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Introduction of continuous haulage (4FCT) at the Clarence Colliery

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INTRODUCTION OF CONTINUOUS HAULAGE (4FCT) AT THE CLARENCE COLLIERY

Allison Golsby[1]

ABSTRACT: Clarence Colliery is exploring the 4FCT as a continuous haulage system. The 4FCT (Flexible Conveyor Train) is used as a continuous conveyor between the current continuous miner unit and the fixed boot end of the panel conveyor vs the three shuttle car system, currently in use in a continuous miner partial pillar extraction panel at Clarence Colliery. At Clarence the base case is three shuttle cars per continuous miner, using a cut and flit partial pillar mining method.

The Joy 4FCT has not been utilised in Australia before. The main questions are: What is a 4FCT? How does it function? What are the benefits? How do we introduce the 4FCT safely? Why Clarence Colliery? What else needs to change at Clarence to optimise the 4FCT
? Moving forward?

Clarence Colliery needs to meet specific subsidence, water make, geological and mine design requirements. The 4FCT implementation offers Clarence colliery the opportunity to explore new technology, while testing Clarence's analysis, measurement, assessment and continuous improvement processes.

The choice of the 'better option' in any analysis is not always made for monetary reasons. Often option choice decisions are made for safety, operational ease or engineering or mine design optimisation. Money is not the prime driver, but part of the decision making process.

INTRODUCTION TO CLARENCE COLLIERY

The Clarence Colliery is located at Newnes Junction on the Newnes Plateau at Clarence in the Australian State of New South Wales. The Clarence Colliery is 10 km from Lithgow off Chifley Road between Dargan and the Zig Zag railway and 140 km East of Sydney, as shown in Figure 1.

Coalex Pty Ltd (ACN 000 694 315, Clarence Coal Investments Pty Ltd (ACN 003 772 174), Japan Energy Australia Pty Ltd (ACN 003 919 668) and SK Australia Pty Limited (ACN 003 694 225) are participants in an unincorporated joint venture (the Clarence Joint Venture). Clarence Colliery Pty Ltd (ACN 001 680 584) is the manager of the Clarence Joint Venture.

With resources of approximately 230 mt, the Clarence Colliery (Clarence) has large reserves of good quality coal sufficient to support mining for more than 20 years. The marketable reserves, including a recent additional mining lease area, are estimated to be 48 mt.

Clarence is an underground mining operation and has been in operation since 1979. Throughout its history Clarence has mined *The Katoomba Seam* using the partial pillar extraction system technologies. The *Katoomba Seam* is the upper most coal seam in the Illawarra Coal Measures. Clarence Colliery partial pillar extraction system resultant subsidence is minimal, an example is shown in Figure 2. Clarence has achieved safety and innovation awards for the mine site. Careful design combined with environmental monitoring and safety systems has enabled Clarence to gain these awards.

Clarence has a production capacity of up to 2.1 Mtpa with Australia's most productive continuous miner operation using three continuous miners. A high capacity continuous haulage mining system (Joy 4FCT) has been ordered for installation by April 2010. A place change mining method is used in development and in partial pillar extraction panels.

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Figure 1 – Clarence Colliery Location

Clarence primarily produces low sulphur, thermal coal for sale and export to markets in Korea, Taiwan and Japan where the coal is used for power generation. The efficient coal preparation plant enables the development of various product types. A coal sizing plant serves the domestic market.

The mined coal is transferred to surface by conveyor and reduced in size (<50 mm). The coal is then graded and some washed (to remove additional ash) and screened before it is all stockpiled for loading. The export coal is loaded on trains at the Clarence rail loop on the Western line at Newnes Junction. The Clarence coal exports are shipped mainly through the Port Kembla coal-loader.

Clarence Colliery seam characteristics

Clarence Colliery only mines the *Katoomba Seam*. The seam characteristics described for Clarence Colliery reflect the *Katoomba Seam*. There are other coal seams at Clarence within the Illawarra Coal Measures that have not been exploited by Centennial coal.

Figure 2 – A section of Bungleboori Creek under which Clarence has mined

The Clarence Colliery seam characteristics are typically:

- m to 4 m in height with few partings.
- The seam contains low ash, low sulphur and phosphorous

- The seam gradient dips at an average of 1^{o} to the east by north east
- Depth of cover is generally less than 200 m, though can reach 270 m
- Small geological faults exist in the projected mining panels. The Clarence Colliery geological model has been calibrated against the advancing faces, with a good correlation between the predicted and actual values. The Clarence geological model has been built up from geological mapping projected forward and aerial magnetic surveys calibrated against actual mapping. The faulting found on the surface is vertical and generally extend to the seam.
- The Clarence Colliery experiences a low stress environment
- The Katoomba Seam and adjacent strata contains negligible methane and negligible carbon dioxide gas
- The seam has a below average water make.
- The roof is a competent sandstone, with a hard sandstone floor

Clarence Colliery mine design criteria

Clarence Colliery uses essentially a bord and pillar mining method, using partial extraction. The partial pillar extraction design maximises coal resource recovery without fracturing the over burden. Clarence mitigates ground water inflow and disturbance to aquifers, by keeping the over burden as intact as possible.
Clarence Colliery uses the partial extraction mine design in conjunction with balanced development and extraction timings. This balance optimises conveyor belt utilisation and therefore coal clearance from underground.

The Clarence Colliery mine design results in minimised surface subsidence under sensitive surface features, such as shown below in Figure 3. The extent to which surface subsidence and disturbance can occur is set by the following parameters:

- Subsidence of less than 100 mm
- Tilts of less than 2 mm/m
- Strains of less than 1 mm/m
- Cliff face protection protocols

WHAT IS A JOY 4FCT?

A 4FCT (Flexible Conveyor Train) is used as a continuous conveyor (as shown in Figure 4) between the current continuous miner unit and the fixed section belt of the panel conveyor instead of the three shuttle car system (with an example shown in Figure 5) with a conveyor boot end, currently in use in a continuous miner partial pillar extraction panel at Clarence Colliery. At Clarence the base case is three shuttle cars per continuous miner, using a cut and flit partial pillar mining method.

The choice of the 'better option' in any analysis is not always made for monetary reasons. Often option choice decisions are made for safety, operational ease or engineering design optimisation. Money is not the prime driver, but part of a thorough decision making process, using an investment evaluation process model.

The 4FCT is designed for the hopper to sit under the continuous miner conveyor, moving the coal into the lump breaker to crush the coal to the desired size, then feeding the coal onto the flexible belt and then tipping coal onto the section belt.

Figure 3 – Surface features under which Clarence has mined

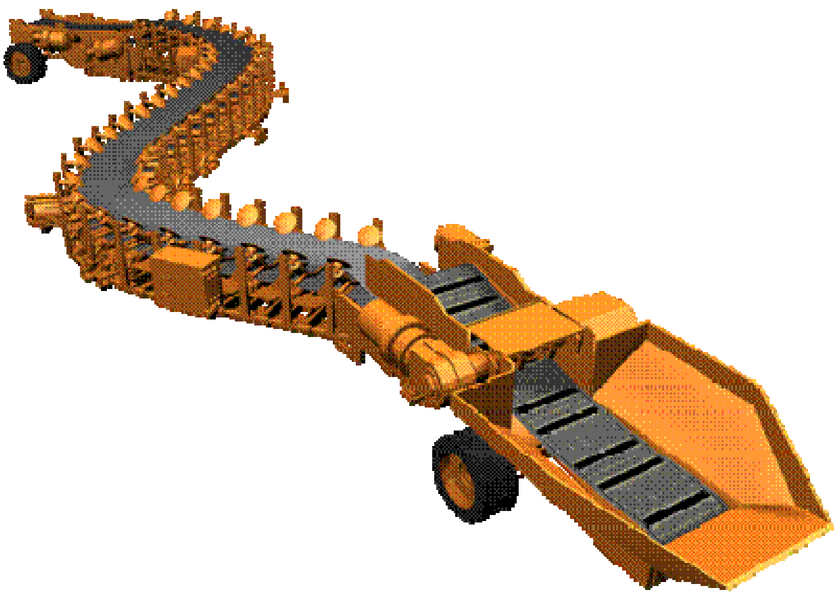

Figure 4 – Flexible Conveyor Train

Figure 5 – Shuttle car

The Clarence Colliery 4FCT (4FCT01) specifications are (Joy Manufacturing 2008):

- 4FCT Flexible Conveyor Train (as shown in Figure 7 and 8)
- Over the top discharge
- Initial train length 110 m
- Dynamic move up (DMU) and retreat with cam, rails, propulsion system and stacker
- Rated capacity - size and convey 1,400 t/h, or 65,000 t/m
- Maximum turning radius of 9.44 m
- Minimum mining height 2.3 m, optimal 2.5 m, max mining height 3.5 m
- Belt width 1 065 mm
- Compatible with Roof Bolter Joy 4 head multibolter
- Coal is the material to be mined
- Maximum Grade < 5^o
- Umbilical cable length 6 m
- Australian compliant engineering
- Traction speed 0-23 m/min
- Belt speed 0-215 m/min
- Conveying rate 24.4 t/min
- Adjustable lump breaker (Global brand) (as shown in Figure 7)
- Compatible with Continuous Miner Joy 12CM12B
- Entry width 5.5
- Machine Input voltage 950 VAC (range 855 to 1045 VAC)
- Machine Input Frequency 50 Hz
- Traction drives – four (4)

The 4FCT is expected to provide for Clarence Colliery:

- Continuous coal clearance for the continuous miner, making the miner truly continuous
- The 4FCT can tram in advance and retreat, convey and deliver coal simultaneously
- The 4FCT follows the miner to multiple drivage sequences
- The 4FCT provides services (as shown in Figure 14) to the continuous miner, such as electrical power, water and communications
- The 4FCT crushes the coal to a predetermined size before the coal is carried on a conveyor

WHY USE THE 4FCT AT CLARENCE COLLIERY?

There were several elements considered by Clarence Colliery; with safety the prime driver. Some of the elements considered are listed below:

- Safety – removes operational personnel from interaction with equipment and shuttle car work environment (as shown in Figure 6), operating at a slower traction speed. The 4FCT removes the ergonomic issues associated with shuttle cars (Joy Mining Machinery and Centennial Coal, 2009). The ergonomic issues involve the operator interacting with rough wheeling roads, roadway clearances, seat belts and canopies approximately 200 times a shift. The 4FCT reduces manual handling significantly in cable handling and section service moves.

- Capability – increased production, improved productivity, increased marginal revenue, with the extra coal sold to current or potential customers, the shuttle cars are the bottle neck in the Clarence colliery coal clearance system. The increased production is a result of eliminating shuttle car wait times and therefore producing continuously.
- Compatibility – Clarence mining conditions are conducive to 4FCT operation, the 4FCT is a modular 'add on' to the rest of the Clarence current Joy upstream and downstream equipment and bolter. The existing coal clearance, preparation and handling facilities match to the 4FCT. The 4FCT is quicker and safer with an optimised maintenance process from variable speed components and interchangeable parts from other Joy machines (Burgess and Raines, 2008).
- Flexibility – The 4FCT is less able to react to a mine design change than the current system of cut and flit with shuttle cars. On the other hand the 4FCT is able to adapt to development and extraction mining methods readily. The 4FCT comes in modular sections allowing for the 4FCT to be lengthened as the mine design changes. Clarence Colliery can still use continuous haulage in a bord and pillar mining method, with partial pillar extraction and meet the regulator's approval requirements.
- Sensitivity – designed for the underground coal mining environment such as at Clarence, as seen in the United States experience and yet to be tested in Australia Drotsky, 2006). The Clarence Colliery employees readily accept and move forward with new technology change.
- Cost – The 4FCT has a higher capital cost compared to shuttle cars, with potentially lower overall pit operating costs. The 4FCT is new to Australia with most of the implementation identified as a research and development project for Clarence Colliery. The 4FCT presents less maintenance than the shuttle car fleet for the following reasons: non intrusive maintenance, low mean time to repair, compatibility with the current equipment used at Clarence and therefore minimising 4FCT life cycle costs.
- Mining approvals – the 4FCT operation is conducive to controlling the surface subsidence in Clarence's mining operation and improving management of ground water.

MINE PLANNING AND PANEL DESIGN

The mine plan will need to change to accommodate the turning angles and the length of the 4FCT. One of the optimal mine plan designed for the 4FCT is shown in Figure 9. This particular mine plan came from 20 options assessed on coal recovery, practicality of mining, geotechnical needs, approval considerations, the 4FCT parameters and logistics of the mining cut and flit system. Current mine plan relies on 90^{o} cut throughs and 5, 7 or 9 heading layouts.

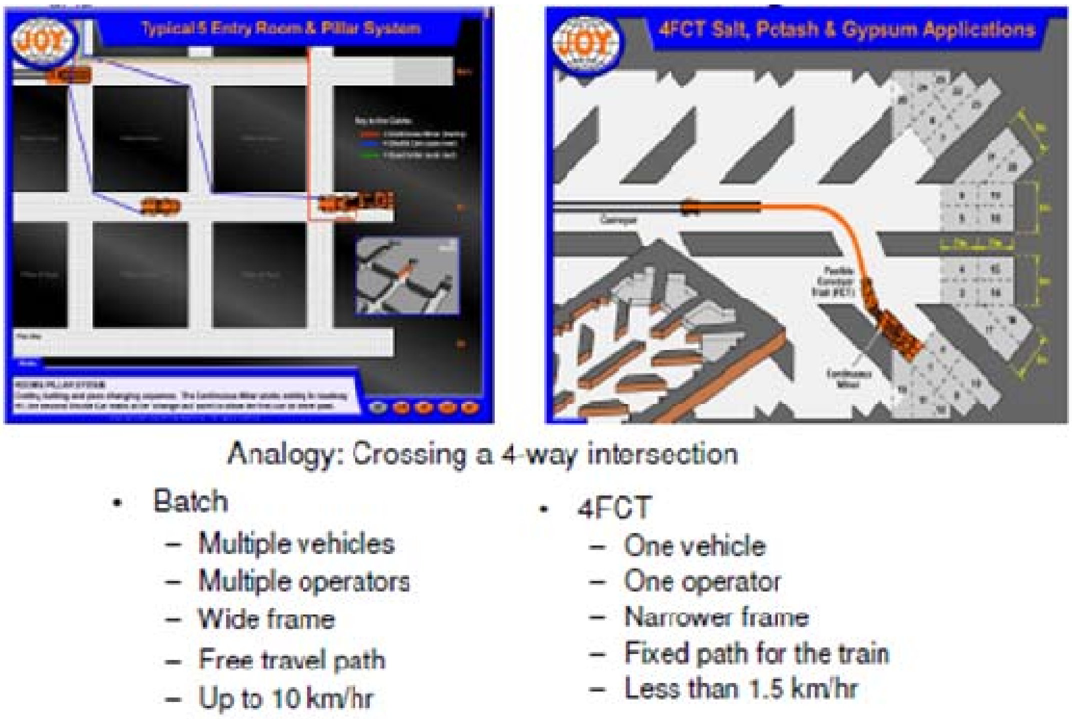

Figure 6 – Shuttle car compared to 4FCT safety

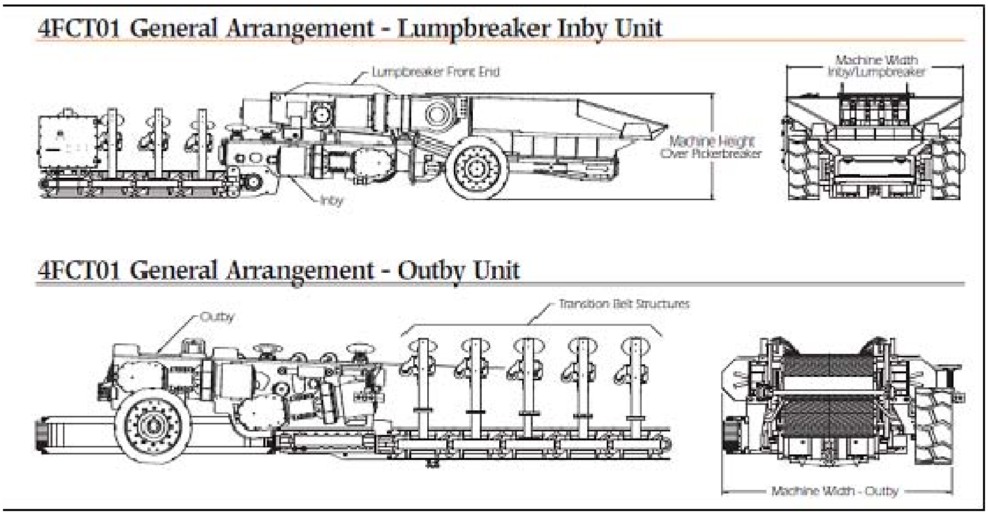

Figure 7 – Schematic drawing of the 4FCT

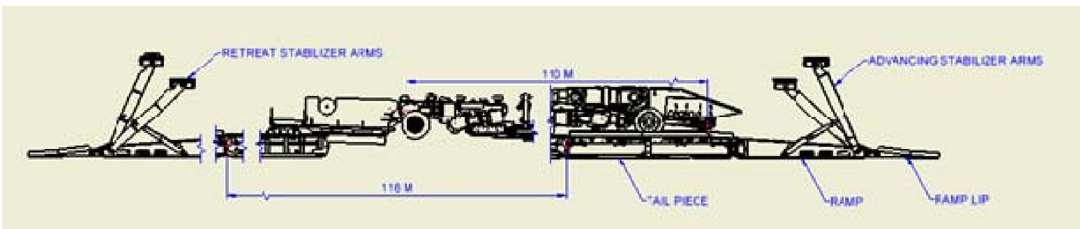

Figure 8 – Staker arm configuration

The proposed 3, 5 and 7 heading layouts have been analysed to assess potential productivity, recovery and safety in development and extraction. The Clarence 4FCT panel designs are driven by the depth of cover, factor of safety for the remnant pillars, geological features and coal properties are a few. The factor of safety for the panel design shown in Figure 9 is 2.3, making these designs very conservative. The panel designs are required to support the roof span above panels. To maintain these spans the panels need to be slender, contain spine pillars for extra support or reduced extraction in less competent roof areas.

As the panel design as shown in Figure 10 has been assessed, so the sequencing needs to be analysed and developed to optimise the productivity, recovery and utilisation of the new 4FCT technology and Clarence Colliery mining operations. This figure shows the mining sequences chosen for the 4FCT in a three heading layout, considering bolter and miner moves, with other associated activity interaction. Currently, with the equipment at Clarence the maximum cut-outs are 15 m. Analysis will be undertaken to optimise this mining sequencing process.

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Because of its length, the 4FCT will not be able to mine start off or mine the current panel designs at Clarence. The new 4FCT panel design to allow installation and start off the panel (as shown in Figure 11) differs radically from the current knowledge, affecting the predictability of subsidence, stability of the pillars, coal output and ventilation design. The change in panel design will need to have a new ventilation plan devised to ensure enough air reaches the mining face as well as the increased panel differential pressures. There will be a requirement for more effective ventilation, requiring the same ventilation flow to the miner as previous with less cross sectional area for the air to travel, increasing differential air pressures in the 4FCT panels. The increased differential air pressure in the 4FCT panel requires the current non pressure rated ventilation stoppings to be higher rated, which is a more expensive stopping requirement.

ALIGNING MINING OPERATIONS WITH 4FCT METHODOLOGY

Clarence Colliery needs to align the current mining operations on site with the new 4FCT mining methodology.

The 4FCT is a piece of equipment designed and built in America. Before being used in Australia, the 4FCT needs to be compliant with Australian legislation, Australian standards, regulatory standards and the Clarence Colliery standards. Risk assessments were completed in the early stages of the 4FCT evaluation, so outcomes could be used to improve the design. There is an identification process, with the original equipment being modified to meet all of the requisite standards. Changes to original plant can result in consequences that will affect facets of the 4FCT operational parameters.

The 4FCT panel will develop in a faster linear advance than the other panels developed at Clarence. To keep the 4FCT advancing, the belt maintenance (Belt take up and loop arrangement) needs to be upgraded to allow for greater belt run out lengths between belt inserts and to speed up belt moves.

The belt advance structure will need to be a fast installation designed. To reduce 4FCT downtime while waiting for a belt move to be completed, the fast installation will be a critical path task for the 4FCT to optimise its utilisation and continue its advance.

The faster panel advances require a method of moving transformers and other services forward to support the continuous miner and the 4FCT. A faster method has been identified. This new technology utilises a monorail support system to rail the services forward in a panel.

The monorail and DMU (Dynamic Move Up Unit as shown in Figure 12) (Sebeck, Freeman and Ziegler 2008) from the 4FCT has a higher profile compared to the shuttle cars. This profile increase reduces the space available to install and maintain an explosion protection system for a coal mine panel. Part of

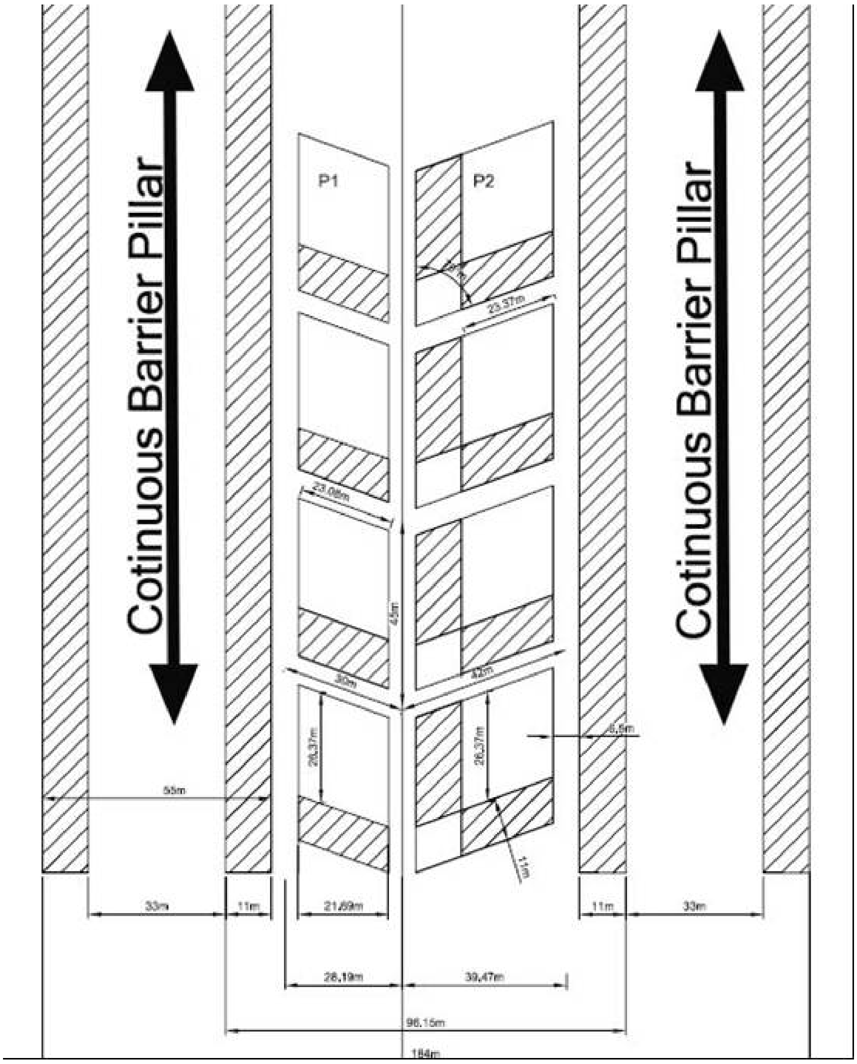

Figure 9 – Three heading layout design with expected extraction shaded

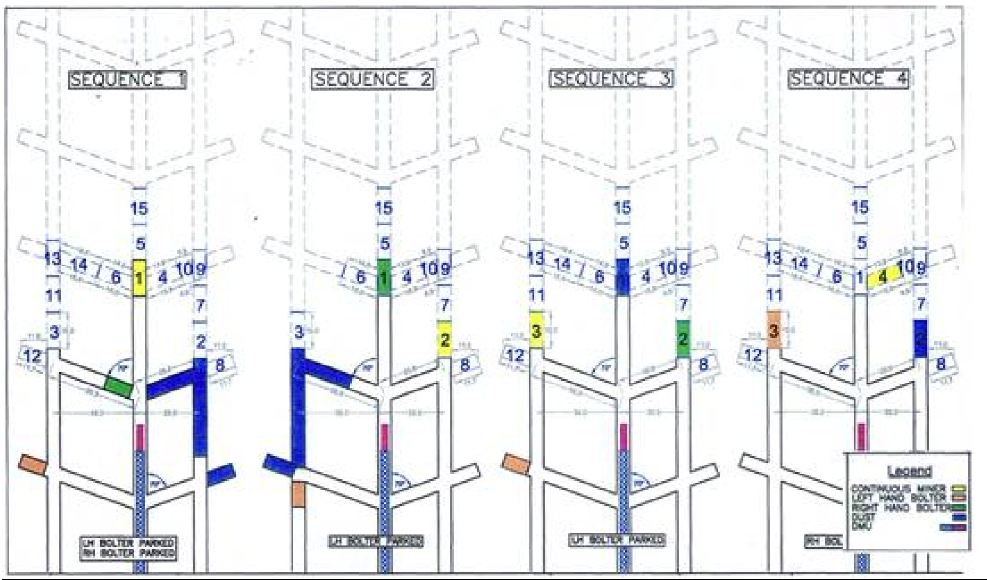

Figure 10 – Planned sequencing of the 4FCT Mining Process (Clarence Colliery 2009)

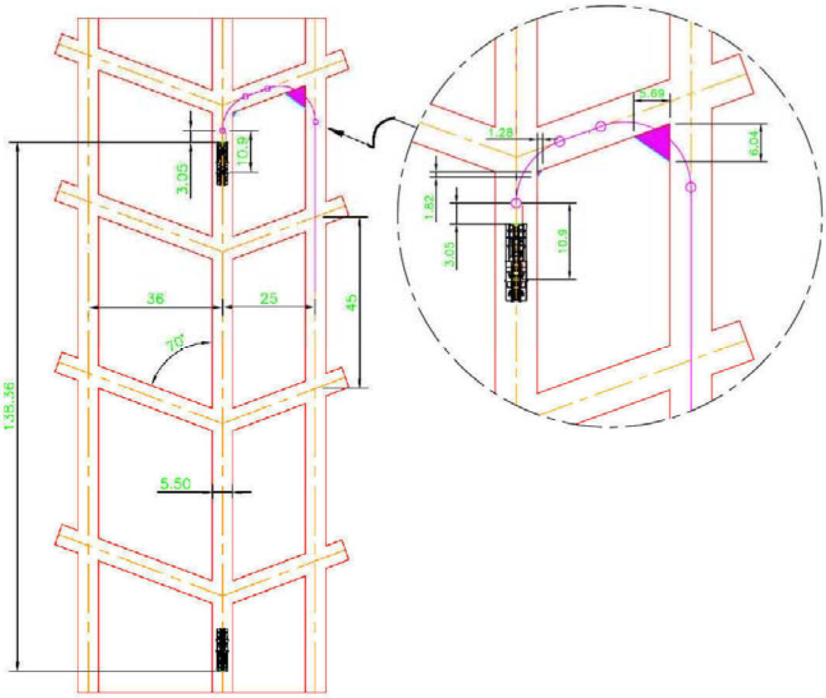

Figure 11 – A proposed 4FCT installation into panel plan (NM Claugh 2008)

the pre-4FCT explosion protection system was a water barrier. With analysis, a stone dust barrier was considered an alternative protection method and then risk assessed (Golsby, 2009). The new installation process needs a pod that is designed for the 'bat bag' installation, with new risks requiring control. One of the solutions is to develop a holistic explosion protection system based on a risk assessment and the regulatory requirements. Application to the regulator would be necessary for these modifications to be assessed and bench marked against best practice methods used by other coal mines.

The 4FCT will require more electrical power and water, compared to the shuttle car base case. There is a need to replan and rearrange our services to meet the needs of the 4FCT.

The 4FCT has been envisaged to potentially carry more coal than the current conveyor belts are rated for. The solution will require the pit conveyors to be analysed to convey coal at the 4FCT coal clearance rate.

The existing bonus system for Clarence Colliery employees is predominantly coal production driven. The new 4FCT technology will require a modified incentive system to ensure that the outcomes desired from the new technology are encouraged.

Consultation with all Clarence personnel will assist the new technology methodologies to align with current practices. This will ensure that all the changes needed and the safety considerations required, have been identified, which may encourage ownership of the new technology. Ownership of the 4FCT by all those at Clarence is necessary to ensure the 4FCT succeeds. The new processes and systems require comprehensive competency based training. This training is an imperative, if the 4FCT is to function as expected, particularly as safety is the first consideration.

The task of aligning the current mining operations at the Clarence Colliery with the 4FCT methodology process requirements involves a degree of complexity. Considerations included:

- Risk assessing the process, the design, time scale, compliance and associated infrastructure. The risk assessment outcomes help identify gaps that can be filled before they become critical.

Figure 12 – DMU sitting above a panel conveyor belt (Joy Manufacturing 2008)

- Change management principles were applied to the introduction of a continuous haulage system at Clarence. The change management process offers a structured path to prompt for system, process and practice development reducing unplanned issues.
- Competency based training in the commissioning procedure, standards and agreed method of resolution will promote safe and effective operation, maintenance, transport, communication and problem solving.
- The new mining process will need to be process driven and not time driven as is current practice. The time driven model allows for mining to progress with panel maintenance (belt moves and installations) only on one shift, no matter where the mining process is up to. The 4FCT will need to have the panel maintenance to occur at a certain point in the mining process. To be effective, the 4FCT will need belt moves and installations 'as and when needed'. The 4FCT cycle will not be able to align with a certain shift. The culture at Clarence is very time driven, with the maintenance specialists all being on the night shift. With the new process driven culture, skills will need to be improved over all shifts.
- Outbye coal clearance system needs to be operated for reliability and efficiency. The Clarence Colliery coal clearance is at optimal efficiency when section advances occur every 24 hours.
- System monitoring and communications reduce downtime, damage, while optimising safety, coal clearance and maintenance.
- The 4FCT has brought the monorail services unit to Clarence and it has readily been accepted. The monorail, an example shown in Figure 13 speeds up section advances and service moves, while reducing manual handling issues.
- Materials and parts require commissioning, to test all the operational parameters and documented for commissioning to be a success. The commissioning outcomes can be used to ensure high standards and expectations from both sides are met.
- The gaps identified during the commissioning need to be remedied before delivery is accepted.

CONTINGENCIES

Contingency plans are developed to optimise the introduction of the 4FCT. The 4FCT could experience teething problems. These challenges, if experienced may require the following contingencies:

Figure 13 – Monorail with services

- The original shuttle car fleet will need to be maintained and kept close to the 4FCT panel for fast deployment if the 4FCT was inoperable for any reason.
- To prevent disruption to the mining cycle workflow, new ventilation and bolting processes or appliances may need to be implemented to reduce the installation change issues, as the panel becomes a process driven, not a time driven mining cycle. The support cycle is critical to the 4FCT continuous mining process in the cut and flit mining method at Clarence. If poor roof is encountered, the support cycle will lengthen, creating 4FCT wait times, reducing coal production.
- Renegotiate the bonus scheme with the Clarence workforce to ensure all find the bonus scheme acceptable. Consult with all personnel to find a win-win solution.
- Implement a culture change to allow the role changes needed to make the new system 4FCT process driven. Ensure that Clarence employees readily accept and apply the agreed processes for the new 4FCT technology changes.
- Training and education from the supplier, using competent personnel. The development of quality quantitative risk assessments with specific outcomes. These outcomes will drive the training and equipment needs associated with the 4FCT mining process.
- As with any other change, technology changes mean there will be a need for measurement of Critical Performance Indicators (KPIs), monitoring, review, analysis and the development of a continuous improvement process. Over time, Clarence Colliery aims to increase production and productivity, with the use of efficient continuous improvement practices
- Ensure safety is addressed with all personnel, especially relating to the changes and consequences surrounding the 4FCT.
- The use of benchmarking to estimate the expected 4FCT behaviour at Clarence by visiting similar mine sites using similar processes.

INVESTMENT EVALUATION PROCESS

An effective investment evaluation process reduces the risk to business and increases the chances of a project succeeding. The 4FCT project is moving through the five phases of the investment evaluation process model. The five phases are concept, prefeasibility, feasibility, execution and operation. These phases each have several steps, which need to be completed before moving onto the next phase in the investment evaluation process model. All projects need to go through an extensive evaluation process. The 4FCT is currently at the execution phase. The Clarence Colliery 4FCT is currently being fully built for testing at the Joy Workshops at Mossvale. Once the testing has been completed successfully, the 4FCT will be broken down and moved to Clarence Colliery for rebuilding and commissioning onsite.

Is the 4FCT the right choice? To ensure the analysis draws the right answers, three other coal transport systems were compared against the same criteria, with the 4FCT being the optimal product choice. The alternative systems were: shuttle cars, *Bucyrus* chain haulage bridge conveyors, *Sandvik* tear drop conveyor system or bridge type conveyor belt system. All of these alternatives were seen to be less reliable, less compatible (needs a cement drive or have a maximum 450tph output) or may not be a proven technology. A feasibility study identified these alternatives, studied them and found the optimal system for continuous haulage at Clarence to be a 4FCT (Hedges, Griffith and Hack, 2008).
Some of potential risks with the introduction of the 4FCT to Clarence Colliery, identified in risk assessments (Clarence Colliery 2009) are:

- The 4FCT does not function as expected or planned, an iterative design process, with a specific original scope of work, good cooperation between OEM and customer and a thorough contract management system has ensured that all

Figure 14 – 4FCT section Underground (Joy Mining Machinery 2008)

- stakeholders have the same understanding of the 4FCT expectations (Hargraves Martin 1993).
- The 4FCT does not appear to be compatible with the other parts of the cut and flit mining system
- The 4FCT is not compatible with the culture and skills now available to the pit. Skills need to be transferred between employees and new skills attained.
- The mine plan is not as flexible as the current mining processes at Clarence. The mine plan can not deviate for geological features as readily as the original Clarence mining system.
- There will be a different interaction hazard between the equipment, rib and personnel.
- The ventilation may not perform as anticipated.

Since the 4FCT risk assessments have identified potential issues, these outcomes have been assessed with controls developed to reduce any adverse 4FCT outcomes.

COMPLIANCE?

The 4FCT has been designed and built to American standards and needs to be Australian compliant, an important component of the 4FCT introduction to Clarence Colliery. Effective communication and consultation with the Clarence employees improves the safety, production and system interactions into the future. Effective consultation and communication for the 4FCT project includes:

- Regular meetings with employees outlining plans for the implementation of the 4FCT coal haulage system
- Quarterly meetings outlining steps in design, construction, commissioning and operation of the 4FCT
- Ongoing involvement of the people from different shifts and disciplines in seeking contribution in dealing with potential changes in production, service, and specialist support activities
- Involvement of Clarence tradesmen and operators during the build and compatibility testing at the OEM, Joy Mining Machines Workshops at Moss Vale.
- Commence initial trades and operator training to enable the components to be transported underground and assembled.
- The OEM has readily moved the 4FCT through the Australian compliance process, providing support and cooperation to the regulator and the customer/ mine operator.

MOVING FORWARD

The 4FCT will be assembled at Clarence Colliery, commissioned and will start production shortly thereafter. Moving into the future, there are still factors and requirements to be met for this project to be a success. Some of these are:

- A significant change in safety and productivity
- Opportunity for the OEM and customer mine operator to partner in design, development, and implementation of a safe and efficient system of work
- Recognise and action the requirement to re engineer existing methodologies for advancing and retreating panel services
- Review current production and maintenance process monitoring measurement and analysis for application to 4FCT operation
- Determine appropriate set of KPIs in establishing continuous improvement program for 4FCT operations at Clarence

The identified audit process requirements include:

- Delivery tests need to include dimensions, observation of operation, record all functions, check all fluid pressure levels, check overload levels, test emergency stops and pilots, test thermistors and RTDs, test fluid flows, review compliance with all regulatory requirements, check polarity, test operational parameters, vibration testing, compatibility with other equipment onsite and check signage.
- Providing a risk assessment for operational use with compliance to site procedures, such as isolation.
- Design and operational compliance to Australian Standards, Clarence Colliery standards and legislative requirements.
- Training compliance gap analysis
- Mine extraction actual compared to planned for the 4FCT panels
- Mine schedule actual advance compared to planned

Before the 4FCT was ordered, the elements and components Clarence required of the 4FCT, were identified, described, and measured. The standards set by these requirements were formatted into the required audit system. The audit system will ensure that the 4FCT meets the Clarence Colliery needs, with a method to measure agreed milestones to identify gaps early and to keep the scope of the project on track (Chan and Mauborgne ,1999).

The Clarence expectations of the 4FCT are:

- Life cycle of the 4FCT capable of performing as specified
- High level of automation
- Ease of operation
- High level of reliability
- Meet the legislative requirements of Australia
- Design risk assessment, inspections and test plans to be supplied by manufacturer and may be audited by the mine operator.
- Installation of 4FCT managing hazards, installation procedures supplied, competency training by supplier, supply of drawings, parts manual, supervised installation by supplier using competent personnel, with fit for purpose tools and parts.

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Bob Miller – Business Improvement General Manager
Brian Nicholls – Production Manager
Graeme Owers – Maintenance Manager
Peter Raines – 4FCT Project Engineer
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Justin Ryan – Manager Mechanical Engineering
Gregory Shields - Mine Manager
Grant Sullivan – Safety / Training Manager
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