utilise image processing techniques to facilitate the automated characterisation of spoil in dumpsites. The project involves collection of a large number of drone images from multiple dumpsites, both in New South Wales and Queensland. A parallel project, C29044, was conducted to provide ground validation for the image based characterisation approaches.

In order to bring the project to a comprehensive conclusion, an end-to-end workflow has been developed. This workflow spans from data collection through to the identification of realistic failure risks. To this end, a 3D stability analysis has been conducted (see figure), utilising spatially defined dump material through the established characterisation pipeline in this project. The new approach allows for the identification of critical sections within the dump, providing a more detailed and accurate risk assessment.
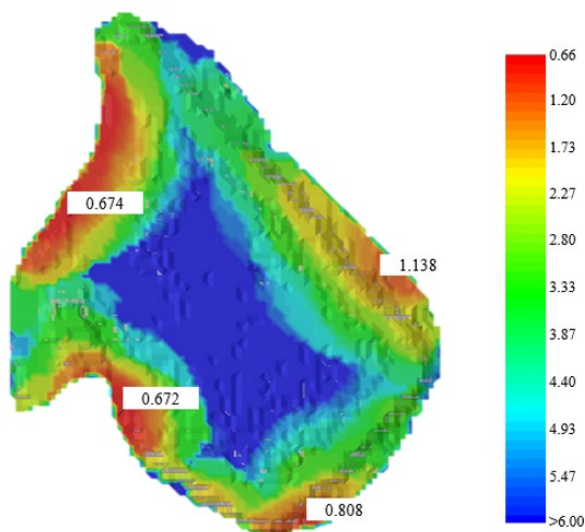

Fig. The outcome of a 3D stability analysis highlighting the slip surfaces along with their corresponding factors of safety.

The final report will be ready for submission in February.

C33040
Machine Learning for Rockfall Analysis

University of Newcastle
Anna Giacomini
Klaus Thoeni
Marc Elmouttie

Value:	$342,240
Report Expected:	November 2025
Industry Monitor/s:	Matt Tsang
ACARP Contact:	Cam Davidson

This project proposes the use of machine learning (ML) for rockfall analysis. The objective is to identify a rapid and reliable method for estimating the location and energy of rockfall events at the base of a highwall for an effective mitigation of the associated risks. The main outcome to the industry will be an ML-based tool to manage rockfall hazard.

Stage 1 investigated the feasibility of ML to predict the rockfall hazard based on an extensive virtual data set of 4.5 million 2D rockfall trajectories. The latter was generated by means of rockfall simulations along 2D sections extracted from 15 different highwalls. The outcomes of Stage 1 show that simple ML models, such as non-linear regression, can be used to estimate rockfall energy and run-out with some confidence. Stage 2 will focus on the application of more sophisticated ML approaches and more rigorous validation. It is also planned to extend the approach to include more site-specific information such as stratigraphy and other geological features.

The last quarter focused on refactoring the code developed in Stage 1 and identifying more advanced algorithms that might be suitable for the analysis of the data. The team is planning to extend the initial virtual data set by analysing additional highwalls. NDAs are currently being signed to allow access to additional data.

C35022
Quantifying Hoek-Brown Disturbance Factor (D) for Coal Measures Through an Integrated Laboratory and Numerical Modelling Approach

University of Queensland
Italo Onederra
Zhongwei Chen

Value:	$355,776
Report Expected:	May 2025
Industry Monitor/s:	Adrienna Robotham
	Matt Tsang
	Peter Chern
ACARP Contact:	Patrick Tyrrell

The main objective of the project is to construct a comprehensive and generalised estimation method for the Disturbance factor (D) in coal measure strata. This mainly includes the quantification of the variation of D in

response to blast-induced damage and scale effects to establish an effective guide for the definition of D in slope stability analysis.

In this quarter, the planned modelling work with the use of the Hybrid Stress Blasting Model (HSBM) has been completed. This work aimed at defining blast damage envelopes based on the maximum particle velocity mapping approach previously introduced in the project. The multi scenario analysis included changes in blasthole and charge diameter, charge length, point of initiation (priming location), explosive density and velocity of detonation (VOD).

With the assistance of a set of purpose built python scripts and employing dimensional analysis, an empirical relationship between blast design parameters and expected damage is currently under development. This pragmatic approach marks a departure from existing methods in predicting blast damage profiles, offering a more accurate yet practical tool without the need of advanced computational models.

In the upcoming quarter, a review of all available experimental and production scale blasting data associated with near-field particle velocity, blast damage and disturbance factors will be conducted. The aim is to develop an appropriate relationship between maximum particle velocity mapping and D factor attenuation.

Maintenance and Equipment

C26020
Preventing Fatigue Cracking Via Proactive Surface Dressing

Bureau Veritas AIRS
Simon Krismer

Value:	$126,940
Report Expected:	March 2024
Industry Monitor/s:	Shane Saunders
ACARP Contact:	Patrick Tyrrell

Condition monitoring mining equipment and structures for fatigue cracking is costly. Proactively dressing surfaces susceptible to fatigue cracking could be significantly cheaper than condition monitoring in terms of labour costs and downtime. This project will assess the effectiveness of using surface linishing to remove accumulated fatigue damage. Surface linishing is a cheap, readily accessible technique that requires no special tooling.

The initial testing regime to determine the baseline testing parameters and sample fatigue life has been completed. This means that the following parameters can now be set for future testing to establish whether accumulated fatigue damage can be removed:
- Sample deflection;
- RPM;

- Number of cycles before treatment to remove fatigue damage; and
- Testing intervals to check for development of fatigue cracking.
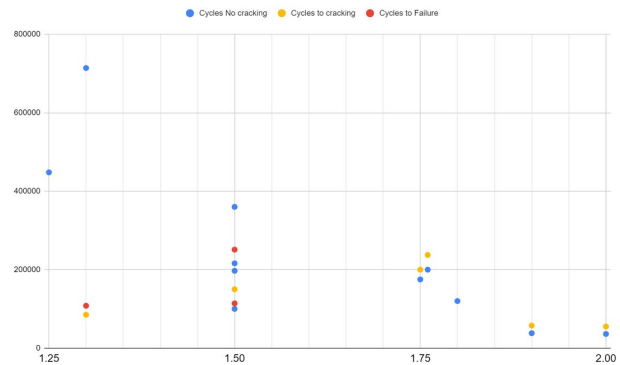
The lab work may now proceed with testing the damage removal and how much needs to be removed from the surface of the samples, and establishing statistically significant data to establish a conclusive outcome.

C33034
Dozer Suspension Seat to Reduce Body Vibration

University of Queensland
Danellie Lynas

Value:	$83,107
Report Expected:	March 2024
Industry Monitor/s:	Shane Apps
	Tim Gray
	Troy O'Reilly
ACARP Contact:	Cam Davidson

The project objective is to evaluate the effectiveness of an innovative passive vibration and movement cancelling seat prototype in reducing dozer operator exposures to excessive whole-body vibration during normal operation at surface coal mines. This project extends projects C23022 and C26026 through an evaluation of a potential engineering control.

Previous project data indicates dozers are associated with whole -body vibration levels that frequently exceed the upper limit of the Health Guidance Caution Zone defined by ISO2631.1. Project C26026 provided the technology to allow continuous remote monitoring of floor and seat accelerations, as well as simultaneous GPS data.

An innovative passive suspension system has been patented and successfully tested in lab-based experiments recreating vertical vibration exposures from several different types of commercial vehicles and in a field-based experiment evaluating an on-road truck application. The design was found to reduce whole-body vibration exposures by 50% compared to conventional, commercially available mechanical and air-suspension seats. Based on these preliminary results, the seat suspension design appears to have the potential to

substantially reduce operator exposure to whole body vibration.

This technology along with data collected in previous projects, will be utilised to develop a prototype seat tuned to the specific vibration attenuation requirements of dozers. Independent evaluation of the performance of the seat will be undertaken in real mine operation utilising the technology developed in project C26026.

Progress to date:
- A prototype seat base tuned to the specific vibration attenuation requirements of the dozer has been laboratory tested in the US and fabricated to replicate the site dozer seats. The prototype seat was fitted to a dozer on site November. Pre and post installation measurements were undertaken.
- The final report is currently being drafted.

C33036
Radar Tyre Monitor System

CSIRO
Luke Powell
Pat Humphries

Value:	$132,382
Report Expected:	March 2024
Industry Monitor/s:	Brendan Wilkins
	Rob Fraser
	Tim Gray
ACARP Contact:	Cam Davidson

Underinflation and/or overloading of mine truck tyres causes undue cyclic stress to the internal steel cords, causing them to fatigue. "Zipper" failures can occur when such damaged tyres are reinflated, potentially causing serious injury or fatality. This project is undertaking the development and trialling of a monitoring system for haul truck tyres to identify tyre fatigue. The proposed system would consist of a continuous monitoring sensor combined with software analytics that will seek to identify and characterise significant changes in the tyre structure that correlate with incipient failure modes.

During the quarter, processing of field data has continued. Further contributions to the preparation of the final project report have been made. An additional tyre rolling setup has been constructed to assist in collecting some supplemental data of off the rim tyre surface scans to provide further comparisons of good tyres and tyres with known damage. Off the rim data processing has continued and will be collected for the final report.

C34026
Human Aspects of Automation and New Technology in Mining: Integrating People and Technology Through Human Centred Design

University of Queensland
Robin Burgess-Limerick

Value:	$375,573
Report Expected:	April 2024
Industry Monitor/s:	Belinda Martin
	Brad Lucke
	David Martin
	Leveson Sutton
	Tony Egan
ACARP Contact:	Patrick Tyrrell

This project focuses on how automated subsystems and other new technologies being introduced to coal mines can fully accommodate human abilities and limitations and be fully integrated into overall operational work systems. Data collection for the project is complete.

In summary, the overall impact of increased mining equipment automation is likely to be improved safety and health. However, from an EMESRT control framework point of view, introducing autonomous components creates new credible failure modes. These failure modes include: software shortcomings; communication technology disruption; cyber security breaches; unauthorised access to autonomous zones; loss of manual skill; over-trust; input errors; inadvertent mode changes; complex interactions; sensor limitations; lack of system awareness of environment; loss of situation awareness; distributed situation awareness challenges; communication difficulties; workload; and musculoskeletal injury risk factors. While guidelines for the implementation of autonomous mining equipment exist, the existing documents pay insufficient attention to the integration of humans and technology during the implementation of automation in mining.

The final report is being prepared which explores the potential benefits and failure modes associated with mining equipment automation and describes a framework for improving safety, health and productivity through human-centred design.

C34031

Reducing Noise Emitted by Heavy Vehicles in Open Cut Coal Mines

University of Technology Sydney
Mahmoud Karimi

Value:	$231,645
Report Expected:	April 2024
Industry Monitor/s:	Brendan Wilkins
	Tim Gray
ACARP Contact:	David Drakeley

The aim of this project is to develop bespoke computational software that will be used to develop and optimise the design of splitter silencers used to attenuate noise on the intake and exhaust openings of cooling systems incorporated on turbomachinery in the mining industry.

The objectives of the project are to:
- Develop a theoretical model for the prediction of sound attenuation by splitter and louvre silencers used in turbomachinery intake and exhaust openings of cooling systems;
- Validate the new model by predicting the performance of existing designs and compare against experimental measurements provided by Hushpak;
- Use the validated model to optimise silencer design, which is likely to be through the optimisation of material parameters and the number and geometry of the baffles;
- Design and test a new silencer for Hushpak, who will build, install and test the new silencer on a real commercial application.

Work is progressing on the final report, which will include an analysis of the previously generated design curves and a review of existing louvre designs under review; these being the Caterpillar 789D, 793C, 775G trucks and a Caterpillar MD6250 rotary drill. The final report will advise acoustic engineers on how to design effective louvres and the effect of altering each design parameter.

The parametric study has been extended to consider the effect of elevated temperatures simulating the higher operating temperatures found in Australian open cut mines. It is expected that increasing temperatures will lead to decreased low frequency performance and a shift in the peak insertion loss to higher frequencies. However, the extent of this change remains to be quantified.

C34038

Development of Innovative Lock Ring Free OTR Wheel

University of Queensland
Lenny McInnes

Value:	$60,000
Report Expected:	February 2024
Industry Monitor/s:	Brendan Wilkins
	Rob Fraser
	Tim Gray
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

Mining and the Community

C28046

Broader Contribution of Coal Sector Employment to Indigenous Individuals, Families and Communities

Myuma
Michael Limerick

Value:	$199,472
Report Expected:	February 2024
Industry Monitor/s:	Andrew Lau
	Brian French
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

Health and Safety

C33008

Relevance and Applicability of Inhalable Dust and Current Issues with AS3640

University of Queensland
Guldidar Kizil
Hsin Wei Wu
Mehmet Kizil

Value:	$244,833
Report Expected:	February 2024
Industry Monitor/s:	Andrew Lau
	Brad Lucke
	Kevin Rowe
	Sharif Burra
	Tony Egan
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C35020
Human Centred Interactive Training Experiences in OTR Tyre Handling

ViVA! Health at Work
Karen Saunders
Sara Pazell

Value:	$688,282
Report Expected:	June 2024
Industry Monitor/s:	Brendan Wilkins
	Rob Fraser
	Tim Gray
	Tony Egan
ACARP Contact:	Patrick Tyrrell

The aim of the project is to test effective, agile, and rapid methods to transfer knowledge of subject matter experts at scale among tyre technicians performing tyre handling operations with known fatality exposures. The objectives of the project are to evaluate the impact of human factors methods of knowledge elicitation, combined with technology-enhanced transfer of this information through an Interactive Product Viewer with scenarios elaborated by different system actors in different points of view, and through Visual Remote Guidance on the tyre technicians' knowledge of hazard exposures that contribute to fatalities in OTR tyre handling.

During the quarter ViVA health at work and Real Serious Games met to review the contemporary technologies: The Novaten Interactive Product Viewer (IPV) in its notepad access format, and the new headwear from Realwear Visual Remote Guidance (VRG). The review to better understand the technology applications and human interface requirements was undertaken. The research investigator reviewed and edited the Novaten supplementary material: A gap analysis, a learner's guide, and a facilitator's guide. From this, the technology partner worked on the second iterations. The research team developed the draft job analysis and job capacity checklist of a tyre technician with input of the industry EMERST Tyres & Rims Technical Working Group subgroup and submitted for review by the group at large.

The EMERST Tyres & Rims Technical Working Group sponsored an industry workshop on 23rd January. This involved the industry monitor ,Tony Egan, who was able to provide direction during the interactions. The project teams facilitated domain expert working groups in their expansion of the library of scenarios (developed during C33005) and their consideration of the use cases of the technologies in preparation for project site visits.

Literature review is continuing, with the current focus on examining the nine levels of human readiness for technology adoption. This will inform ongoing examination of the supplementary materials to support these technologies, and the approaches to prop mining site visits.

COAL PREPARATION

Maintenance and Equipment

C35036
Autonomous Stockpile Dozing: Quantifying Viability

University of Queensland
Ross McAree

Value:	$352,797
Report Expected:	April 2024
Industry Monitor/s:	Chris Huth
	Chris Jackson
	Frank Mercuri
	Jimmy Pollack
	Peter Shumack
ACARP Contact:	Patrick Tyrrell

This project investigates the practicality of employing automated bulldozers for coal stockpile management. Bulldozers, essential in constructing and reclaiming stockpiles, are tasked with redistributing material from piles formed by stackers and later, repositioning it towards the reclaim valves. A significant risk in these operations is the potential for bulldozers and their operators to be engulfed due to ratholes near reclaim valves. The central concept of this project is to eventually deploy unmanned, semi-autonomous bulldozers for material movement from stockpiles to reclaim valves, taking into account supply-demand dynamics. These machines will autonomously make decisions regarding the timing and methodology of their operations. The project's justification hinges on two pivotal aspects:

- Technical viability for efficient, effective, and safe operations; and
- Business rationale, weighing the technology's cost against its operational benefits.

Progress during this quarter has focused on testing the hardware system, including integration testing of LiDAR, GNSS, and camera systems, and refinement of algorithms to determine optimal strategies for stockpile extension and reclamation, aligned with coal arrival and output schedules. A detailed plan for data collection has been developed, which was anticipated to commence in early 2024, but now delayed to March/April. Analysis of data collected will be crucial in determining the feasibility and advantages of transitioning to semi-autonomous bulldozer operations.

Dewatering

C27016
Eriez HydroFloat in Plant Evaluation

Eriez Magnetics
Darren Mathewson
Liam Davis

Value:	$155,600
Report Expected:	March 2024
Industry Monitor/s:	Han Hooi
ACARP Contact:	Ben Gill

The Eriez HydroFloat is a small footprint, high capacity, coarse particle flotation technology capable of recovering coal from a fine (eg -2.0 +0.25 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 flotation.

The yields from 19 tests on the TBS feed stream at the first site were very high at an average of 97.1% (ad) at low average product ashes of 8.8% (ad). The tailings ashes were high at an average of 75.4% (ad) and the combustibles recoveries were extremely high at an average of 99.2% (ad). As expected, the greatest variation in yield was in the +1.4 mm size fraction, which ranged from 79 to 96.3% (averaged 89.4%) (ad). The yield of the other size factions was >95% (ad), on all but one occasion. The Organic Efficiency for the -2.0+0.25 mm fraction was up to 99.7%.

The Whiten equation was curve fitted and showed cutpoints between 1.80 and 2.20 RD with -2.0+0.5 mm Eps of between 0.087 and 0.166 for the four best tests. Due to the higher than expected cutpoints, there is often only one, or zero, float-sink fractions above the calculated cutpoint, so the curve-fit is significantly overestimating the cutpoint and the Ep. Being the very first Australian HydroFloat trial, it was also expected that some results would be sub-optimal. A test work plan is being discussed with an alternate site.

C28056
Surface Alloying of Centrifuge Baskets and Sieve Bends Screen Surfaces to Increase the Service Lifetime

CSIRO
Teresa Kittel

Value:	$131,644
Report Expected:	February 2024
Industry Monitor/s:	Caitlin Campbell
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C29060
Tailings Management - Dewatering Flume Site Trials

University of Newcastle
Craig Wheeler

Value:	$242,500
Report Expected:	February 2024
Industry Monitor/s:	Kevin Rowe
	Peter Shumack
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C33048
Capability for Dewatered Tailings and MPR Testing in Support of a Critical State Soil Mechanics Framework for Potential Liquefaction Assessment

University of Newcastle
Jubert Pineda

Value:	$232,600
Report Expected	February 2024
Industry Monitor/s:	Jianping Li
	Kevin Rowe
ACARP Contact:	Ben Gill

The draft final report has been submitted to the Industry Monitors for review.

C33049
Emerging Pulsed Power Technology for Dewatering Mineral Tailings

University of Queensland
Mansour Edraki

Value:	$277,630
Report Expected:	May 2024
Industry Monitor/s:	Dan Delahunty
	Jack Lauder
ACARP Contact:	Ben Gill

Mechanical dewatering of wet tailings is expensive and eliminating final moisture remains challenging. A new dewatering method is proposed that uses pulsed electric fields to liberate water bound within, or to, the mineral component. A bench top study will be undertaken to test the system at two scales (1L and 5L).

In the last quarter the focus was on the dewatering process for 5 L of tailings. Various electrical conditions were tested to identify the most energy efficient condition for dewatering. Figure 1 shows the energy efficiency results for 1 L and 5 L samples while using the pulsedpower technology. The dewatering process was repeated using the DC power to prove the efficiency of the pulsed-power pethood.
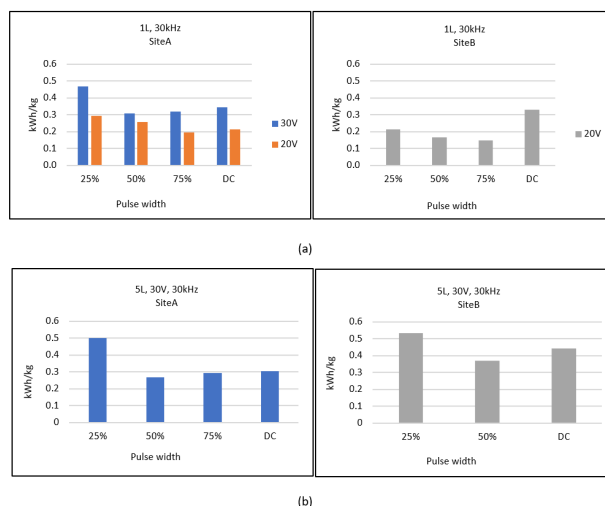

(a)

(b)

Figure 1: The energy efficiency of both (a) 1-liter and (b) 5-liter tailings was evaluated.

Table I presents a comparison of the achieved results in terms of energy efficiency with several recently published research outcomes. It is worth noting that the dewatering results in our approach were solely derived from the application of electrical energy (the pulsed power technology), and no mechanical press was utilised during the tests. Currently, the data analysis and preparing the final report are being worked on.

Table I: The summary of the dewatering conditions and consumed energy for each trial.

factor study	Raw sludge weight	Applied voltage	Applied pressure	Tailing's moisture content (MC%)	MC% after treatment	Treatment time	Energy consumption (kWh/kg)
Wei [2022]	50 g	40V(DC)	2 MPa	86.1%	54.7%	10 min	1.24
Wei [2022]	50 g	40V(DC)	3.5 MPa	86.1%	44.6%	10 min	0.96
Shafaei [2022]	Not reported	50V(DC)	0.3 MPa	50%	30%	120 min	0.57
Yuksek [2022]	3 kg	30V(DC)	Null	56.99%	37.63%	165 min	0.56
Deng [2020]	110 g	30V, pulse (30Hz, 40%)	0.6 MPa	83%	58%	30 min	0.07
This study	1 kg	20V, PP (30kHz, 50%)	< 0.0002 MPa	38.7%	24.2% (upper layer)	100 min	0.27
This study	5 kg	30V, PP (30kHz, 50%)	< 0.0002 MPa	38.7%	22% (upper layer)	120 min	0.25

C33050

Dewatering Efficiency of Fine Flotation Concentrates by De-Aerating Froth Products - Plant Demonstration

University of Queensland
Yongjun Peng

Value:	$627,923
Report Expected:	March 2024
Industry Monitor/s:	Frank Mercuri
	Naresh Racha
	Shivank Vijayakumar
ACARP Contact:	Ben Gill

The objectives of this project are to:
- Develop large demonstration scale mechanical and vacuum deaerators which are fully automated and can run continuously in plants;
- Identify optimum operating conditions and control strategies through continuous plant trials;
- Evaluate and optimise equipment stability, wear, maintenance requirement and operational costs;
- Identify equipment size and key parameters for future full-scale operation in plants.

UQ researchers and DADI engineers have been actively engaged in facilitating the installation of the mechanical deaerator at Mine Site 1. Currently, the installation of mechanical deaerator is in progress and expected to be finished early February. UQ researchers have made a detailed research plan to conduct the plant trial on site. Upon the completion of the installation, UQ researchers will organise the plant trial at Mine Site 1. Once the trial is approved by Mine Site 2, the deaerator will be delivered to the site for installation.

C33051

Hybrid Microwave Technology for Dry Stacked Tailings Applications

University of Queensland
Christian Antonio

Value:	$121,335
Report Expected:	March 2024
Industry Monitor/s:	Frank Mercuri
	Kevin Rowe
	Naresh Racha
ACARP Contact:	Ben Gill

One of the most pressing challenges facing the mining industry today is the increasing frequency of catastrophic tailings dam collapses. There is a strong industry push to move away from wet tailings dams to drier and safer options. A viable alternative to tailings storage in dams is Dry Stack Tailings (DTS) technology.

This project proposes a new approach that could reduce tailings moisture contents to levels required for dry stacking – the use of Hybrid Microwave (MW) Technology. This approach combines microwave treatment with conventional dewatering techniques. This method could bridge the moisture content gap between conventionally dewatered material and Dry Stack Tailing requirements.

The project aims to evaluate the feasibility of a continuous process and measure the energy requirements to achieve different product moisture content. Finally, it will provide a concept for a microwave-assisted dewatering process for future research studies.

Progress during this quarter includes:
- Batch and continuous MW processing of the two proposed processing pathways were completed at MW power ranging from 0.5-2.5kW. In general -
  - tailings drying is achievable, with higher MW power resulting in more rapid moisture removal,
  - higher MW power resulted in higher absorption efficiency,
  - H_2O entrainment due to rapid moisture evaporation is likely occurring,
- Analysis of the results are being finalised;
- An external consultant assisting with the techno-economic analysis of the process was re-engaged.

C33053

Improving Centrifugal Dewatering via Modelling and Analysis

University of Queensland
Liguang Wang

Value:	$149,400
Report Expected:	February 2024
Industry Monitor/s:	Clinton Vanderkruk
	Colin Surawski
	Josh Kowalczuk
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34051

Cost Effective Approach for Coal Tailings Dewatering using Semi Inverted (SIV) Hydrocyclones

University of Queensland
Christian Antonio

Value:	$174,500
Report Expected:	March 2024
Industry Monitor/s:	Michael Carnell
	Naresh Racha
	Tom Wilson
ACARP Contact:	Ben Gill

The application of coagulation, flocculation, and mechanical dewatering units such as belt press filters (BPF), centrifuges, and horizontal belt filters (HBF) is currently used by industry as a practical approach for

dewatering coal tailings. However, there are still challenges that limit dewatering of coal tailings which affects the performance of these dewatering processes. These include the presence of clay materials, elevated fines and ineffective coagulation and flocculation methods, amongst others.

This project aims to develop a technologically and economically viable approach to reduce moisture content and capture fine clay particles in tailings to improve tailings dewatering outcomes, by using Semi-Inverted (SIV) Hydrocyclone Technology, followed by coagulation, and flocculation. The project aims to use the SIV to split a tailings sample into a coarse stream (underflow product), with reduced moisture content, and a clay-rich fines stream (overflow product). This will enable targeted processing of the two streams that could consequently improve the efficiency of downstream dewatering units. A potential tailings sample has been received for evaluation for use in this project.

Progress during this quarter include:
- Troubleshooting of the overflow (OF) sampler was undertaken and a fault was found to be from a faulty controller. The controller has been ordered and delivery is pending. Selected experiments will be repeated once the sampler is in working order again;
- Coagulation and flocculation experiments are pending.

C35032
Improving the Dewatering of Fine Coal Tailings by Minimising Micro-Nano Bubbles

University of Queensland
Yongjun Peng

Value:	$238,470
Report Expected:	January 2025
Industry Monitor/s:	Han Hooi
	Naresh Racha
	Tom Henshaw
ACARP Contact:	Ben Gill

The objectives of this project are to:
- Understand how micro-nano bubbles are stabilised in fine coal tailings and evaluating their effects on the settling, filtration/centrifugation and compaction of solid suspensions;
- Evaluating physical and chemical methods in collapsing micro-nano bubbles in enhancing the settling, filtration/centrifugation and compaction of solid suspensions; and to
- Demonstrating the benefit of breaking micro-nano bubbles to fine coal tailings dewatering.

In this quarter, the influence of flocculants on the generation of microbubbles in a two-phase system to address the first objective was investigated. The investigation identified the important role of the molecular weight of flocculants in generating microbubbles. The effects of flocculants on the

dewatering of concentrated tailings to address the second objective was also studied. It was found that the introduction of flocculants led to an increase in the viscosity of concentrated tailings, consequently decreasing the dewatering efficiency. Application of some physical methods to treat the concentrated tailings enhanced the dewatering efficiency.

Environmental Improvement

C29042
Tailings to Topsoil

University of Newcastle
Ken Williams

Value:	$765,300
Report Expected:	September 2026
Industry Monitor/s:	Bill Baxter
	Paul O'Loughlin
	Phillip Enderby
ACARP Contact:	Patrick Tyrrell

Stage 2 of this project was supported to further develop a co-utilisation and soil improvement program that addresses the environmental challenge of tailings management for mining operations. This transformational alternative for tailings management research optimises existing technologies for dewatering, delivery, and soil remediation processes into an integrated "pit to paddock" mobile plant emplacement and cultivation system.

The first large-hectare site trial began at the mine site. After a site visit in late January, the field trial layout was updated to better fit the allocated space (Figure 1). The plots have started to be pegged out (Figure 2 (A)). Figure 2 (B and C) shows the coal tailings and cow manure collected for the trial. The trial plan is outlined below:
- Two Blocks (Site A and Site B);
- Blocks are divided into 5 plots, (1) 0:100 tailings:soil, (2) 5:95 tailings:soil, (3) 10:90 tailings:soil, (4) 25:75 tailings:soil, and (5) Modified Tailings (50:50 tailings:waste-rock + cow manure);
- Plots are 15 (w) x 60 (l) x 0.1 (d) m with 1 m spacing (to avoid contamination from neighbouring plots);
- Tailings and topsoil will be mixed at the target ratio before land application. Ripping will occur in the same week of seeding. Seeding is anticipated to take place in late April or early June (but is dependent on the mining company's seeding schedule).
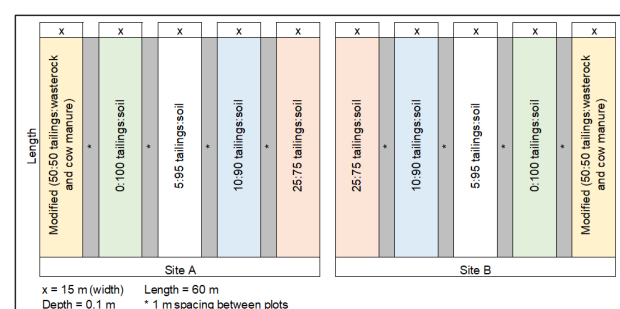

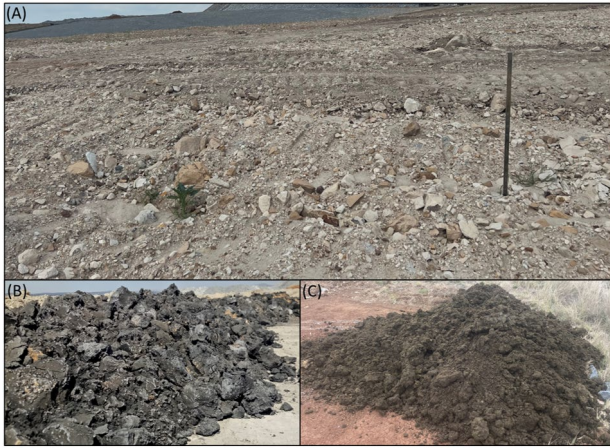Figure 3: Layout of large hectare field trial site.

Figure 4: (A) Plots at the trial site have started to be pegged out. (B) Coal tailings. (C) Cow manure.

C35019
Utilisation of Coal Mining Tailing in Australian Cement Production

Central Queensland University
Hassan Baji

Value:	$277,017
Report Expected:	October 2024
Industry Monitor/s:	Kevin Rowe
	Luke Dimech
	Shaun Booth
ACARP Contact:	Patrick Tyrrell

This project proposes a new framework of the circular economy and sustainable development by incorporating coal mine tailings as an alternative raw material in cement and concrete production instead of being a source of risk in polluting the environment. The project, in partnership with Holcim Australia and Cement Australia, has two major parts. In the first part, the use of treated coal tailings as a supplementary cementitious material (SCM) will be investigated, while in the second part the feasibility of utilisation of the coal tailings as a raw material in production of Portland cement will be explored.

Analysis of the reactivity data according to ASTM C1897 reveals that higher treatment temperatures result in increased pozzolanic reactivity (see Figure 1). However, the influence is not considered significant.
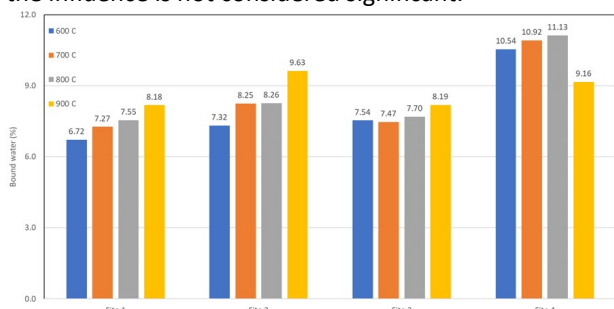

Figure 1: Reactivity of tested coal tailings (sites 1 to 4) as a function of temperature

On the other hand, the analysis of the strength and workability of mortar samples, prepared according to AS

3582.4, reveals that water demand decreases with treatment temperature. Additionally, it indicates that the 7 day strength is not sensitive to treatment temperature. Further analysis of the effect of curing time on reactivity and strength is currently underway.

Other research activities, specifically the cost-benefit analysis of using coal tailings as a SCM in concrete production and the use of coal tailings as a raw material in cement clinker production, are currently ongoing.

C35033
Non-invasive and Real Time Monitoring of Slurry Tailings Density and Velocity in the Transmission Pipeline using Electrical Resistance Tomography Method

University of Queensland
David Williams

|	
Value:	$259,000
Report Expected:	March 2025
Industry Monitor/s:	Angus Morrison
	Naresh Racha
	Peter Shumack
ACARP Contact:	Patrick Tyrrell

The objective of the project are to:
- Develop a resistivity inverse model that converts the longitudinal and cross-sectional resistivity tomography of coal slurry to its density and velocity, accounting for the effects of temperature, EC, air content and coal tailings mineralogy;
- Test the system at a coal transmission pipeline for in situ and real-time monitoring of the slurry transport conditions; and to
- Verify the monitored results with those obtained using concurrent technologies.

This quarter the following work has been undertaken:
- A shed situated at the University of Queensland, Long Pocket Campus has been designated to accommodate the pipe loop experiment setup. The shed has power supply and drainage needed for the experiment. Three phase power line used for the centrifugal pump has been connected to the room.
- The design of the "dam break" experiment is revised based on the assembly processes:
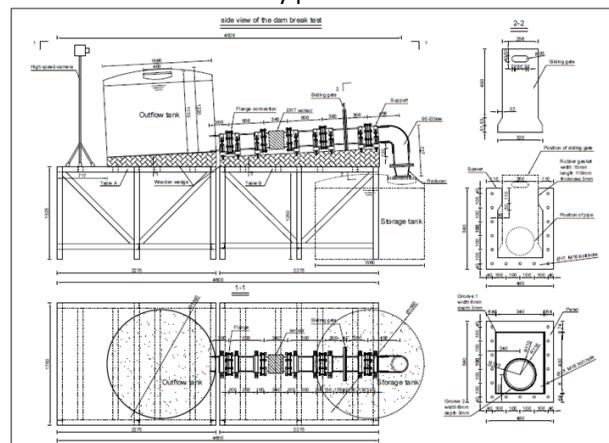
- After the dam break test, the facility will be repurposed to carry out the pipe loop test, according to the design below:

Aerial view of the pipe loop test
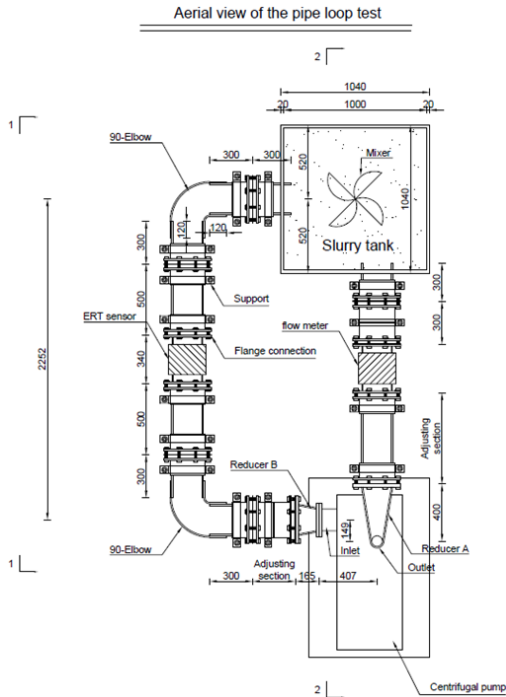
- The 1-D acrylic column (200mm in diameter, 1.2m high) for tailings settling test was delivered. Once the tailings densitometer arrives in mid-February 2024, settling test will be conducted.
- The centrifugal pump is ordered and expected to be delivered in late February. An emergence switch off enclosure for the pump is currently under production.

C35048
Cost Effective Rehabilitation of Tailings Dams

CSER Research
Carmen Castor
Mike Cole

Value:	$973,580
Report Expected:	March 2027
Industry Monitor/s:	Andrew Lau
	Shaun Booth
	Trent Cini
ACARP Contact:	Patrick Tyrrell

This project develops the research undertaken in C27009, C29041 and C34030 towards a possible conclusion allowing cost effective closure of tailings dams. It will aim to assist in developing a final land use plan with each mine and further test tailings amelioration techniques to maximise success for the native vegetation used. In addition, the project will work to maximise plant and soil biodiversity of the dams and their surrounds.

The research program has returned to the site of the original parent projects (C27009 and C29041) as noted in the C34030 report. The species used in the matting experiment have also been tested in seed germination trials in the controlled environment chamber and are showing interesting results. Most species used

germinated within one to two weeks on sand. Some germination was also observed for two of the species on a pilot study on tailings. This will allows selection of species potentially suitable for direct seeding into tailings. Further experiments are now being planned to develop methods to successfully gain germination on tailings.

Another site has been surveyed for long term survival of seeded species. The results have been incorporated in a growing data base which will address objective 3 of the grant to understand the biology and ecology of species that are hard to incorporate into rehabilitation or that disappear over time.

Preconditioning experiments are being continued under semi-controlled conditions and we will soon start to test different soil mixes for the Hunter Valley mine to develop a constructed soil capable of supporting the plants, their associated microbes and herbaceous ground cover species that assist with soil building and dust prevention.

Fine Coal

C29061
Improving Flotation Recovery and Throughput with a Combined Method

University of Queensland
Liguang Wang

Value:	$199,000
Report Expected:	April 2024
Industry Monitor/s:	Clinton Vanderkruk
	Doug Field-Akred
	Kevin Rowe
ACARP Contact:	Patrick Tyrrell

The objectives of this project are to:
- Develop and assess a method combining the use of oscillatory air supply and vibrators for further improving the flotation recovery and throughput; and to
- Prove the new method on an industrial scale.

A series of flotation trials in semi-continuous mode were conducted, with placing the loudspeaker at different locations. The preferred location of the loudspeaker for improving froth stability and flotation efficiency was identified.

A coal sample was received from a participating site for the pilot scale flotation trials in continuous mode. Preparation of the flotation feed for the trials is ongoing. Further test work has been done to optimise the operation of the pilot-scale test rig. The flotation tests in continuous mode will be conducted in the following quarter.

C29065

Wash Plant Fines Testing Methods Enhancement

McMahon Coal Quality Resources
Chris McMahon

Value:	$197,330
Report Expected:	May 2024
Industry Monitor/s:	Frank Mercuri
	Jason Schumacher
ACARP Contact:	Patrick Tyrrell

This project seeks to better determine predictive size distribution on small samples by testing multiple enhanced attrition apparatus and methods.

Originally a new "attrition" apparatus was to be designed, manufactured and trialled on "unbroken" coal (from strip samples and/or borecores supplied) and compared against plant feed/in-plant samples and standard laboratory drum tumbling test outcomes. CHPP operations data and operator expertise in relation to predictive/actual size distributions will also will be sought, documented and used in the planning and evaluation stages.

On further consultation with industry and examination of potential for building such an attrition apparatus, the process has evolved to test existing laboratory attrition processes in elevated time allotments, and the gauging of increased attrition effects compared with CHPP outcomes.

The attrition apparatus now being evaluated include additional drop shatter, dry and wet tumbling, sieving and use of a coke testing "Micum" tumbling drum. Individual and compounding effects (fines generation increase) will be examined.

Two potential coal sources have been confirmed. Source I has had sample retrieved, dispatched to the laboratory, methods confirmed and issued, and testing of all Stages (1, 2 and 3) now completed. Source II has had sample retrieved, dispatched to the laboratory, methods confirmed and issued, and testing of Stage 1, Stage II and Stage III completed. Lab processing of final Stage IV reporting is imminent, with a draft report to be submitted at the end of May.

The outcomes of this project will be testing of each attrition apparatus with attained bore core/in-pit site samples, and comparison of outcomes with both current methods of processing and CHPP actual outcomes (pre-plant / estimated in-plant). Methods for use of such will be produced for application to routine unbroken coal predictive samples (borecores and strip samples).

C33055

Optical Profiling of Coal and Mineral Particles in the Ultrafine Circuit for Online Analysis

University of Newcastle
Rohan Stanger

Value:	$157,387
Report Expected:	February 2024
Industry Monitor/s:	Clinton Vanderkruk
	Jason Schumacher
	Michael Carnell
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C33058

Full Scale Studies of Diesel Emulsification by Ultrasonication for Fine Coal Flotation

University of Queensland
Anh Nguyen

Value:	$180,000
Report Expected:	February 2024
Industry Monitor/s:	Clinton Vanderkruk
	Frank Mercuri
	Luke Dimech
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34002

Full Scale Beneficiation of Coal Fines by Novel Agglomeration

University of Newcastle
Kevin Galvin

Value:	$3,283,000
Report Expected:	February 2024
Industry Monitor/s:	Ben Gill
	Kevin Rowe
	Luke Dimech
	Paul Sainsbury
	Penny Walker
ACARP Contact:	Patrick Tyrrell

The objective of this project is to investigate the scale-up of a novel fine coal agglomeration technology through a study at full-scale. The project involves the design, commissioning and operation of the novel agglomeration technology. The feed source is expected to be a fine coal tailings stream suitable for the thermal market. The study will quantify the scale-up at 500m^3/h in terms of yield, ash, moisture and economic benefits.

The novel agglomeration technology offers the prospects of a low capital investment for processing the fine coal tailings stream normally sent to the thickener. The

agglomeration can be achieved by pumping the slurry and novel binder through an orifice plate in a pipe. Oil consumption is an order of magnitude below conventional requirements, while the final product moisture is lower than the usual level. Dry and wet process commissioning have been completed. Safety systems to address the delivery, storage, management and handing of RO chemicals were finalised. Full commissioning was then completed leading to the entire system being operated.

This project involves a substantial scale-up from a 25mm diameter pipe configuration to a 300mm diameter pipe system requiring the flow of the slurry and binder through a single hole in an orifice plate to produce agglomerates. The emulsion was successfully produced at full scale using the air sparging column, and its performance verified through bench scale tests. However, the emulsion formed using salt water from the process water via an RO system was also less robust than the traditional NaCl salt-based binder used in the past, hence it was necessary to base the design on a pressure drop at the lower end of the usual range, at about 50 kPa. The recent work on the full-scale plant demonstrated the difficulty of utilising a single, 100mm diameter, hole in the orifice plate, with poor agglomeration observed. The results suggested that the system does not scale directly, and that the collision efficiency with the emulsion binder is impacted negatively.

It was concluded that many smaller holes in the orifice plate would need to be used, but this created the additional requirement of a higher pressure drop to secure the uniform distribution of slurry and binder through those holes. This higher-pressure drop restricted the air flow and the feed rate that could be delivered, but also led (we believe) to a breakdown in the emulsion binder.

To address the above issues, the system was operated with a substantial increase in the binder addition rate, while using an orifice plate with 53 holes. The strategy here was to identify the hydrodynamic conditions necessary to ensure agglomerates could be produced, and to then reduce the dose to lower levels using the conditions identified. This approach delivered for the first-time high combustible recoveries (~80%) and low product ashes (~10%) based on a lab separation of the downstream flow. The volumetric feed rate was lower than the targeted level due to the high pressure drop. The conclusion reached is that the technology does produce the rapid separation, but the process is inefficient at the current pipe size. It is believed that a smaller standard pipe size should deliver much stronger agglomeration efficiency. These smaller pipes could then be bundled together to deliver the targeted feed flow rate.

C34040
Optimising the Diesel Droplet Size in Coal Preparation Plants

University of Queensland
Yongjun Peng

Value:	$231,157
Report Expected:	March 2024
Industry Monitor/s:	Albert Blom
	Han Hooi
	Jason Schumacher
ACARP Contact:	Ben Gill

The objectives of this project are to:
- Develop full-scale emulsification systems incorporating the online droplet size measurement;
- Determine the optimal diesel droplet sizes in representative coal preparation plants varying with coal type, water salinity and diesel dosing through statistically designed ON/OFF trials;
- Identify the most efficient and economic diesel dispersion system to achieve each optimal droplet size;
- Develop the most suitable diesel dispersion strategy for each representative plant through an assessment of flotation improvement, reduction of diesel consumption, hurdles to implementation (e.g. safety, ease of installation and conversion, ease of operation) and capital and operating costs.

This quarter, data obtained from the on-site plant trial at Mine Site 1 was analysed, and results were presented to industry monitors and communicated with site engineers. The mechanic part of the emulsifier was tested during the trial with a low water pressure, which produced a droplet size of 15 μm (D50). The ultrasound part of the emulsifier was delivered to site for installation. Once site engineers complete installation, another plant trial will be arranged at the same site to use the ultrasound to emulsify diesel and investigate the effect of smaller diesel droplets on flotation performance. After the approval of the trial by Mine Site 2, work with site engineers will occur to plan the trial.

C34041
Coal Spiral for the 2020s

Mineral Technologies
Ian Mangelsdorf
Wendy Nutt

Value:	$199,646
Report Expected:	April 2024
Industry Monitor/s:	Dan Delahunty
	Naresh Racha
	Phillip Enderby
ACARP Contact:	Ben Gill

The objective of the project is to develop an enhanced coal processing spiral incorporating learnings from recent improvements in spiral design used in other mineral processing operations.

During the quarter:
- Both coal test samples have now been received;
- Test work has been conducted on several configurations of the CT1 spiral and the LC3 8 turn spiral model for baseline comparison;
- A small bulk process run has been conducted on a selected CT1 spiral configuration using 1 coal test sample;
- Sub-samples for analysis are currently being processed;
- No test work was conducted over Christmas.

C34043
In Plant Demonstration of the Next Generation Flotation System

University of Queensland
Liguang Wang

Value:	$258,347
Report Expected:	July 2024
Industry Monitor/s:	Kevin Rowe
	Nic Roberts
ACARP Contact:	Ben Gill

The objectives of this project are to:
- Build a prototype of the next generation flotation system with low energy and maintenance requirements for coal preparation; and to
- Demonstrate the prototype in a coal preparation plant.

The construction of the main body of the pilot scale column flotation system is near completion, in a commercial workshop outside UQ, which is expected to arrive at UQ in several weeks. The supporting frame and other auxiliary parts will be built or sourced in the following quarter, with safety requirements taken into consideration. The prototype will then be assembled and tested to meet the safety requirements. Gas dispersion studies will also be undertaken to examine a novel sparging system recently constructed at UQ.

C34045
Real Time Automatic Measurement of Frother Distribution in a Coal Preparation Plant

University of Queensland
Liguang Wang

Value:	$124,560
Report Expected:	July 2024
Industry Monitor/s:	Chris Denyer
	Peter Shumack
ACARP Contact:	Ben Gill

The objectives of this project are to:
- Build a prototype for real-time automatic measurement of frother concentration;
- Evaluate and demonstrate the prototype at a participating site to maximise coal recovery and prevent the overfrothing ('froth out') problem.

The construction of the prototype for the automatic frother concentration measurement device is underway. In this quarter, a short site visit to the participating site to discuss the potential installation point and to share the final design of the prototype unit was undertaken. A comprehensive HAZOP study has been conducted with the site engineers to ensure the control and safety measures are effective. Opportunities have been identified for minor upgrades to the unit to further enhance operational and safety features and these improvements will be integrated with the prototype unit. The construction of both hardware and software component has been following the schedule and is expected to be finalised next quarter.

Following the completion of the construction phase, the prototype unit will undergo rigorous testing to ensure optimal functionality before moving on to the on-site testing phase. The formulation and the hardware within the prototype unit (i.e., reagent pumps) will be fine-tuned to guarantee a safe and effective operation on site.

C35024
Froth Flotation Predicted v Actual Definition

McMahon Coal Quality Resources
Chris McMahon

Value:	$41,360
Report Expected:	November 2024
Industry Monitor/s:	Jason Schumacher
	Mel Robbins
	Michael Carnell
ACARP Contact:	Patrick Tyrrell

The project seeks to collate and evaluate data in froth flotation raw ash and product yield / ash outcomes from borecores and actual coal handling and preparation plants. Several froth flotation methods from borecores, including the pseudo-density method (with efficiency factors trialled to fit data) will be evaluated against actual data. Several deposits will be evaluated.

A request for information memorandum issued was in November with receipt of information and commencement of data processing and review scheduled for February. Three databases are expected for review.

The outcomes of this project will be the definition of accuracy (precision and bias) information for varying coal types, in yield and product ash, with notes on methods relevant to the accuracy of outcomes. This will benefit the industry by providing a guide for use and defined accuracy of outcomes for the data and methods evaluated, and potentially saving very expensive mine, coal handling and preparation plant design and resource misrepresentation. The outcomes then will provide a financial risk reduction and/or evaluation enhancement.

C35031
Demonstrating Better Classifying Cyclones

Elsa Consulting Group
Andrew Swanson
Andrew Vince

Value:	$377,475
Report Expected:	April 2026
Industry Monitor/s:	Clinton Vanderkruk
	Jack Lauder
	Jenny Park
	Jimmy Pollack
ACARP Contact:	Ben Gill

The overall objective of this project is to leverage off the significant past ACARP research on better classifying cyclones, to build and demonstrate the industrial benefits of the new Rong Classifying Cyclone Concept (RCCC) at an appropriate scale, namely 380 mm diameter cyclone. Specifically, coal-independent performance efficiencies will be determined using: 1. Size separation partition curves and related characteristic parameters α, d50 and Rf 2. Size-by-size Tromp curves and related characteristic parameters d50 and Ep. These will then be used as benchmarks to compare against such curves generated by existing technologies.

The first stage is to determine how small detail RCCC design adjustments impact on capacity/pressure/metallurgical performance characteristics prior to unit construction and testing. Western Sydney University (Centre for Infrastructure Engineering, School of Engineering) have developed a discrete element model (DEM), and the results of using said model suggest that unexpectedly high alpha values can be expected. Simulations are on- going, with a PhD student engaged to finalise the numerical aspect of this project and, specifically, to identify dimensions for a 380 mm unit to be designed and built.

Initially it was thought there would be a need for extensive, and expensive, fine coal float/sink work to be included in the project. However, given the surprisingly good alpha values from simulation work, it has been concluded that more modest testing will satisfactorily demonstrate the new design of 380 mm unit. If the alpha values are confirmed to be high, supported by sizing and some conventional float/sink work, then the demonstration is complete.

The nature of the demonstration trials and the resultant sample testing have been extensively discussed with our project monitors to the extent that the originally proposed and budgeted analytical procedures will be followed.

C35034
Working Effectively with Swelling Clays in Fine Coal Flotation to Improve Product Quality and Recovery

University of Queensland
Anh Nguyen
Ngoc Nguyen

Value:	$200,304
Report Expected:	September 2024
Industry Monitor/s:	Ed Provan
	Jack Lauder
	Jason Schumacher
	Luke Dimech
ACARP Contact:	Ben Gill

The objective of this project is to investigate effective measures (clay suppressants and wash water) to reduce ash (clay) content and increase recovery of fine coal flotation. Specific aims include:
- Characterise clay types and compositions in coal flotation feed, clay-coal liberation, and surface properties;
- Screen (design) and test clay suppressants to remove clay slime coatings;
- Design and conduct experiments to evaluate the effect of wash water hydrodynamics on reducing clay entrainment; and
- Conduct experiments using mechanical cell, Microcel, and Jameson cell for evaluating and benchmarking effective of clay and ash removals.

The ultimate goal of the project is to deliver higher quality products and opportunities to increase overall plant recovery by avoiding high ash/clay entrainment.

In this quarter the effect of chemical reagents (as clay depressants) on coal flotation was investigated. Industry Monitors have been actively communicated with to collect the samples from sites. The sites have confirmed that samples will be arriving at UQ in the coming weeks. In the meantime, the potential clay depressants with chemical suppliers to identify new reagents has been discussed. Reagents using coal samples available in UQ laboratories has been tested. Significant results are expected for presentation them at the next project review meeting in March.

C35035
3D Particle Surface Composition Analysis for Flotation Using Micro CT

University of Newcastle
Rohan Stanger

Value:	$81,730
Report Expected:	June 2024
Industry Monitor/s:	Araz Ejtemaei
ACARP Contact:	Ben Gill

This project aims to characterise a suite of plant flotation samples using microCT surface analysis. The technique involves determining the composition (vitrinite, inertinite, mineral content) at each particles surface interface. The project will focus on +38um material for this technique development to suit this microCT instrument resolution.

Work in the quarter has trialled several different mounting substrates to adhere particles to. The work prior has characterised sized particle fractions in packed bed, requiring mathematical methods to separate each particle boundary. These mathematical processes take additional computation time. Examples of substrates trialled include several plastic films, polystyrene foam films and thin balsa wood. Ideally, the substrate would be of sufficiently low density to appear "invisible" relative to the coal particles. This work is on-going, whilst a second coal sample is sought.

Gravity Separation

C33054
Measurement of DMC Wear Using 3D Laser Technology

CSIRO
Andrew Taylor

Value:	$173,022
Report Expected:	February 2024
Industry Monitor/s:	Luke Winkelman
	Peter Shumack
	Phillip Enderby
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C33056
Modelling and Control of Classifying Cyclones

Ausenco Services
Andrew Swanson

Value:	$227,080
Report Expected:	February 2024
Industry Monitor/s:	Colin Surawski
	Michael Carnell
	Naresh Racha
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34046
Clay Type Effect on Magnetite Medium Properties in Dense Medium Cyclones

CSIRO
Clint McNally

Value:	$155,488
Report Expected:	March 2024
Industry Monitor/s:	Chris Denyer
	Frank Mercuri
ACARP Contact:	Ben Gill

The project aim is to examine how the clay component in a dense medium influences the performance and functioning of dense medium cyclones. It has been observed that when different types of clay are mixed into slurries with identical solid percentages, the resulting viscosities can vary markedly based on the type of clay used. Such variability has potential implications for the operation of dense medium cyclones.

A literature review is currently underway to identify the types of clays found in Australian coal seams. Concurrently, dense medium samples from various mines have being collected and analysed for their Magnetite content, as well as for the type and quantity of clay present. These samples have undergone processing and X-ray diffraction (XRD) analysis, results of which are now available. The samples have also been tested for settling rate and viscosity at RTP. Next phase involves testing the constituent parts of the dense medium (different clay types and magnetite size grades) to prepare various combination mediums for performance testing in the small dense medium circuit at QCAT.

To further understand the impact of varying clay properties, synthetic (non-mine) dense medium samples, representing different clay characteristics, will be tested in a 150mm pilot plant dense medium cyclone circuit at CSIRO QCAT. This will aid in assessing their influence on DMC operation. The Small Dense Medium Cyclone circuit is currently undergoing commissioning, following an upgrade of sensors and refurbishment. Once commission testing is finalised, the experimental program to investigate the effects of different clay types will commence.

C34048

Using Clay Stabilised Medium for the Separation of Small Coal in a Dense Medium Cyclone

CSIRO
Andrew Taylor

Value:	$204,432
Report Expected:	April 2024
Industry Monitor/s:	Chris Denyer
	Frank Mercuri
ACARP Contact:	Ben Gill

The objectives of the project are to demonstrate the capability of Dense Medium Cyclone (DMC) processing with good cut point control for fine coals from 4mm down to 0.100mm with good magnetite recovery and high yields compared with other water based gravity processes. The DMC medium will be operated with a minimum of 20% by weight clay (kaolinite) and both deslimed and non-deslimed feeds will be tested.

Work has progressed to the point of completion of the experimental rig for the sample runs. It is expected that the sample runs will commence in two weeks' time and run for approximately one month alongside C34046 work. Unfortunately, samples that were expected to be sourced in 2023 did not eventuate and alternative samples are currently being secured and crushed to the correct size fractions. The fine coal samples are to be processed through a repulping spiral with samples collected. A parallel sample will also be run through a dense medium cyclone. Both performances will be assessed for efficiency of separation with numerous measurement points around the pilot rig including Electrical Impedance Spectroscopy (EIS) on DMC underflow and overflow, mass flows and % non-magnetics. Once pilot scale work is completed the report writing will be completed within two months.

Process Control

C33057

Foreign Contaminants Detection on Conveyor Belts Using Digital Imaging Processing Techniques and Coal Penetrating Sensors

Mincka Engineering
Fidel Gonzalez

Value:	$365,000
Report Expected:	February 2024
Industry Monitor/s:	Dan Delahunty
	Dave Young
	Kevin Rowe
	Phillip Enderby
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C34039

Soft Sensor for Predicting Dense Medium Cyclones Performance

University of Queensland
Gordon Forbes

Value:	$189,300
Report Expected:	July 2024
Industry Monitor/s:	Araz Ejtemaei
	Peter Shumack
	Rick Jeuken
	Sam Rynne
ACARP Contact:	Ben Gill

This project aims to develop a soft sensor for predicting dense medium cyclone performance. The soft sensor will build on current state of the art DMC models, with the aim of including a wear model, as well as data driven machine learning models to better characterise the feed and pump operating regime.

A successful site visit has taken place. During the visit, the proposed soft sensor architecture was discussed, along with site specific implementation requirements, measurements, and information about the DMC circuit operation.

Development of Excel based soft sensor for primary and secondary DMCs is nearing completion. The initial python implementation of the primary DMC and pump is complete, and now requires inclusion of the secondary DMC and pump. The python implementation allows for rapid evaluation over large datasets as it is considerably faster than the initial Excel based soft sensor prototype.

After finalisation, the soft sensor implementation will be tested on historic data and then run on site for a suitable duration. Feedback from site will be utilised to undertake final model adjustments and modifications.

C34044

Real Time Monitoring and Control of Froth Flotation

University of Queensland
Liguang Wang

Value:	$106,667
Report Expected:	March 2024
Industry Monitor/s:	Albert Blom
	Angus Morrison
	Chris Denyer
	Chris Huth
	Josh Kowalczuk
	Rick Jeuken
ACARP Contact:	Ben Gill

The objectives of this project are to:
- Further evaluate and demonstrate a simple, cheap and fast sensor for monitoring the efficiency of multiple flotation cells; and to

- Develop remote control strategies corresponding to the sub-optimal operation identified by the sensor.

The construction of the updated drag sensor and its holder is currently underway, with significant enhancements in the design based on valuable feedback received during the last site visit. In addition to these improvements, we have also conceptualised and developed a new type of drag sensor with a different sensing mechanism. It is anticipated that both types of drag sensor and its holder will be ready to use in a month or so.

Negotiations for a follow-up site visit with the participating mine site are ongoing. The data management plan has also been discussed with the site process team regarding the data management plan; which includes:

- Types of operational parameters to be adjusted during site testing;
- Sampling locations and the number of repeats for each sampling;
- Required information from the site SCADA system. This collaborative discussion resulted in a comprehensive data plan that not only provides crucial insights for sensor design and installation but also sheds light on the process optimisation at the participating site.

In the next quarter, a week-long site testing period is scheduled with the updated drag sensors and its holder. Following this testing phase, a thorough analysis of the collected data will be conducted. The insights gained from this analysis will be used to improve drag sensor design for the upcoming long-term field testing.

C34050

Hand Held Sensor for Real Time Measurement of Fluorine Mineral Contamination in Coal

University of Adelaide
Nigel Spooner

Value:	$261,215
Report Expected:	July 2024
Industry Monitor/s:	Jack Lauder
	Jenny Park
	Mel Robbins
	Rick Jeuken
ACARP Contact:	Ben Gill

The project objective is to create a new type of hand-held sensor for real time measurement of fluorine (mineral) contamination in coal. The minerals targeted are the two dominant non-clay fluorine minerals, fluorite and fluorapatite.

The prototype handheld sensor was used to observe samples with various apatite concentrations: real-world samples of crushed coal with non-uniform top-size. Optimisation of image-grabbing settings was performed. Qualitative analysis shows correlation between known apatite concentration and fluorescence (Figure 1a). Higher apatite concentration present in the sample is shown in Figure 1a and lower concentration in Figure 1b. Image processing algorithms will enable isolation of the fluorescent particles and areas from the non-fluorescent coal, and fluorine concentration calculation will be available.
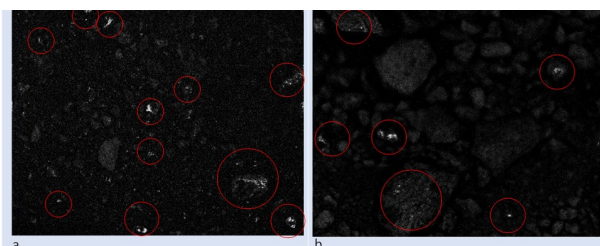

Figure 5: Raw images after background subtraction. Larger particles and areas of fluorescence emission from apatite are circled red.

Software: Initial GUI scheme was designed, based on parameters utilised in image acquisition. GUI functionality is in development over the project duration.

Next steps:

- Technical: Additional button will be programmed for image acquisition.
- Software: GUI will be further developed and adjusted according to requirements. Automatic image acquisition tab will be designed for imaging of unknown apatite concentration and grain brightness.
- Data collection: New coal samples have been provided by industry partners, to further characterise device detection limit capabilities and develop application image processing.
- Data Analysis: Further analysis will be performed to confirm the fluorescence attributions for signal isolation. Optimisation is ongoing for image acquisition of low-concentration or low fluorescence samples, to inform prototype design for field tests. These include optimising signal/noise by control of exposure time and other imaging parameters, and implementing image-grabbing algorithms to minimise the impact of noise (random or systematic).

C34052

Simulation Enabled Digital Twin for the Control, Design and Optimisation of a Teeter Bed Separator

University of Queensland
Kym Runge

Value:	$232,531
Report Expected:	January 2025
Industry Monitor/s:	Albert Blom
	Chris Denyer
	Chris Jackson
ACARP Contact:	Ben Gill

Up to a fifth of in-plant material in Queensland metallurgical coal preparation plants is too fine to be efficiently upgraded using a DMC and too coarse to be

separated using froth flotation. This middling fraction (typically -2+0.35mm) is processed using hydraulic classifiers, such as teeter bed separators. In this project, researchers will use a combined experimental and simulation-based approach to develop a computational model that can be used as the basis of a performance-maximising advanced control strategy for the teeter bed separator (TBS).

The work to be performed will involve site surveys of full-scale TBS units, laboratory fluidisation test work, regression modelling of site survey data and development and validation of a CFD model.

During the quarter, CFD simulations on the 2.1m TBS unit have advanced to incorporate multi-density particle systems, expanding on prior water and mono-density particle studies. A notable improvement involves the implementation of a PID underflow rate controller, to mimic the typical operation of TBS units on-site. Simulations predicted distinct segregation, with lighter particles favouring the overflow and heavier particles concentrating in the underflow, as is expected in the TBS unit (Fig. 1a). This led to the derivation of a partition curve, indicating an ability of the simulation methodology to produce a prediction of separation efficiency under given conditions (Fig. 1b). Future simulations will focus on investigating how operational variables (e.g. teeter water flow rate, pulp density, and target bed density) impact TBS performance.

The next step is to calibrate and validate the CFD models using site and laboratory data. Site surveys are planned to be conducted at two Coal Processing Plants in the first half of 2024. This will be followed by laboratory fluidisation test work using collected TBS feed samples.
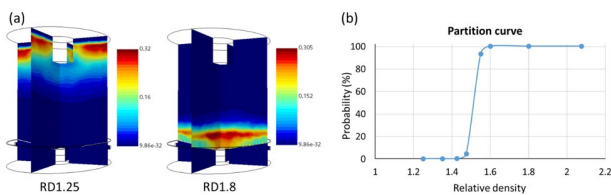

Figure 1: 2.1m TBS model: (a) segregation of coal particles from two selected density groups in a simulation involving 8 particle relative density (RD) values from 1.25 to 2.075, displayed by volume fractions on the central vertical planes; and (b) partition curve derived from the simulation results, with RD50=1.516 and Ep=0.021.

General

C26011
CSIRO Instruments at Multiple Plants

CSIRO
Mike O'Brien
Teresa Kittel

Value:	$427,798
Report Expected:	February 2024
Industry Monitor/s:	Frank Mercuri
	Luke Dimech
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C26016
Benefits of Online Thickener Underflow Rheology Measurements

Clean Process Technologies
Alexander Everitt
Noel Lambert

Value:	$251,000
Report Expected:	April 2024
Industry Monitor/s:	Michael Carnell
ACARP Contact:	Patrick Tyrrell

Although the thickener underflow monitor is able to generate information about the rheology of coal thickener underflow, plant operators are not using this data. This project will determine 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. There are no existing online rheology measurements of thickener underflow and it may be possible with online measurement to reduce flocculant dose rates, particularly where flocculant is dosed after the thickener.

Onsite and laboratory test work for this project has been completed. Writing of the final report is underway and is expected to be submitted by the end of February.

C28061

Quantitative Based Structural Integrity Evaluations Using Modal Parameters Estimation

Mincka Engineering
Fidel Gonzalez

Value:	$363,651
Report Expected:	March 2024
Industry Monitor/s:	Chris Jackson
	Kevin Rowe
	Peter Shumack
	Phillip Enderby
ACARP Contact:	Patrick Tyrrell

The objectives of the project are to:

- Develop a technique for reliable, cost effective and objective structural condition assessments of mining infrastructure used in coal mining;
- Eliminate the subjectivity and conservative structural condition assessments; and to
- Enable data driven decision making and increased the reliability of structural condition assessments.
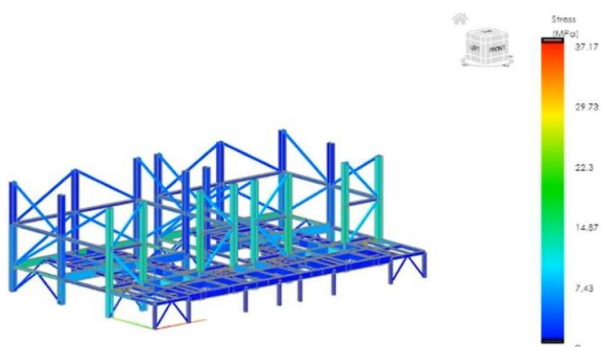

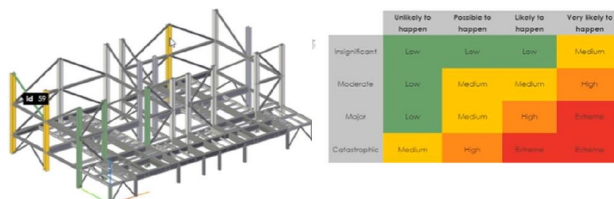Figure 1. Stress distribution using 3D visualisation of the asset

Figure 2. Risk analysis tool using 3D visualisation of the asset

This project is waiting for an installation day.

C33042

Coal Quality Borecore Methods Amalgamation Guide

McMahon Coal Quality Resources
Chris McMahon

Value:	$42,180
Report Expected:	April 2024
Industry Monitor/s:	Clinton Vanderkruk
	Jason Schumacher
	John Kelly
ACARP Contact:	Ben Gill

This project seeks to produce a guide that will amalgamate the various Australian and ISO Standards for borecore sampling and testing (preparation and measurement) so that definition of resources and reserves can be planned more effectively and efficiently.

The outcomes of this project will be a guide that can be applied to multiple coal quality testing scenarios for borecores. Different method options for raw coal mines, mines with wash plants and for coking and thermal coal will be made. Definitions of ply, raw, wash and product stages will be made in reference to Standards requirements and links between the relevant Standards where overlapping information is required.

This will benefit the industry by providing practitioners with a concise, referenced method for determining methods of sampling and testing, resulting in reduced time spent in planning, increased accuracy in planning, better definition of resource and reserve potential, and minimised financial risk. A further significant aim is to document comparison of ISO versus AS Standards equivalence/if they are comparable and differences along with rationale for decisions made.

Standards required have been identified and attained and collation review of overall targets is set.

A project review meeting was held in September that set out some completed sections of the guide including formatting and examples. Initial work was adequate, though further work is to be completed before finalisation of formatting. A partially completed report update was issued in January for industry monitor review for format style and content direction.

TECHNICAL MARKET SUPPORT

Maritime Regulation

C27001
Maritime Regulation Project

Goodwin Port Solutions
Ash Goodwin

Value:	$4,169,012
Report Expected:	December 2026
Industry Monitor/s:	Maritime Regulation Task Group
ACARP Contact:	Anne Mabardi

The project includes research to investigate issues relating to the accuracy, repeatability and reliability when testing coal cargoes for self-heating potential.

Experimental work investigating the test methods was finalised in May 2022, with the outcomes presented to the Australian Maritime Safety Authority (AMSA) in June 2022.

In September 2022, AMSA provided the project report and recommended regulatory responses to the International Maritime Organisation's Sub-Committee on Carriage of Cargoes and Containers (CCC) for consideration. Work continues to progress amendments to the International Maritime Solid Bulk Cargoes (IMSBC) Code via informal correspondence group discussions with IMO stakeholders. In September 2023, AMSA submitted a brief update paper (CCC 9/5/13) to the CCC Sub-Committee summarising the discussions and potential regulatory alternatives.

As an interim measure, AMSA has issued Certificate of Approval No. 8024, allowing coals meeting specified criteria to be classified and shipped as materials hazardous only in bulk (MHB). This approval is available on the AMSA website and remains valid until 31 December 2026.

Metallurgical Coal

C33066
Washability and Distribution of Sulphur and Trace Elements for Different Sizes and Densities of Product Coals

University of Newcastle
Rohan Stanger

Value:	$128,550
Report Expected:	February 2024
Industry Monitor/s:	Caroline Lang
	Jane Lawson
	Shaun Booth
ACARP Contact:	Ashley Conroy

The draft final report has been submitted to the Industry Monitors for review.

C34054
Design of Cokes from Biomass Coal Blends for Sustainable Blast Furnace Ironmaking: Scoping Study

University of New South Wales
Pramod Koshy

|	
Value:	$181,700
Report Expected:	March 2024
Industry Monitor/s:	Shaun Booth
	Stephen Brant
ACARP Contact:	Ashley Conroy

This project is focussed on understanding the impact of biochar addition and coal type on determining the quality of cokes for ironmaking. The aims of the present work are:
- Understand the impact of biomass addition (up to 10 wt%) and base coal properties on the macrostructural and microstructural characteristics and room-temperature and high-temperature (1100°-1400°C) strengths after gasification of the resultant cokes,
- Correlate the mineralogical, microstructural, microtextural, bonding and fracture characteristics of these cokes with strength measurements at room and high-temperature, and
- Compare the properties using standard coke quality indicators such as CSR/CRI to determine optimal addition levels.

New cokes containing finer particle size fraction of biochar were fabricated. Permeability and thermoswelling measurements were conducted on the coal-biochar blends (<3 mm size) during simulated cokemaking process using the unique facility at UON. The results showed that sample C2 (5 wt%, -0.5 mm) showed the lowest permeability drop while C1 sample (2.5 wt%, -0.5 mm) showed the highest decrease. The slopes representing permeability changes with temperature as well as the particular temperatures at which softening

started appear to be similar for the blends irrespective of the addition level or particle size of biochar. The thermoswelling behaviour was also similar for all samples, except C3 (10 wt%, -0.5 mm) which showed the lowest swelling.

Charge	Blend information
SR0588-C1	97.5 wt% Base coal & 2.5 wt% Biomass crushed to -0.5 mm
SR0588-C2	95.0 wt% Base coal & 5.0 wt% Biomass crushed to -0.5 mm
SR0588-C3	90.0 wt% Base coal & 10 wt% Biomass crushed to -0.5 mm
SR0588-C4	95.0 wt% Base coal & 5.0 wt% Biomass crushed to -0.5 mm
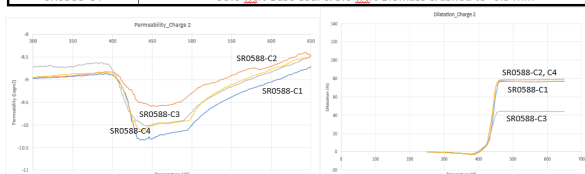
C34055
Factors Underpinning the Reactivity of Coke RMDC and IMDC

University of Newcastle
Hannah Lomas

Value:	$171,436
Report Expected:	March 2024
Industry Monitor/s:	Morgan Blake
	Sean Flanagan
ACARP Contact:	Ashley Conroy

Gasification reactivity of inertinite maceral derived components (IMDC) and reactive maceral derived components (RMDC) can affect the strength of coke, and thus its integrity in the blast furnace.

In this project, a series of experiments was carried out to examine factors that influence the CO_2 reactivity of the individual IMDC and RMDC components of three head coal samples, including:
- Influence of parent inertinite types;
- Degree of microtextural anisotropy;
- Degree of accessible porosity at the IMDC surface;
- Degree of interaction between IMDC and RMDC.

Lump versus intrinsic reactivity of IMDC and RMDC was also be examined. For each experiment, the kinetics of the reaction of each coke with CO_2 under CSR test conditions was measured using thermogravimetric analysis (TGA).

In the last quarter, the ash content of each coke sample was measured using TGA to allow conversion of mass loss to carbon conversion. BET analysis of the porous structure and microtextural analysis of each coke sample, both before and after reaction to 40% carbon conversion, is underway. In the next quarter, this data will be analysed and linked to the reaction kinetics of each coke sample, to identify the most influential factors for coke reactivity to CO_2 for each experiment. Key influential factors include the inertinite content, ash chemistry and rank of the parent coal sample.

The draft report is ~ 40% complete, will be submitted for review in early March.

C34056
Real Time Three Dimensional In-Situ Imaging of Structural Evolution of Coal During Coke Making Process Using Adaptive Electrical Capacitance Volumetric Tomography

University of Newcastle
Behdad Moghtaderi

Value:	$128,755
Report Expected:	February 2024
Industry Monitor/s:	Graeme Harris
ACARP Contact:	Ashley Conroy

The draft final report has been submitted to the Industry Monitors for review.

C34057
Impact of Co-Injecting Hydrogen and Australian PCI Coals on Overall Blast Furnace Performance Using a Heat and Mass Balance Model

University of New South Wales
Yansong Shen

Value:	$166,200
Report Expected:	February 2024
Industry Monitor/s:	Cameron Tasker
	Geoff O'Meley
	Peter Austin
ACARP Contact:	Ashley Conroy

The draft final report has been submitted to the Industry Monitors for review.

C34059
Coke Reactivity with CO2 and H2O and Impacts on Coke Microstructure and Gas Diffusion

University of Newcastle
Arash Tahmasebi

Value:	$170,700
Report Expected:	March 2024
Industry Monitor/s:	Shaun Booth
	Stephen Brant
ACARP Contact:	Ashley Conroy

The overall project objective is to investigate the differences in coke reactivity, and microstructure and microtexture evolution during gasification reactions relevant to the conventional and hydrogen rich blast furnace conditions. The specific project objectives are to:
- Evaluate the impact of CO_2 and H_2O gasification reactions on the physical structure of cokes made from Australian coking coals using micro-CT analysis.
- Investigate the mechanism of coke gasification under CO_2 and H2O, i.e., reaction at the coke surface vs. reaction throughout the coke volume.

- Gain a deeper understanding of how coke quality indices relate to its degradation mechanism by studying three cokes with varying CSR/CRI.
- Evaluate the susceptibility of IMDC/RMDC and associated microtextures to reactivity with CO_2 and H_2O by exploring changes with the progression of coke gasification.
- Develop a reaction-diffusion model for comparing CO_2 and H_2O gas diffusion in coke microstructure with the progression of gasification.

Progress during the quarter:
- Image registration to identify the regions of reaction and grayscale quantification has been completed for all samples and repeat cokes.
- An algorithm was successfully developed to quantify the CT grayscale and mass loss changes along the radius of coke cylinders. The method was used to evaluate the gasification mechanism of cokes of varying CSR with CO_2 and H_2O.
- This quarter focused on developing a reaction-diffusion model to fit the TGA gasification and radial grey-scale mass loss data. Model validation and estimation of kinetic parameters for all test conditions was completed this quarter.
- Pearson microtexture analysis of unreacted and partially gasified coke samples was also completed in this period.

C34060

In-situ Investigation of Coke Structure Formation Under Stamp Charged Coking Conditions

University of Newcastle
Arash Tahmasebi

Value:	$158,900
Report Expected:	February 2024
Industry Monitor/s:	Graeme Harris
	Stephen Brant
ACARP Contact:	Ashley Conroy

The draft final report has been submitted to the Industry Monitors for review.

C34063

International Round Robin for Coke Reactivity Index, Coke Strength after Reaction and I600

CSIRO
Lauren Williamson

Value:	$77,800
Report Expected:	April 2024
Industry Monitor/s:	Caroline Lang
	Graeme Harris
ACARP Contact:	Ashley Conroy

The main objectives of this project are to:
- Update the understanding of the consistency of practice with regards to CSR and CRI across a group of international laboratories by conducting a round

robin using two cokes produced in a pilot scale coke oven; and to
- Investigate the extent of use of I600 in coke testing laboratories and determine its potential as a standard test.

The following activities have been completed:
- Two coal blends have been coked in the moveable wall oven at CSIRO-QCAT;
- Coke samples have been crushed and subsampled for despatch;
- Samples have been sent to 17 participants from six countries, noting that freight delays have been experienced;
- Results have been received from 12 participants;
- Review meeting held in November; and the final report is being prepared.

C34065

Impacts of Plastic Layer Permeability and Internal Gas Pressure on the Formation of Coke Microstructure and Coke Quality

University of Newcastle
Soonho Lee

Value:	$158,900
Report Expected:	February 2024
Industry Monitor/s:	Cameron Tasker
	Morgan Blake
	Nick Andriopoulos
ACARP Contact:	Ashley Conroy

The draft final report has been submitted to the Industry Monitors for review.

C35037

Examination of Contraction Pre and Post Resolidification using a High Temperature Dilatation Rig

University of Newcastle
David Jenkins

Value:	$99,250
Report Expected:	May 2024
Industry Monitor/s:	Cameron Tasker
	Graeme Harris
ACARP Contact:	Ashley Conroy

The project objectives are to:
- Measure the dilatation and contraction behaviour of a range of coals, both pre- and post-resolidification, using the UoN dilatation/contraction test rig.
- Develop a mathematical model of the configuration used in the dilatation/ contraction test rig and calibrate with experimental results.
- Utilise the combined results from experiment and modelling to understand the key processes of dilatation and contraction of coal particles at coke

oven feed size, particularly in the region around re-solidification.

Progress to date includes:
- Test coals chosen, in consultation with project monitors and most coals sourced from ACARP coal bank.
- Standard Gieseler plastometer and dilatation tests conducted on all coal samples. Use made of whole measurement curves to relate to key parameters – max fluidity, softening, re-solidification temperatures.
- Further modifications of the dilatometer rig are ongoing, in order to minimise sticking and other effects that reduce the accuracy of the test.
- On-going experimental work to measure the mean size of particles in the sample, and gas evolution (mass loss via TGA) is being conducted, to provide additional information to the project.
- The model of swelling of particles during the plastic phase, due to volatile evolution, gas transport through the plastic melt and bubble growth in the particles has been further developed, including use of information from Gieseler plastometer. A simple model for post-resolidification shrinkage has been added.

C35038

Microalgae Blending for Low Carbon Metallurgical Coke Production

University of Newcastle
Arash Tahmasebi

Value:	$172,000
Report Expected:	November 2024
Industry Monitor/s:	Nick Andriopoulos
	Stephen Brant
ACARP Contact:	Ashley Conroy

This project aims to evaluate the impact of microalgae blending on the coking behaviour, coke properties, and coke gasification performance of selected Australian coals to determine the tolerable microalgae addition level and carrying capacity of Australian coals. Specific objectives are to:
- Analyse the influence of microalgae on the thermoplastic and thermal decomposition behaviour of Australian coals.
- Evaluate the coking behaviour and pressure generation of coal/microalgae blends at different addition levels.
- Determine the optimal microalgae addition rate and study the carrying capacity of Australian coals in blend with microalgae from coke property analysis.
- Evaluate the impact of microalgae on coke microstructure and microtexture and coke quality indices.
- Explore the fate of alkali species during the coking process.
- Evaluate high temperature reactivity of bio-cokes.

Progress during the quarter:
- 16 blends incorporating up to 20 wt.% microalgae in 4 coals were prepared and analysed for volatile matter, ash content and chemistry, and standard fluidity measures.
- The rheological testing at UQ was completed in this quarter. Coals with high fluidity exhibited a high carrying capacity in blends incorporating up to 10 wt.% microalgae.
- Progress was also made in CT image analysis of plastic layer samples prepared in the 4kg oven. Analysis of the remaining samples is underway.
- Coke samples incorporating microalgae pellets were also prepared and imaged at the Synchrotron to study the bonding mechanism of algae to the coke matrix. Results show that the bonding quality was coal-type dependent.
- The new 8kg coke oven has been successfully commissioned at NIER. Preparation of coke samples for CSR/CRI testing is currently underway.
- TGA analysis of the coal-algae blends and the microtextural analysis of the bio-coke samples are also planned for the next quarter.

C35039

Impact of Coal Grain Composition and Macerals Association on Fluidity Development in the Plastic Layer of Australian Coals

University of Newcastle
Arash Tahmasebi

Value:	$141,600
Report Expected:	May 2024
Industry Monitor/s:	Graeme Harris
	Stephen Brant
ACARP Contact:	Ashley Conroy

The project aims to understand the impact of grain composition and maceral associations on the thermoplasticity of Australian coals from different coal measures. The project utilises the coal grain analysis (CGA) capability at CSIRO, rheometry and micro-CT expertise at UQ, and in-situ coking, plastic layer characterisation, and micro-CT analysis expertise at UoN. Specific objectives are to:
- Improve the mechanistic understanding of the thermoplastic behaviour of Australian coals.
- Explore the differences in vitrinite and inertinite size distribution and the degree of association between reactive and non-reactive macerals in coals sourced from different measures.
- Analyse thermoplastic behaviour of selected coals using the permeability/dilatation and the 4kg coke oven test facilities at UON and the rheological testing at UQ using the coke oven feed size.
- Develop correlations between coal grain composition and fluidity development in the plastic layer.
- Analyse micro-CT images of quenched plastic layer samples to determine the difference between the "real" plastic range of coals and those measured by standard tests.

Progress during the quarter:

- The rheology (UQ), in-situ coking tests (UoN), and micro CT image analysis (UoN) of seven out of eight coal samples were completed in this quarter.
- The last coal sample has also been received with coking tests currently underway.
- Coal grain analysis (CGA) of the available coal samples was also completed at QCAT. The results showed significant differences in grain compositions of seemingly similar coals.
- Project findings to date show strong evidence that the composition and degree of association between coal macerals influence the development of fluidity.
- Micro-CT image analysis of plastic layer samples was used to estimate the plastic range of the coal samples and compared with the standard fluidity tests.

Work in the next quarter will focus on the CGA, rheology, and in-situ testing of the remaining coal sample.

C35040
Changes in Combustibility of Coal when Co-Combusted with Hydrogen Rich Fuels in PCI

University of Newcastle
Liza Elliott

Value:	$218,367
Report Expected:	June 2025
Industry Monitor/s:	Cameron Tasker
	Caroline Lang
	Oliver Scholes
ACARP Contact:	Ashley Conroy

With the steel industry under pressure to reduce CO_2 emissions, there are several possible changes to the steelmaking process that could be adopted. The first and easiest step in improving sustainability is the introduction of a material with high hydrogen content via tuyere injection. This injectant could be coke oven gas, waste plastics, biomass materials or hydrogen and hydrogen containing gases. However, as most of these materials have lower coke replacement ratios, most steelmakers will be looking to introduce these fuels along with coal. It is unclear, however, what the impact of co-combustion has on the possible injection rate.

This project aims to determine the impact on coal reactivity of co-combustion of hydrogen rich fuels: biomass, plastics, coke ovens gas, ammonia, and hydrogen. Two techniques will be used: the combustibility of solid fuels will be assessed using the Drop Tube Furnace technique developed in project C19049, that compares the combustion behaviour of coals in a set standard condition. Then a TGA (Thermo-Gravimetric Analyser) will be used to measure the reactivity of these materials individually and when co-combusted with coal. This will show changes in behaviour expected due to reduction of oxygen concentrations caused by the consumption of the hydrogen rich fuel.

All samples required for this project have been sourced and prepared for testing. Drop Tube Furnace tests and TGA analysis are all underway. The Drop Tube Furnace has been activating a circuit breaker when at temperature. Replacement of the main circuit breaker has been completed and replacement of a flow switch, hoped to be the main cause, is underway.

Unfortunately, the TGA to be used in this study has been found to allow feed gas to fill the electronics chamber and it was therefore decided that ammonia combustion was unsuitable for this machine. An alternate TGA is being sought for tests utilising ammonia, with further safety reviews required for the alternate TGA.

C35041
Effect from the Co-Combustion of Coal and Biomass on Production of Fine Particles (<PM10)

University of Newcastle
Liza Elliott

Value:	$228,531
Report Expected:	August 2025
Industry Monitor/s:	Cameron Tasker
	Caroline Lang
	Oliver Scholes
ACARP Contact:	Ashley Conroy

Many power stations are looking to reduce their CO_2 emissions with the addition of biomass to the feed coal for combustion. Biomass is an overarching term to describe organic material derived from plants and is considered CO_2 neutral as the CO_2 emitted during combustion is equivalent to the CO_2 absorbed during the plant's growth. However, biomass generally has much higher contents of Na and K than coal, and these elements are associated with the organic structure of the plant. In bituminous coals these elements are generally associated with minerals that may be liberated during milling. The proximity of the alkalis to carbon increases the chance of vaporisation during combustion.

Recent project, C29075, has shown that the proportion of PM10 particles produced during combustion of relatively refractory ashes is much higher than expected. When co-combusted with biomass, the PM10 produced would be expected to increase dramatically as the alkalis associated with the biomass would be expected to report predominantly to the fine particle fraction of the particle size distribution, though a high ash load associated with the coal ash may limit this. It is unresolved where other species within the biomass would report. The source of PM10 from co-combustion materials must be understood if the value of coal is not to be undermined.

This project aims to assess the scope of fine particle emissions produced during combustion of biomass and the interactions expected between biomass and coal when these fine particles are forming during co-combustion.

The samples for this project have been sourced and prepared for testing. An additional biomass sample has been requested as the original sample will be insufficient. Combustion of the coal in coal only tests is complete, with collection of the ash including the ultrafine portion. Analysis of the ash has started. Failure of the feeder box due to deformation from furnace heat has required a short stoppage as a new box is produced.

C35042
Physical and Chemical Interactions Between Charcoal and Coal During Coking

University of Queensland
Karen Steel

Value:	$135,694
Report Expected:	December 2024
Industry Monitor/s:	Graeme Harris
	Morgan Blake
ACARP Contact:	Ashley Conroy

This project addresses the demand from coke makers to add high proportions of biomass to cokemaking blends whilst not compromising on coke strength. It has been recognised for some time that addition of biomass decreases coke performance in terms of the both CSR and CRI. One of the major adverse effects is reduced fluidity. It has been established that converting biomass to charcoal at high temperature (800°C) in the first instance reduces the adverse effect. Given that oxygen content decreases as charring temperature increases, it is strongly suspected that high temperatures are preferred due to the loss of oxygen from the char; oxygen is already well known to decrease fluidity through condensation reactions.

This project investigates the blending of biomass with high fluidity coals to deliberately interact with biomass at low temperature, thereby mitigating the adverse effects caused by biomass and preserving the function of the prime coking coal. The project involves studying three high fluidity coals, three biomass types (sugar cane bagasse, bamboo, and Jarrah), and two coking coals.

Test work has been focused on small scale coking studies, determining the interactions occurring between high fluidity coals and charcoals made from sugarcane bagasse and bamboo. Whilst it was expected at the outset of this project that charcoals would have highly negative effects on fluidity, we've found there to be minimal physical or chemical interactions for the charcoals produced. They appear to behave like an inert solid such as inertinite, or graphite. Given that the role of the high fluidity coal was to deliberately compensate for adverse effects on fluidity it is necessary to expand thinking on the role of high fluidity coals. We have found that blending 25 wt% charcoal with high fluidity coal has a minimal effect on viscosity (fluidity) while 30% addition causes a step change in viscosity. The reason for the step change at 30% addition is being considered.

A review meeting has been scheduled to discuss these findings and future work on the role of high fluidity coals in blend design.

C35043
Abrasion Resistance of Coke Under Hydrogen Reduction Blast Furnace Conditions

University of Newcastle
Hannah Lomas

Value:	$159,416
Report Expected:	December 2024
Industry Monitor/s:	Nick Andriopoulos
	Oliver Scholes
	Stephen Brant
ACARP Contact:	Ashley Conroy

The hydrogen enriched blast furnace is emerging as a viable alternate technology to reduce the carbon footprint of blast furnace ironmaking, during which injected hydrogen reduces the ferrous burden, generating water vapour as a by-product. To develop the practical applicability of the hydrogen reduction blast furnace, it is important to understand how the degradation of coke under such conditions differs in comparison with the conventional ironmaking blast furnace, and thereby identify the impact of a hydrogen reduction blast furnace on coke quality requirements.

This project will specifically focus on the impact on coke abrasion resistance. Project objectives include:
- Evaluate the impact of reaction conditions that simulate both the conventional and the hydrogen reduction blast furnace on coke abrasion resistance;
- Develop correlations between conventional coke quality indices and abrasion resistance measured using tribological testing at 950°C in an atmosphere comprising steam or CO_2.
- Relate results to the microtextural components, including the degree of anisotropy of those components, and the rank and maceral composition of the parent coal.

Five RCO cokes were selected for this project. Three of these have varying CSR values but similar MBI values, to minimise differences in ash chemistry influencing the results.

In the last quarter, preparation of samples for tribological testing was completed, using an optimised sample preparation procedure. In the next quarter, trial samples will be tested by Hui Wu and Zhengyi Jiang at the University of Wollongong (UoW) to determine their suitability for the tribological test, due to the change in the sample preparation protocol. We will also in collaboration with UoW identify the most appropriate method for introducing an atmosphere comprising water vapour to the tribometer. We expect the tribological tests to commence in April. The testing will be carried out in stages based on the availability of the tribometer at UoW.

C35044

What We Now Know about Coking Coals and Coke

CSIRO
Lauren Williamson

Value:	$96,284
Report Expected:	June 2024
Industry Monitor/s:	Lauren North
	Morgan Blake
ACARP Contact:	Ashley Conroy

The main objectives of this project are to:
- Integrate the findings from ACARP projects completed since 2014, with other, primarily Australian, research into an overall picture of what makes a coke "good" and what is a good coke;
- List new findings that research has established that are useful to industry; and to
- Review the effects of adding biomass and hydrogen into the iron making process.

Work has commenced on reviewing the 56 reports that have been completed.

C35045

Impacts of Chemical Structure Transformation in the Plastic Layer on the Microtexture Development during Coking

University of Newcastle
Soonho Lee

Value:	$158,900
Report Expected:	November 2024
Industry Monitor/s:	Morgan Blake
	Nick Andriopoulos
ACARP Contact:	Ashley Conroy

The main aim of this project is to explore the fundamental mechanisms contributing to microtexture development during the plastic layer formation, using bireflectance analysis and micro-FTIR chemical mapping techniques. We've selected plastic layer samples with distinct layered structures, including particulate coal, the plastic layer, and coke/semi-coke, providing a solid basis for analysis. Five coal samples have been chosen with varying properties in terms of rank, maceral content, and fluidity to assess their impacts on microtexture development.

Throughout this quarter, the obtained bireflectance maps across the plastic layer samples have been analysed. Microtextural compositions relative to the distance from the plastic layer to the coke, have been quantified, revealing how microtextures evolved across the characteristic layered structures.

Following that, 3-4 spots of small areas (100 * 100 microns) containing inertinite particles and softened vitrinite surroundings within the intermediate and resolidified layers for IR chemical mapping have been selected. The plastic layer samples were taken to Synchrotron IR, where they underwent macro-IR scanning to produce high-resolution functional group chemical maps (4 microns/pixel). Currently, the plastic layer samples for one rank set have been completed for IR analysis, and the rest (maceral and fluidity set) will be analysed in the upcoming Synchrotron IR experiments. These maps will be aligned with the microtexture image.

Looking ahead to the next quarter, the primary focus will be on correlating coal properties, microstructure transitions, and IR results. This approach aims to uncover the underlying mechanisms of microstructure evolution, exploring both chemistry aspects and the impacts of coal properties.

C35046

Gasification Reactivity and Degradation of Coke Lumps Under Simulated Conventional and Oxygen Rich Blast Furnace Processes

University of Newcastle
Apsara Jayasekara

Value:	$98,500
Report Expected:	June 2024
Industry Monitor/s:	Lauren North
	Nick Andriopoulos
ACARP Contact:	Ashley Conroy

The project aims to explore the differences in coke reactivity, microstructure and microtexture evolution, and coke degradation during gasification reactions relevant to simulated conventional and oxygen-enriched blast furnace conditions.

The project objectives are to:
- Assess the gasification reactivity of different coke samples under simulated conventional and oxygen blast furnace conditions;
- Investigate the influence of varying oxygen enrichment levels (ranging from 21% to 100% O_2) in the input gas on the evolution of coke microstructure and microtexture, and coke degradation;
- Compare the post-gasification strength of coke samples at both room and high temperatures under conventional and oxygen blast furnace conditions;
- Establish correlations between oxygen content and coke degradation; and to
- Establish connections between coke qualities and coke reactivity under oxygen-enriched scenarios.

Progress during this quarter includes the following:
- Micro-CT imaging of reacted coke samples has been completed, and the analysis of the images, including image registration, is currently underway;
- Samples were prepared and sent for Pearson microtexture analysis. Microtextural analyses are currently underway;
- Room temperature compressive strength testing has been completed at UNSW.

Completion of post-reactivity image analysis and high-temperature compressive strength testing is planned for the next quarter.

C36004

Physical and Chemical Structure Characterisation of Biomass for Biocoke Production

University of Newcastle
Arash Tahmasebi

Value:	$54,100
Report Expected:	March 2024
Industry Monitor/s:	Cameron Tasker
	Lauren North
	Morgan Blake
	Nick Andriopoulos
	Shaun Booth
	Stephen Brant
ACARP Contact:	Ashley Conroy

The project aims to conduct a scoping investigation to better understand the impacts of parent species and pre-treatment methods on the physical and chemical structures and properties of biomass. A selection of woody, crop waste and algal biomass species will be used and characterised using a range of analytical instruments.

The specific project objectives are to:
- Conduct a comprehensive compositional evaluation of microalgae and lignocellulosic biomass species aiming to identify key differences.
- Prepare and analyse the physical and chemical properties of torrefied and pyrolysed char samples from a range of woody and crop waste biomass species.
- Study the impact of biomass type and pre-treatment method on thermal decomposition behaviour.
- Provide input into the selection of biomass samples for biocoke preparation in the RCO pilot oven for use in detailed biomass related projects. Biomass samples with distinctly different properties and structures to allow a meaningful comparison in the detailed biomass evaluation projects will be selected.
- Select suitable biomass samples to gain maximum compatibility between the detailed biomass-related projects.

Progress during the quarter:
- Preparation of the torrefied and char samples of the woody and crop waste biomass samples in the new fixed-bed reactor was completed;
- The standard characterisation of raw and pre-treated samples, including elemental and ash composition was also completed;
- The thermal decomposition tests of the prepared samples in TGA were conducted with data analysis currently underway;
- The morphology of all samples was also analysed using an SEM;

- FTIR analysis of the samples for chemical structure characterisation was also completed this quarter, with data analysis currently underway; and
- The BET surface area tests are also underway.

Work in the next quarter will focus on the drafting of the final report.

Thermal Coal

C34058

Strength Development in Fouling Deposits

University of Newcastle
Liza Elliott

Value:	$213,600
Report Expected:	July 2024
Industry Monitor/s:	Caroline Lang
	Oliver Scholes
ACARP Contact:	Ashley Conroy

Deposition within the convective pass of boilers can significantly affect gas and heat flows and alter boiler performance. Regular cleaning is required to ensure optimal boiler efficiency and ease of ash removal. Timeframes required for cleaning depend on the time it takes for strength to develop in the ash deposits, which can build-up in temperature regions well below the ash melting temperature. At present, to assess a coal ash's behaviour, a boiler operator will compare the ash fusion temperature (AFT) to those of coals with known performance in their boiler. But AFT has no correlation with strength development at sintering temperatures, instead is related to the surface tension of liquid phases present.

This project aims to produce a model for the development of strength in ash compacts to be able to predict the optimum time required for cleaning boiler walls. To do this the project will:
- Determine a correlation for the sintering temperature of Australian thermal coal ash;
- Gain an understanding of strength development in these coal ashes by assessing the impact of particle size and ash chemistry.

Fourteen fly ash samples have been collected and analysed for chemistry and particle size. The sintering temperature of each fly ash has been measured, along with the sintering temperature of blends of the selected fly ash samples. Additional tests to determine the impact of particle size have shown that the sintering temperature is not impacted by the size of the particles and is solely a function of chemistry. Modelling of the sintering temperature based on the ash chemistry using a neural network is complete. Figure 1 shows the model predictions compared to the measured values.
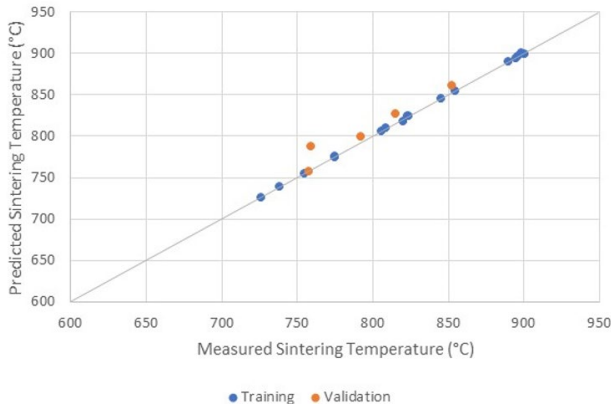
Figure 1: Model predictions of sintering temperature compared to measured values.

Sintered compacts have been produced. Measurements of the closed porosity have been completed by measuring the open porosity using pressure drop measurements of gas flowing across the compact, using Endo's equation. The shear strength of the compacts has also been measured. Figure 2 shows the relationship between the closed porosity and shear strength.
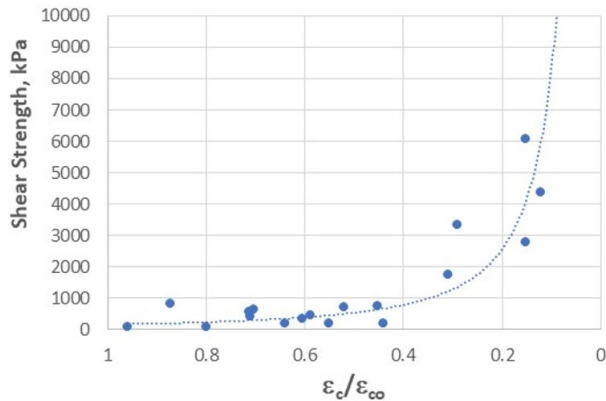

Figure 2: The relationship between Shear Strength of flyash compacts and the ratio of the closed porosity and the original closed porosity.

As the sample begins to sinter the ratio of closed porosity starts at 1 and progressed with sintering towards 0. Shear strength starts to become significant at a ratio of closed porosity of 0.4.

Using Frenkel's equation of sintering due to viscous flow, the time required to reach the closed porosity ratio of 0.4 can be predicted for the temperature experienced by the ash. The time required to reach a set strength is a function of the temperature experienced by the ash, the sintering temperature (a function of chemistry) and the particle size of the ash. Some ashes never reach the prescibed strength, predominantly due to the ash particle size, with more strength developed in finer particles.

Further work is underway to include more data in Figure 2 and work has started on the draft report.

C35005
Feasibility Study, Upgrade and Commissioning of ALS-ACIRL Pilot Scale Combustion Test Facility

ALS Coal
James Bottle

Value:	$591,250
Report Expected:	March 2025
Industry Monitor/s:	Caroline Lang
	Greg Wickman
	Jane Lawson
	Oliver Scholes
ACARP Contact:	Ashley Conroy

The overall project objective is to upgrade ALS-ACIRL's existing pilot scale coal combustion test facility so that it can more accurately simulate current and emerging coal fired combustion technology.

The focus for the last quarter has been the purchase and fabrication of the equipment required for the upgraded facility. This includes:
- Repair and installation of heat exchangers;
- Ordering an improved gas analyser;
- Ordering a Malvern particle sizer;
- Upgrading the current control system to allow co-firing with biomass;
- Fabrication of the improved slagging panel design;
- Installation of air compressor with higher capacity;
- Ordering of stainless-steel filters for improved ESP inlet and outlet sampling; and
- Fabrication of independent biomass feed system.

The upgraded plant is expected to be complete by June and following this the commissioning project will commence in July.

General

C25053
Coal Sample Bank

CSIRO
Lauren Williamson

Value:	$451,801
Report Expected:	November 2024
Industry Monitor/s:	Technical Market Support Committee
ACARP Contact:	Ashley Conroy

The project objective is to operate the sample bank to make coal and coke samples available to researchers and to enhance the systematic provision of the samples for ACARP projects.

To date, 86 coal samples have been delivered, stored at -18°C and their details recorded in a database, there are also 37 cokes, 4 biomasses and 1 fly ash stored. Of the

coal samples stored coal quality data has been provided by coal producers for 77 of the samples.

During this quarter coal and biomass samples were provided to project C35042 and coke was provided to C35043. In 2023 the coal bank provided 41 samples to nine projects.

C26003
Management of SA and ISO Coal Technical Committees Work Programs

Carbon Connections Consulting
Barry Isherwood

Value:	$391,150
Report Expected:	July 2024
Industry Monitor/s:	Graeme Harris
	Kevin Rowe
	Lauren North
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 Subcommittee MN/1/1 Coal Analysis held a hybrid meeting in November, with half of the SC members attending the meeting in Newcastle in person. Topics included:
- There are 5 ISO Standards due for Systematic Review in February. General discussion was held with a project leader appointed for each.
- The future of AS 2096, Coal Classification was discussed with unanimous agreement that the Standard is not used and a recommendation will be made to MN/1 for its withdrawal.
- The future of AS1038.16, Reporting of Results was discussed with a restructure required and a possible proposal to ISO for a new Standard.

ISO succession planning for TC27 and its SC's is being actively developed with the Chair of TC27 and all of its SC's to be replaced over the next few years, at the expiry of their allowed terms.

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

Standards Australia
Ben Russell

Value:	$330,370
Report Expected:	August 2024
Industry Monitor/s:	Graeme Harris
	Kevin Rowe
ACARP Contact:	Anne Mabardi

SA support for Australian Mirror Committee—Schedule of meetings.

MN-001 (Coal and Coke)—Mirror Committee for ISO/TC27
Chairman: Barry Isherwood
Last meeting: 20 July 2023 (Zoom meeting)
Next meeting: 8 August 2024 (Venue: TBC)

MN-001-01 (Coal analysis) —Mirror Committee for ISO/TC27/SC3 and SC5
Chairman: Barry Isherwood
Last meeting: 16 Nov 2023 (Newcastle with Zoom Option--Hybrid)
Next meeting: 21 March 2024 (BHP Office, Brisbane with Zoom Option--Hybrid)
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: Darren Mathewson
Last meeting: 30 November 2023 (NIER, Newcastle)
Next meeting: 28 March 2024 (NIER or SGS Office, Newcastle).
Meeting objective: Review of ISO/TC27/SC1 & SC4 documents including systematic reviews and finalise Australian mirror Committee position on ISO ballot (and comments). Review update on national Standards and projects.

MN-001-05 (Coal Mining and Geology)
Chairman: No Chair
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.

C33065
Digital Petrographic Atlas of Australian Coals - Maintaining the Knowledge

University of Queensland
Joan Esterle

Value:	$197,537
Report Expected:	April 2024
Industry Monitor/s:	Graeme Harris
	Sean Flanagan
ACARP Contact:	Ashley Conroy

This project will create a Digital Petrographic Atlas of Australian Coals, their maceral and mineral composition at different ranks, linked into our current understanding of basin scale variation in rank, type and grade, highlighting case studies that assist with conceptual mine scale models for understanding and predicting coal quality variation. In addition to the atlas, a library of scanned petrographic images of product coals from different basins and formations, illustrating the variation in rank, grade and type will be developed. This can be used for reference, training and round robins.

The Final report is in preparation. Photomicrograph plates illustrating the range of macerals at different ranks and from different coal seams in the selected Queensland coal measures are in draft form. Selecting representative images, as well as those which might create discussion, from thousands of images has been a major task. The petrographic assessment of case studies is being written up, focussing on what controls variability within a seam and between seams in the same coal measures, and how this varies with rank. A comparison of variability observable in core (megascopic lithotype analysis) with that in homogenised ply samples (microscopic maceral analysis) is included in these studies. Again, this approach illustrates trends in composition linked to depositional environment and trends in reflectance values linked to burial history, which can explain why different coals have different utilisation behaviours.

MINE SITE GREENHOUSE GAS MITIGATION

C28078
Technical Development Unit (TDU) for Catalytic Conversion of VAM

University of Newcastle
Michael Stockenhuber

Value:	$1,040,592
Report Expected:	August 2024
Industry Monitor/s:	Jim Sandford
	Russell Thomas
ACARP Contact:	Patrick Tyrrell

An increased need to minimise fugitive greenhouse gases emissions has put pressure on industries to reduce their emissions, in some instances deemed a necessary requirement to maintain financial viability. This has led to the development of systems to mitigate the fugitive emissions, particularly those associated with mining. Catalytic technologies hold numerous advantages over existing thermal methods, as it has demonstrated an ability to effectively mitigate lower concentrations of methane in the ventilation stream at reduced temperatures, demanding a considerably lower energy input and footprint. To implement this technology on an industrial scale, it is imperative to validate the safe operation of reactors, specifically under abnormal conditions.

This project utilises structured monoliths to support the catalysts. The monoliths have demonstrated good ability to support the catalyst whilst not developing significant pressure drop across the reactor. The catalyst has shown high conversion of methane streams from 0.1% to 10% with the main limiting factor for higher concentrations being the stoichiometry with oxygen. The catalyst has shown the ability to operate in said methane concentration ranges without producing carbon monoxide. It has been shown that an uncoated monolith required higher temperatures to auto ignite compared to an empty reactor tube, indicating an increased safety from the structure. This will be further compared to a catalyst coated monolith, with the expectation of a further increase in the inherent safety of the reactor.

C33068
Airbag Inspired Explosion Suppression System for Mitigation of VAM Explosions

University of Newcastle
Behdad Moghtaderi

Value:	$360,678
Report Expected:	February 2024
Industry Monitor/s:	David Webb
	Jim Sandford
	Russell Thomas
ACARP Contact:	Patrick Tyrrell

The principal vision in this project is to advance the development of a Rapid Action Inflating Nitrogen Bag Obstruction Explosion Suppression (RAINBOES) concept as an effective and ultra-fast suppression system for gas explosions. The project aims at proving the concept through a combined theoretical and experimental approach. Theoretical studies will involve both analytical assessments and CFD modelling aimed at gaining a deeper understanding of the fundamental science that governs the operation of RAINBOES and its key components. The experimental studies include prototype development followed by small-scale assessment and concept validation.

All the key tasks and milestones associated to phase II-Part I of the project have been completed. The project final report for this stage has been prepared and submitted to the industry monitors for review and feedback.

C34008
Satellite Remote Sensing - A New Tool for Coal Mine Emissions Management

Zephyr Environmental
Damon Roddis

Value:	$816,725
Report Expected:	September 2024
Industry Monitor/s:	Andrew Lau
	Ben Klaassen
	Jim Sandford
	John Watson
	Ned Stephenson
ACARP Contact:	Patrick Tyrrell

Phase 2 of the project has commenced. The objectives of this extension are threefold; to:
- Quantify methane emissions from open cut coal mines;
- Evaluate candidate methods for any future National Greenhouse and Energy Reporting (NGER) Method 4; and
- Provide a comprehensive data source to challenge claims made by lower temporal/spatial instrumentation (e.g. satellite imagery).

Stage 2, Phase 1 was completed in July 2023 and involved a field campaign to both quantify methane emissions/fluxes from open cut coal mines and to ground-truth observations from satellites. Specifically, this stage involved:

- Monitoring campaign at the chosen mine to quantify methane fluxes from different surfaces across the site;
- Use this to inform a conventional atmospheric dispersion model to predict methane 'heat maps' across the mine site;
- This has allowed us to optimise the location of medium/long duration monitoring equipment to be deployed in Phase 2

The fieldwork for Stage 2, Phase 2 is in progress and the project as a whole is due for completion September. In this quarter we have:

- Maintained two Picarro instruments in a (predominantly) upwind-downwind configuration;
- Maintained additional research-grade instrumentation (open-path FTIR) to characterise methane emissions/flux across the active pit;
- Towards the end of February we will relocate the instrumentation to the coal handling and preparation plant to assess methane emissions from this source.

C34066

Safe Operation of Catalytic Reactors for the Oxidation of VAM Operating Under Abnormal Reaction Conditions

University of Newcastle
Michael Stockenhuber

Value:	$406,740
Report Expected:	February 2024
Industry Monitor/s:	Jim Sandford
	Russell Thomas
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C35049

Optimisation of Operational Parameters of Catalytic Reactor for the Oxidation of Ventilation Air Methane

University of Newcastle
Michael Stockenhuber

Value:	$238,464
Report Expected:	August 2024
Industry Monitor/s:	Jim Sandford
	Russell Thomas
ACARP Contact:	Patrick Tyrrell

Reducing fugitive methane emissions from mine shaft ventilation (VAM) is crucial for the environmental sustainability and financial viability of mining operations. Previous projects have highlighted the potential of catalytic reactors as effective solutions for mitigating these emissions, surpassing the limitations of current thermal abatement systems. The proposed Catalytic Oxidation of Methane with Multidimensional Structured Supports (COMMSS) system operates at lower temperatures and requires a smaller footprint and lower energy input compared to alternative technologies. While long term stability has been demonstrated at the laboratory scale using micro-packed bed reactors, their commercial implementation faces challenges such as significant pressure drops and susceptibility to channelling. Addressing these issues is essential for realising the full potential of this technology in large-scale applications.

To investigate the feasibility of the COMMSS system as a stable abatement technology, a technical development unit has been designed based on previous micro-reactor studies to demonstrate long-term activity and operation. The behaviour of catalytic systems has been investigated at varying methane concentrations, with high levels of conversion for concentrations between 0.2% to 1%. Reactor response and minimum system requirements to achieve desired activity and stability will be further examined.

C36001
Open Cut Fugitive Greenhouse Gas Emissions

Australian Coal Mining Consultants
Andy Self

Value:	$227,500
Report Expected:	February 2024
Industry Monitor/s:	David Webb
	De Nicholls
	Iain Hornshaw
	Jim Sandford
	Sandy Tickell
ACARP Contact:	Patrick Tyrrell

The draft final report has been submitted to the Industry Monitors for review.

C36002

Investigation into the Technical Feasibility of In-Pit Gas Capture for Open Cut GHG Mitigation

GeoGAS
Christian Boucher
Yvette Heritage

Value:	$404,000
Report Expected:	May 2024
Industry Monitor/s:	David Webb
	De Nicholls
	Iain Hornshaw
	Jim Sandford
	Sandy Tickell
ACARP Contact:	Patrick Tyrrell

The key objective of the project is to determine how open cut mining modifies the coal seam gas reservoir and how these changes could be leveraged to provide a more cost effective way of capturing gas from within the operating pit for the purpose of fugitive emission mitigation.

Progress during the quarter included finalisation of reservoir inputs and drainage criteria as inputs for emission models. Models were developed to provide estimation of emissions over time from exposed coal to across a range of reservoir/mining conditions. Preliminary results demonstrate that the extent of emissions is complex interaction of gas reservoir, coal resource and mining factors. Although not addressed in the current study, the geotechnical study identified the extent of groundwater re-charge will require further assessment to understand its influence in depletion around exposed faces.

Drainage modelling commenced for both ex-pit (ahead of mining) and in-pit (concurrent with overburden removal) scenarios across a range of reservoir conditions and mining inputs. While key factors are emerging, it is clear that the interaction between factors is complex in an operational setting.