

Underground conveyor equipment incident puts workers at risk

Causal investigation

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Executive summary

During a conveyor extension on a flexible conveyor train at the Ulan West Operations underground coal mine near Mudgee, NSW on 29 August 2017, seven workers sustained minor injuries when the boot end was unexpectedly dragged about 16 metres.

Due to an unrelated incident, power had been lost to the conveyor drive head, winch and the dynamic move up (DMU) during the conveyor belt extension. The subsequent restoration of power did not restore power to the conveyor winch and, as the DMU was advancing inbye, an over-tensioning of the belt occurred. This caused a failure of a linkage point between the DMU and the conveyor boot end, breaking large steel components. The release of stored energy resulted in the boot end unit being dragged about 16 m by the belt, impacting on the installed conveyor structure and also the workers who were standing in the area.

Following the incident and preliminary investigation, the regulator determined to undertake a [causal investigation](#) into the incident to enable the quick and full understanding of the causes of the incident and publication of the corresponding lessons to reduce the likelihood of recurrence.

A causal investigation team comprising representatives from Ulan West Operations, Glencore Coal Assets Australia, Joy Global, the CMFEU and the regulator was established to investigate and identify the causal factors, determine the effectiveness of the controls being used and to discover what factors contributed to the failure of controls.

The investigation has now been completed and identified the following matters as contributing causal factors:

- mechanical design that enabled the DMU advancing cylinders, if not controlled, to have enough force to break the boot end frame from the DMU
- parameter management that enabled password-protected settings to be altered and all users not to have visibility of the actual settings
- safe work procedures for the DMU advance not being followed
- changes to safe work procedures not being communicated.

In addition, the investigation identified the following key learnings:

- even though the design review process for the equipment was extensive, the consequences of the over-tension of the panel belt was under-estimated by the installation team
- this under-estimation led to a lower level of engineering analysis being applied to the design of the mechanical structure and the integrity of the electrical control system interlock between the dynamic move-up advance and the panel belt winch
- passwords to control parameters in various original equipment manufacturer equipment were found to be widely known across the industry allowing the security to be compromised
- where safe work procedures have been developed, workers should guard against normalising the risks involved in the task by their experience of doing the task many times, and periodically take the time to step through the procedure on the job, particularly after any changes have been made to procedures or environment.

When safety controls are updated into safe work procedures, these safety features need to be clearly and concisely communicated to the workers in a formal manner. The importance of the introduced safety controls should be emphasised to workers.

1. Causal investigation

A preliminary investigation and assessment of the incident was carried out by the regulator which did not identify any material breaches of the work health and safety laws. Following this assessment the regulator determined that an investigation under the regulator's [causal investigation policy](#) was the most appropriate way forward to enable the quick and full understanding of the causes of the incident and publication of the corresponding lessons to reduce the likelihood of recurrence.

Notably, a causal investigation is an investigation into a safety incident notified to the department under the work health and safety laws, not to obtain evidence for a prosecution but rather to identify the causal factors of safety incidents, the effectiveness of the controls being used and what factors may have contributed to the failure of the controls. Timely communication helps ensure that duty holders under the work health and safety laws are able to better understand the risks they must manage, and the necessary controls to prevent reoccurrences of similar safety incidents.

The regulator invited relevant stakeholders to participate in the causal investigation process and an investigation team comprising of representatives from Ulan West Operations, Glencore Coal Assets Australia, Joy Global, the CMFEU and the regulator was established.

2. The incident

At 12.36pm on 29 August 2017, seven workers were conducting a planned conveyor belt extension in maingate development panel MG5. This process involved advancing the dynamic move-up unit (DMU) which forms part of a system known as a flexible conveyor train (FCT). This system is used to transfer coal from a continuous miner to the panel conveyor. The DMU advancing process (part of a panel belt extension) included reducing tension in the panel conveyor belt system from its normal operating set-point, and isolating certain parts of the conveyor drive systems. The DMU was then advanced using hydraulic rams, which caused the belt to be pulled from the conveyor storage unit (commonly known as a loop-take up) at the conveyor drive head.

During this extension, an over-tensioning of the belt occurred causing a failure of a linkage point between the DMU and the conveyor tail-end, breaking large steel components. The release of stored energy resulted in the tail-end unit being dragged 16.4 metres by the belt, impacting on the installed conveyor structure, and also the workers who were standing in the area. A worker was transported to Mudgee Hospital by Ambulance Service NSW for suspected head injuries but was released later that evening. Nobody was seriously injured although there was a potential for multiple fatalities.

Figure 1 - Failed hitch point on DMU.



Figure 2 – Boot end frame showing where hitch was attached.



Figure 3 - Side shift mechanism GA.

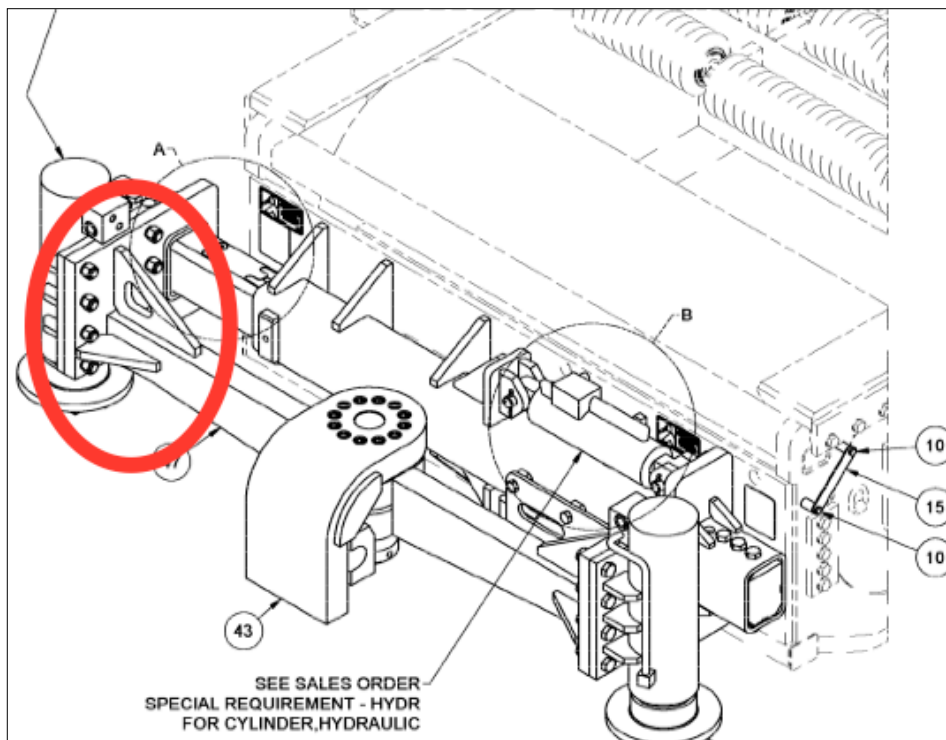


Figure 4 - Damaged conveyor structure outbye of bootend looking inbye.



2.1. Equipment specification

Equipment	Specifications
CV105 Joy Global conveyor	<p>Length 3000 m existing and to extend to 5000 to 6000 m.</p> <p>Width of belting 1600 mm solid woven belt 10000 series with 2 x 2 covers.</p> <p>Lift 36 m.</p> <p>Power 2 x 250 KW electric motors driving through Voith TPKL coupling through a 90 degree gearbox.</p> <p>Storage loop with about 300 m belt storage. At the time of the incident, the loop was at 243 m.</p> <p>Winch 55 KW drive vector winch. Two load cells installed at the winch rope anchor point. The tail pulley was 600 mm diameter. The winch has a normal operating tension of 58 KN.</p>
DMU Joy Global manufacturer	<p>Joy Global 4 FCT floor mounted.</p> <p>DMU length = 232.8 m and the FCT length ~ 180 m. The total length of the Ulan West Operations flexible conveyor train, including DMU, was 337 m</p>

2.2. Site inspection

An initial scene assessment of the MG5 FCT/DMU and CV105 was conducted.

CV105 panel conveyor inspection

The inspection followed the belt advance process starting at the CV105 drive head to the DMU and CV105 tail pulley frame and associated connection (the structural failed component).

The CV105 drive head area was quarantined. The CV105 drive head was found to be isolated and locked out as per requirements relevant to the task. This included the application of a mechanical belt clamp at the drive head to facilitate slack belt feeding out the loop take-up.

The belt tension was 21.2 KN on the winch control panel on the loop. The mode switch was in automatic on the auto/manual winch mode selector switch.

Outlet 5 for the winch power was de-energised. The conveyor was inspected and the belting found free from obstruction or jamming. Inspection of the loop and winch identified two load cells on the winch rope static connection. The travelling carriage was square to the loop frame and the belt tracking was centred on the pulleys.

DMU/FCT inspection

The failed connection hitch on the DMU (figure 1) and the boot end frame (figure 2) were inspected. The distance of separation was measured as 16.4m. Refer to appendix 4.

The tramming switch on the boot end frame was in the “off” position (vertical). The switch was de-tented, firm to move and was not faulty.

The stab jacks on the inbye end of the boot end frame were in the up position.

Version 12 of a safe work procedure (ULW SWP MIN PRO 0365) was on the ground between the two separated items.

An inspection of the failed connection and the welded joints, the broken welds were all clean with no fatigue cracks, indicating a catastrophic failure of the welded joints. This was seen on all joints on the boot-end frame side shift and the DMU connection hitch.

The DMU mode switch was in the vertical position on enclosure five, on the DMU ramp area on the inbye end of the DMU.

The area outbye the boot end frame showed concertinaed damaged belt structure (figure 4).

2.3. Injuries

There were five injuries directly related to incident event and one injury related to the incident response. Of all injuries, none were identified to be significant in nature, with all workers returning to work the following day.

2.4. The damage

The side shift mechanism on the tail end unit failed when greater than normal force was applied by advancing the DMU while the panel belt loop take-up winch was not powered. The point of mechanical failure was the welded sections in the side shift mechanism.

Five bays of conveyor structure were severely damaged and were not reused. Various cables and hydraulic hoses were torn off because the tail end unit moved in a sudden and unintended manner.

The estimated cost of the damage to electrical and mechanical components was \$50,000.

Refer to figures 1, 2 and 4.

Components repaired/replaced during DMU repair activities

Table 1: Mechanical

Components Replaced			
Manufacture P/N	QTY	Component	
100652212	4	PIN,STRAIGHT,HEADLESS,DIA 32MM,L 137MM	4x side shift cylinder pins replaced due to being damaged on cylinder replacement
100217141		CYLINDER,HYDRAULIC,DOUBLE ACTING	1x side cylinder replaced due to corrosion on hard piping
100528988	20	ROLR,IMPACT,SUSPNDED,OD 178MM,LG 456MM	20x replaced. 5x new ones installed 15x removed from DMU01 bootend
100528104	10	ROLR,IMPACT,SUSPNDED,OD 178MM,LG 777MM	10x replaced. 3x new ones installed 7x replaced from DMU01 Bootend
100652213	1	PIN,STRAIGHT,HEADLESS,DIA 64MM,L 500MM	DMU tow hitch mounting pin replaced
100302374	1	SCRAPER,BELT,CONVEYOR	New Belt Scraper installed
100494861	1	PULLEY,DEADSHAFT,D 630.0,FW 1840MM	Panel Belt End Pulley replaced with new component
100328769	5	GUIDE,ROLLER	5x top hat rollers replaced due to failed bearings
100084545	4	ROLLER,PLAIN,STEEL,OD 127MM,LG 476MM	Carry side rollers replaced.

Table 2: Electrical

Components Replaced			
Manufacture P/N	QTY	Component	
100653154	1	(ACS#1) CONVSULAN05 STATION,CONTROL,OPERATOR	Replaced due to Boot under quarantine
100653155	1	(ES2) SWITCH,PUSH BUTTON,EMERGENCY STOP	Replaced due to Boot under quarantine
CONVSULAN07	1	Switch Lanyard	Replaced due to Boot under quarantine
100393224	1	(2MA) 2.5mm 3C Gas monitoring panel supply cable	Replaced due to damage to original cable
100393229	1	(3C) 2TP ORG – Interface controller#3 to Camera #4	Replaced due to damage to original cable
	1	Camera #4	To be replaced

2.5. Environmental conditions

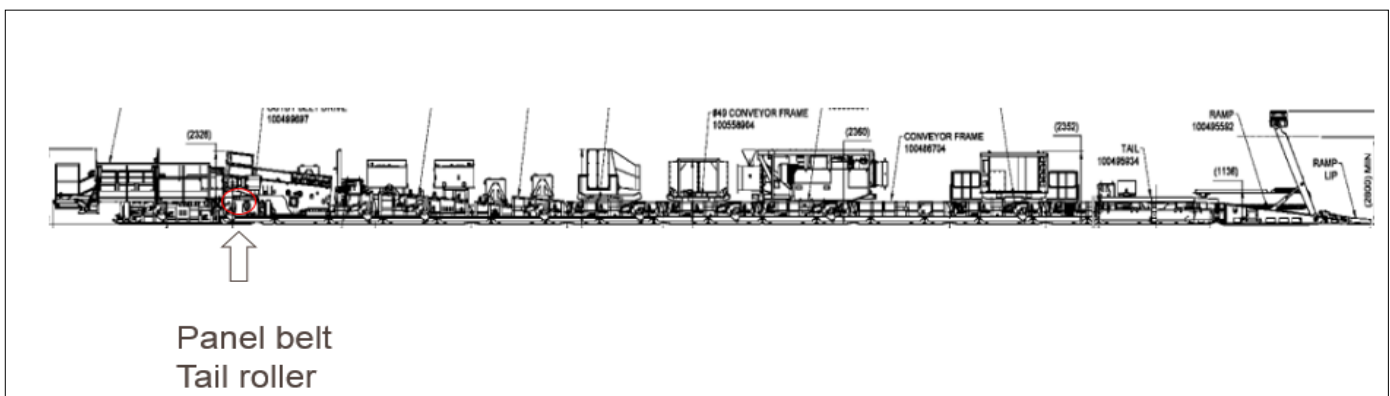
The working environment in MG5 at the scene of the incident was normal and not considered a contributing factor in this incident.

2.6. Equipment and process overview

2.6.1. Dynamic move-up unit (DMU)

The DMU is a semi-fixed item of plant that can advance under its own hydraulics. The panel belt boot roller is integrated into the out-bye section. It is about 220 m long and is used as a platform for the FCT to operate.

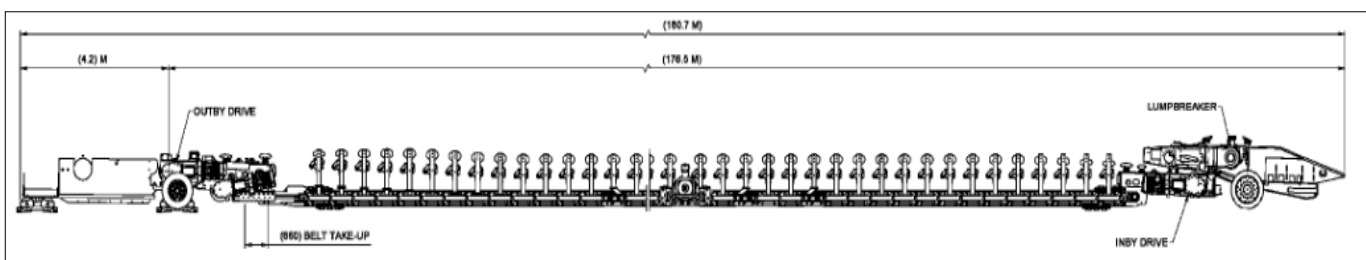
Figure 5: The DMU



2.6.2. Flexible conveyor train (FCT)

The FCT is a mobile conveyor about 178 m long with a self-contained drive unit and “hopper”. The FCT is able to “follow” the continuous miner in all headings and cut throughs. The system is highly mobile and when not required, it “parks” on top of the DMU.

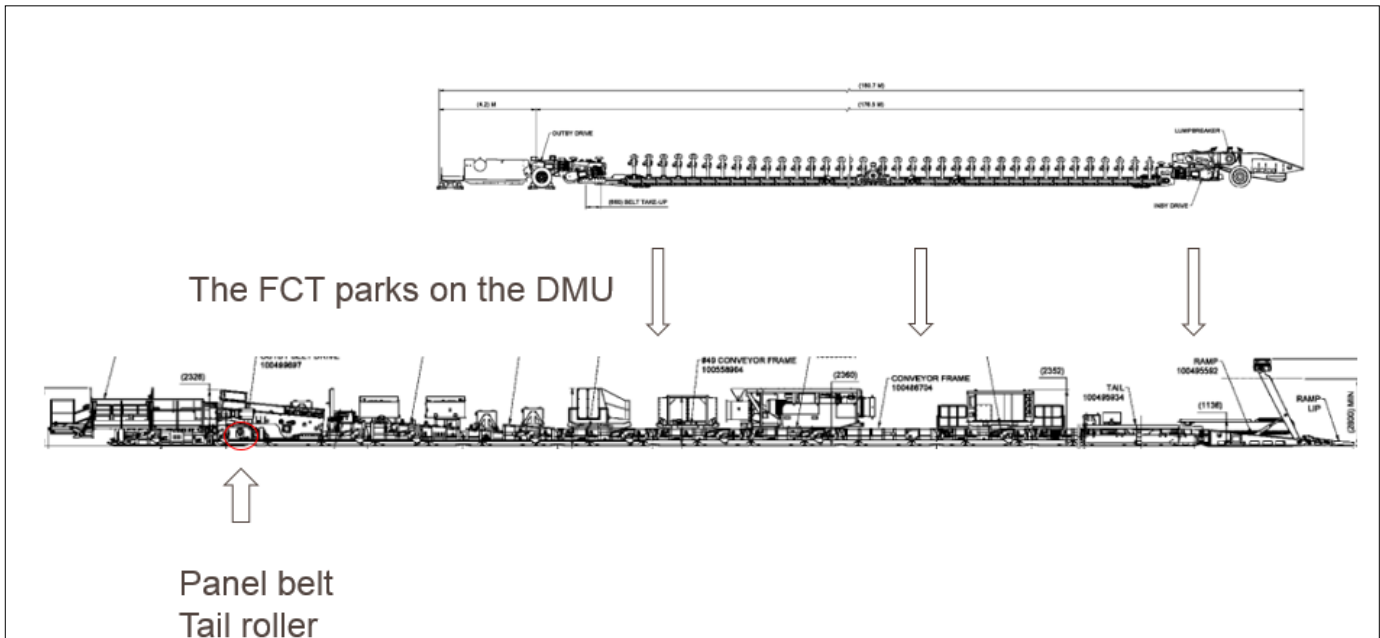
Figure 6: The FCT



2.6.3. FCT/DMU package

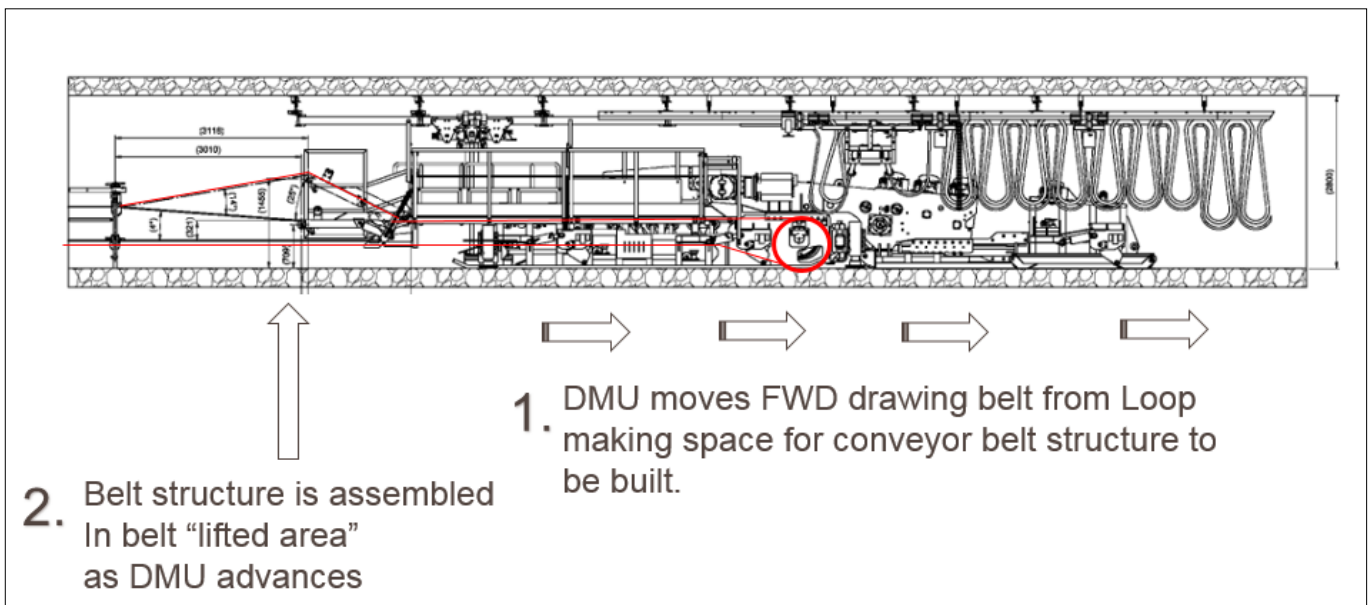
When not in use, the FCT is retreated onto the DMU and parks up.

Figure 7: FCT/DMU package



2.6.4. Building belt structure

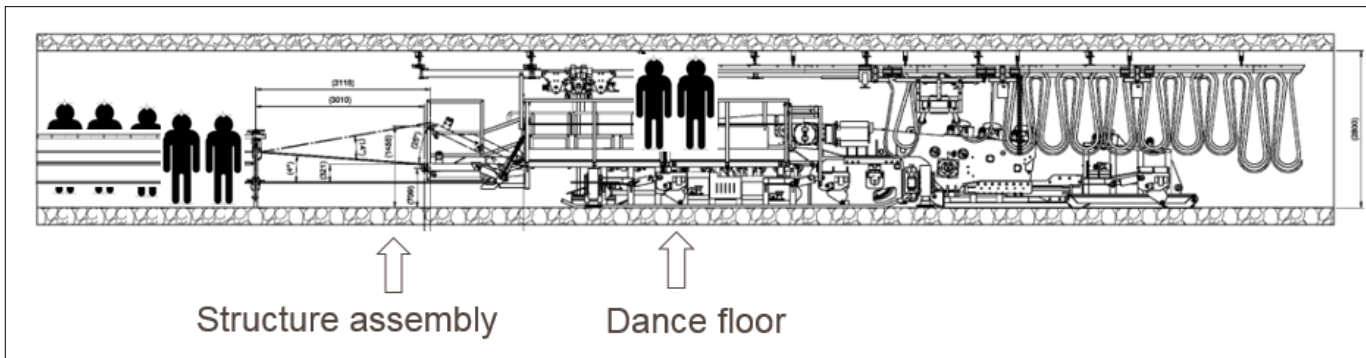
Figure 8: Belt structure



2.6.5. Positions of workers during DMU advance

The normal procedure requires crew members to be outbye of the DMU assembling structure, observing no go zones during the DMU advance (move-up) and conveyor structure build. Part of the crew (x2) stand on the lift platform “dance floor” recovering secondary monorail beams and installing hanging chains.

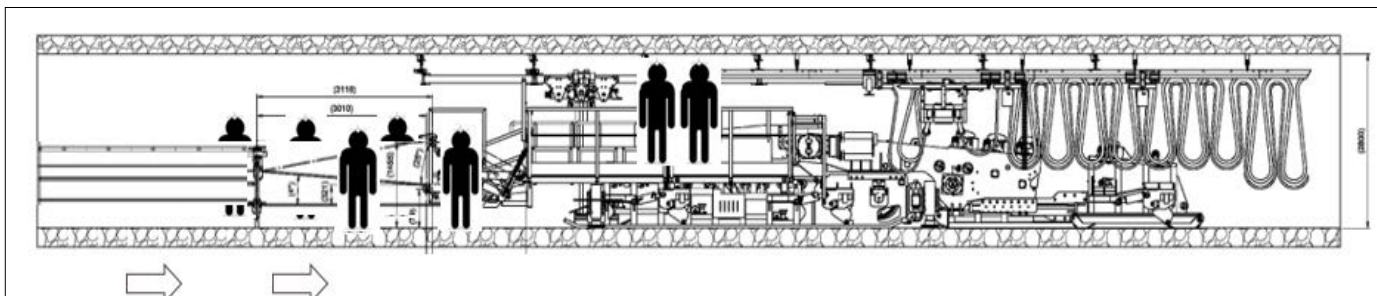
Figure 9: Outbye DMU to conveyor tail frame.



2.6.6. Positions of workers during belt structure assembly

The structure assembly crew then move to the “belt lifted” area when the DMU has advanced and stopped.

Figure 10: Outbye DMU to conveyor tail frame.



Refer to Appendix D for positions of workers involved at time of incident.

2.7. Events leadings up to the incident

2.7.1. Purchase of the equipment

Ulan West contracted Joy Global to supply, install and commission the following equipment:

- roadway development systems
- conveyor belts for mains and panels
- longwall system

Part of the roadway development system is a flexible conveyor train (FCT) – Joy model number 4FCT and dynamic move-up unit (DMU).

All other FCT/DMU installations around the world are used on place change mining. This is the only FCT/DMU installation used on gate road development.

In place change mining installations, the panel belt runs into the DMU and the tail roller for the panel belt is actually at the inbye end of the DMU, and as such there is no tail end unit as there is in the Ulan West design. The panel belt width is typically 1200 mm or less. Refer to figure 5.

As the panel belts at Ulan West are required to carry longwall production at 5000TPH, the gate belt width was set at 1600 mm. As a 1600 mm belt would not fit into the standard DMU frame, Joy Global designed the DMU with its own belt drive. The frames could have been widened to accept the 1600 mm belt but this increase in frame size would have reduced clearances and walkways around the machine. Refer to figure 5.

As a result of the change in conveyor belt width, a new tail end unit was developed for the outbye end of the DMU to support the tail end roller for the panel belt.

This change also introduced the advancing forces to be applied to every joint in the DMU from inbye to outbye end. In previous installations, the advancing force was only applied to a small number of components at the inbye end with the remaining majority of the frames simply rolling on rails.

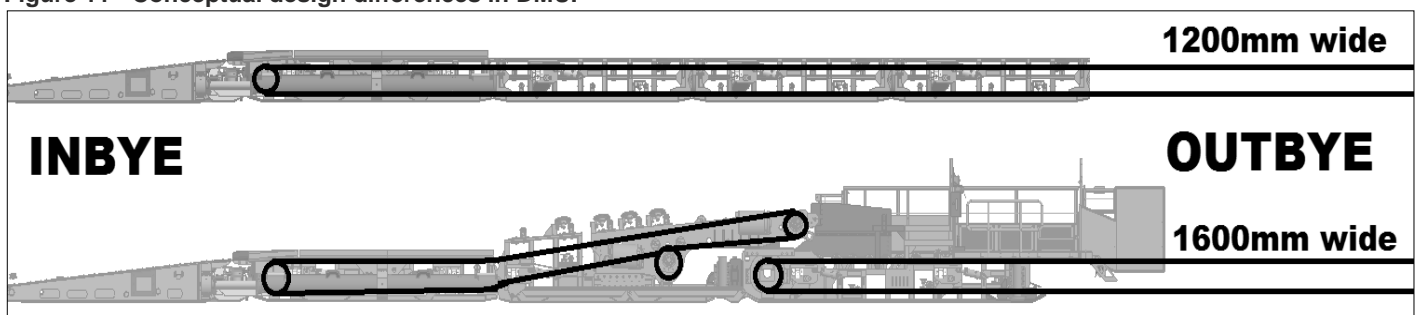
Because this equipment is 233 m long, it had to be assembled on site. This onsite assembly occurred between 2012 and 2013.

During detailed design reviews in 2013 it was identified that a mechanism was required to side shift and level the tail end unit. Joy Global designed and manufactured this mechanism and fitted it to the tail end unit before the equipment was first used underground.

Joy Global designed the boot end hitch and the DMU frames using the monitored panel belt tension as the maximum expected force rather than the maximum potential force from the advancing rams.

Note: Image is to demonstrate belt paths only.

Figure 11 - Conceptual design differences in DMU.



Incident cause analysis method (ICAM) timeline refer to appendix 1.

2.7.2. Equipment design risk reviews

A workplace risk assessment and control (WRAC) type design risk assessment was completed in line with ISO31000 which concentrated only on preventing injuries to workers.

The design risk assessment involved representatives from both Joy Global and Glencore and identified a total of 348 individual hazards across all phases of the equipment life cycle.

Once the design risk assessment was completed, Joy Global performed a layer of protection analysis (LOPA) as per AS61508.5:20011 to identify the independent protection layers (IPLs) and any resultant safety related control functions (SRCFs).

The results of the LOPA study were that 44 IPLs and 12 SRCFs were identified. The SRCFs were then assessed and their achieved SIL levels validated.

Joy Global completed and supplied numerous documents to Ulan West Operations including a:

- safety management plan (SMP) which details the overall safety philosophy and safety case for the FCT/DMU
- risk management plan (RMP) which provides a summarised report of the FCT/DMU design risk assessment
- functional safety management plan (FSMP) which provides an overview of the functional safety activities and the outcomes of the LOPA study and SIL validation assessments.
- development system risk assessment
- DFMEA for the FCT/DMU mechanical, electrical and hydraulic systems.
- risk management plan (RMP) which provides a summarised report of the conveyor system design risk assessment.

The development system risk assessment identified the following hazards during a panel advance:

- Interactions between the DMU and personnel during panel advance. Injuries result i.e. operators putting in bays of structure at back of DMU or operators advancing monorail drive cars.
- Outbye monorail over tensioned when the DMU is advanced. Services are damaged.

The design risk assessment underwent multiple revisions throughout the design, installation and commissioning phases of the supply to ensure it accurately reflected the equipment that was put in to service at Ulan West Operations.

Key observations:

- The FCT/DMU design risk assessment did not identify the possibility of an over tension on the conveyor panel belt system.
- The only hazards where over tension was detailed related to those associated with the miner or FCT/DMU monorail tow arms.
- The DFMEA's only identified structural failure of the panel tail frame as a result of corrosion, wear or physical damage. Failure due to over tension from the belt was not considered.
- As the possible hazards on the DMU associated with an over tension on the belts from the winch had not been identified in any of the above reviews, the interlock signal between the DMU and the winch had not been considered a SRCF and had therefore not undergone SIL assessment or validation.

Ulan West Operations risk assessments

Two risk reviews were undertaken by Ulan West Operations during the introduction of the FCT/DMU to the mine.

Ulan West Operations followed a process known as the design review process to introduce the FCT/DMU to the mine (refer to Appendix 3).

Key observations:

- The first risk assessment focussed solely on the operation of the FCT and did not identify conveyor over-tension as a hazard.
- The second assessment did identify the risk of over-tension; however, the risk was rated as low.

2.7.2.1. DMU structural design

The DMU is advanced by first extending the hydraulic rams at the inbye end of the DMU. Once the rails have been lowered and the weight of the DMU is resting on the rails the advancing rams are retracted, advancing the DMU. The maximum force the rams can apply is 824kN each (1648kN total). The pump pressure is nominal 150bar (2200psi).

The following analysis of forces in the DMU when advancing was supplied by Joy Global on 17 October 2017.

The diagrams below show the move-up forces required are split into two sections. The main DMU, which is lifted and rolling on the rails and the panel tail section that is dragged on the ground with the belt pull out tension.

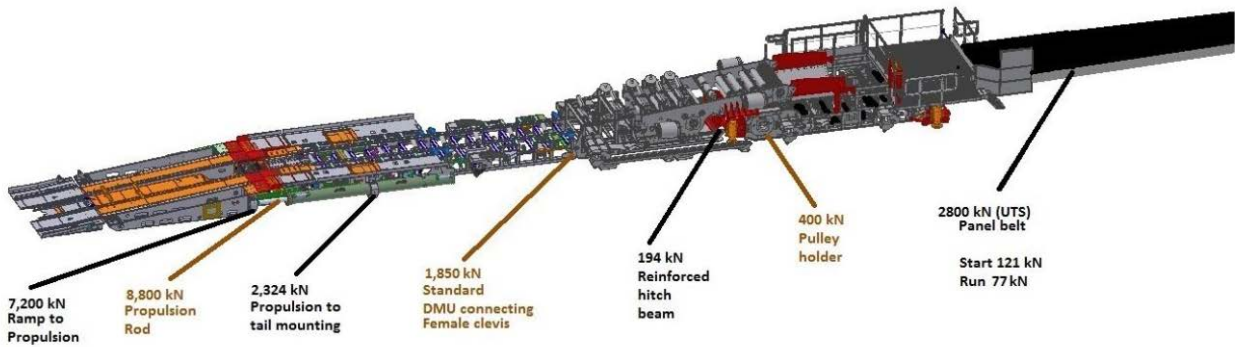
The bottom chart is the addition of these two combined forces for the total theoretical pull up force required by the propulsion cylinders.

The belt pull out tension used is the max 30kN + 14kN for losses over 6 km section, so total of 88kN on the panel belt tail pulley.

The operating angle referenced is the incline of the panel.

Figure 15: DMU system minimum yield loads structures/connections

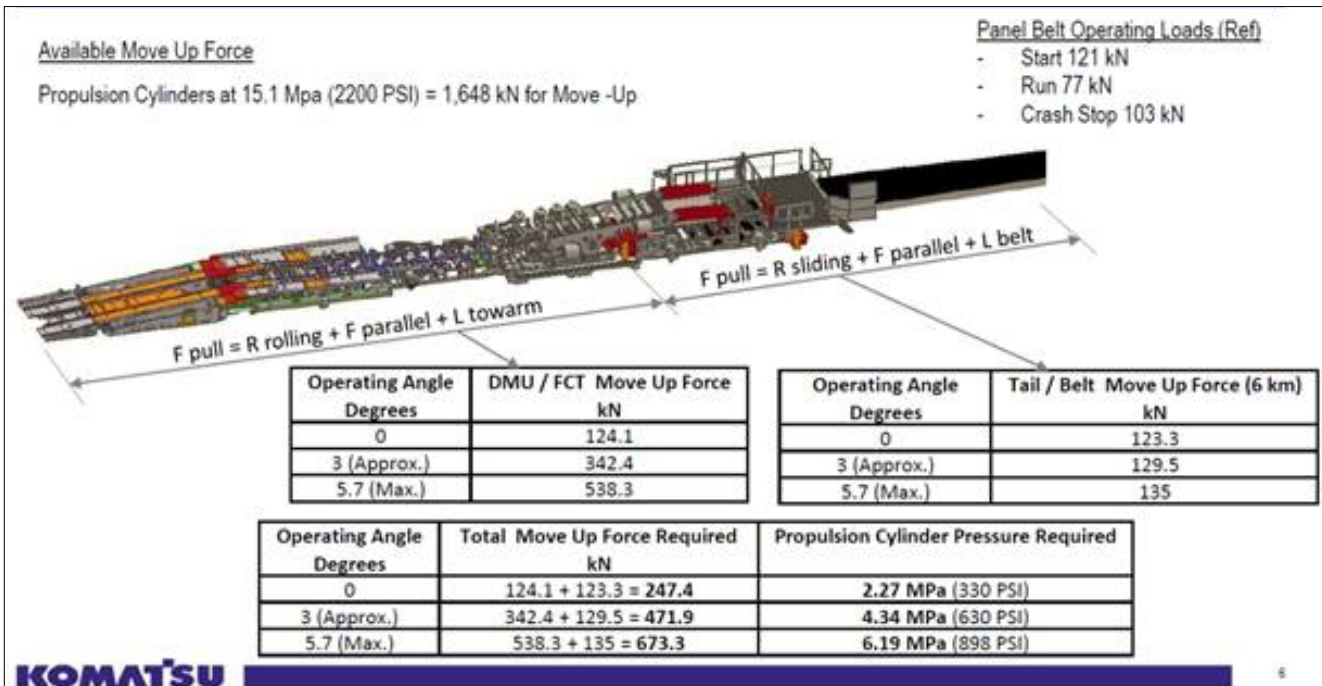
The following DMU components are labelled with the minimum yield loads for that structure / connection in the DMU system.



KOMATSU

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Figure 16: DMU/FCT required move up forces based on operating parameters



KOMATSU

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2.7.2.2. Analysis of the failed structure

The causal investigation team commissioned Bureau Veritas Asset Integrity and Reliability Services Pty Ltd to conduct an analysis of the failed structure. An extract of the report follows:

A failed DMU crossover slide was submitted for metallurgical examination to determine the mode and cause of failure.

The failed DMU crossover slide components material met the Joy Global drawing specifications. In general the welds sizes were less than the weld sizes specified on the Joy Global drawings. The level of weld flaws present in the failed welds suggested that the welds would not meet the requirements of AS/NZS1554.1 – 2014 Weld Category SP.

The deformation and impact damage present probably occurred during or subsequent to failure.

Failure of the crossover slide had occurred through the welds on the end plate at each end of the crossover slide and through the weld securing the main bar to the tow point on one side by shear overload.

The level of welding flaws and the smaller-than-specified weld sizes present would have reduced the load bearing capacity of the crossover slide and increased its susceptibility to failure when subjected to high stresses. However, whether failure would not have occurred if the weld sizes were larger with no weld flaws present could not be determined.

2.7.3. Parameter passwords

Joy Global equipment such as the DMU has a computerised control system. These systems have a number of inputs and outputs that are then controlled by a main processing unit that runs the controlling software, which is known as a CCU.

All Joy Global CCUs have parameters to allow customisation of the equipment for the conditions at a particular mine site. Passwords are used to protect the parameters.

The different password levels allow for differing read/write access to each individual parameter. The access levels for each parameter are based on the potential level of consequence associated with changing each parameter.

Parameter level	Description	Example
“Customer”	Have a lower level of consequence and can be changed by a customer in line with their own site-based procedures.	The maximum “sumping” speed of a continuous miner, which could be changed based on the site’s mining conditions and practices
“Joy”	Require a higher level of scrutiny and machine design understanding before being changed. Within Joy Global this access is generally provided to service engineers and product specialist with the relevant level of knowledge and experience.	The temperature alarm settings for certain alarms such as hydraulic oil temperature.
“Engineering”	Require the highest level of scrutiny and machine design knowledge before being changed. These are generally only required during initial design commissioning stages and are not usually changed once a machine has been placed into service.	The thermal overload settings of each of the motors on board a machine.

Joy Global also has the concept of temporary parameters. A temporary parameter is one that can be changed

to a new value but when the machine is powered down and later repowered, the parameter will reset automatically to the default value.

The user name corresponding to the password will be entered into the parameter change log, on board the machine, when a parameter is changed.

Parameter passwords are issued to Joy technicians and customers from Joy engineering. A database is kept for all passwords issued. Passwords are stored on the machines when a software update is installed.

Joy official policy states “passwords shall not be disclosed to any other person in Joy or outside of Joy”.

In mining equipment, such as the FCT/DMU, there are often parameters to disable functions. This is provided to allow testing and fault finding usually in the OEM workshop. The more critical the parameter, the higher the level of password required.

The DMU has 149 parameters in total. For comparison, a Joy shearer has in the order of 650 parameters.

There is also a feature in Joy equipment that allows remote access to parameters if the equipment is connected to the mine’s network. This feature allows a remote computer to read all parameters using the Ethernet/IP industrial protocol regardless of the password protection on the machine.

Key observations:

- Not all parameters are visible to all users. If a user only has a customer level password they cannot see parameters at the Joy or Engineering levels.
- At interview, it was stated that when Joy could not supply a service engineer to an event, a Joy employee had authorised the use of a password by a non-Joy person.

2.7.4. Winch to DMU advance interlock

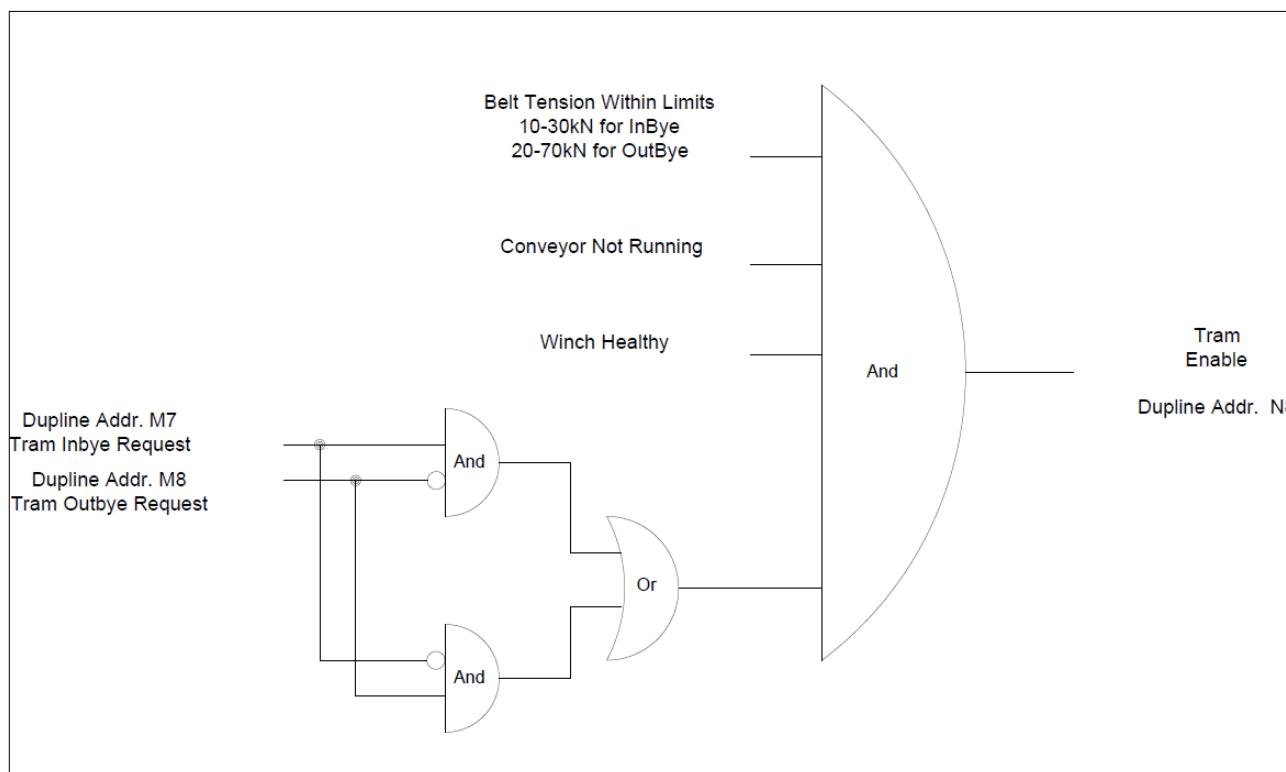
There is an interlock between the panel loop take-up belt winch and the advancing function of the DMU. This interlock is implemented using the dupline-based belt signal line.

A three-position selector switch on the tail-end unit sends a signal to the winch that inbye (M7) or outbye (M8) tramming mode is required. When the winch PLC receives this signal, it checks that it is healthy and if healthy sends another signal (N8) over the dupline back to the DMU. This signal is used by the DMU to enable belt advance.

The winch considers it is “healthy” when all the following conditions are met:

1. The winch is powered, and;
2. The winch tension is in the range 10 to 30kN (for inbye mode), and;
3. The conveyor is not running and;
4. The tramming switch at the tail end unit marshalling box is set to “inbye”.

Figure 16: Conveyor software advance logic diagram.



This interlock is a typical design for conveyors but no functional safety assessment was undertaken on the design. During design risk reviews of the equipment, attended by both the OEM and site personnel, the consequences of over tension on the belt was foreseen as minor and so this interlock did not get elevated to requiring a functional safety assessment.

The Joy CCU in the DMU there is a parameter “BeltAdvanceModeEnabled” that has two settings.

- a) 0 = disabled (ignore the signal from the winch and allow the DMU to advance regardless)
- b) 1 = enabled (do not allow the DMU to advance unless the signal is received from the winch)

The configuration of the panel belt loop take-up winch is such that if the tension display is showing 100kN then there is 100kN in both the top and bottom belt.

A voice intercom system runs the length of the conveyor which allows personnel to communicate with each other from comms stations along the conveyor. There is also a system that automatically announces pre-recorded messages such as faults or different operating status.

During a DMU advance the intercom system broadcasts the tension on the winch at about three minute intervals. On each comms unit the interrogate button can be pressed and the current belt tension will be immediately announced.

The belt tension announcement only occurs when the tramming switch on the DMU boot end is set to either inbye or outbye.

Key observations:

- The consequences of over tension on the belt was foreseen as minor and the interlock did not get elevated to requiring a functional safety assessment.

- After the incident, the tramming switch was found to be in the off position. Interviews of the workers involved confirmed no regular voice announcements of tension were heard.

2.7.5. Last software update to DMU

The software in the DMU was last updated on 24 March 2016 by Joy engineers. A software change form was completed by the mine and the Joy software commissioning acceptance form was filed in the mine's software change system. The complete list of parameters in the DMU was provided to the investigation team with evidence that each parameter was checked and ticked off at this time by a Joy engineer. BeltAdvanceModeEnabled was set to 1 (enabled).

2.7.5.1. Parameter changes

During April 2017, the DMU equipment that was to be used in MG5 was repaired and tested on the surface of the mine.

On the 23 April 2017, software in the DMU 118 was updated during testing and fault finding. There was also an issue with a variable frequency drive unit that required the DMU software to be reloaded a few times on this day. When software is loaded into a Joy control system all parameters are set to default.

Logs in the control system of the DMU show that the parameter "BeltAdvanceModeEnabled" was changed from the operational value of 1 (enabled) to a value of 0 (disabled) at 9.12 am on 29 April 2017. This parameter is password protected with a Joy service engineer password. The password used was assigned to the user "USEngineers".

There were no Joy service engineers on site at Ulan West Operations on Saturday 29 April 2017.

A Ulan West Operations (contract) electrical service technician was on site on Saturday 29 April 2017 and was working on the DMU. He completed a shift report for the day but there was no note about changing any DMU parameters. There was no evidence to indicate any other person was working on the DMU on this day. The technician informed investigators he did not change any parameters on this day and does not know how this could have happened. He also said he did not know the "USEngineers" password.

The mine requires each tradesperson to complete a report even if they are working together on the same job. If people other than the technician were working on the DMU that day there should have been a trades report. The daily supervisor's report showed no record of people working on the DMU. As this work was done on the surface mini-build pad it was unlikely the underground supervisors would have been intimately involved in this work. There was no software change form completed and filed in the mine's filing system for this parameter change. The person that organised this work on the 29 April 2017 left Ulan West shortly after this date and no record can be found of the work instructions given to the technician, who said his work instructions were given verbally.

2.7.5.2. Installation of equipment underground

The equipment was installed into MG5 during June and July 2017.

Commissioning documents developed by Joy in 2014 were provided with the equipment as part of the documentation. These documents were used by the mine to commission the machine in July 2017 and are unchanged from those supplied in 2014. These documents are extensive and form part of the mine's work order system and commissioning documents.

The DMU electrical post power commissioning document contains 15 pages and is of a typical standard and suitability for this type of equipment.

This document contains a specific line item to check all parameters:

18	FaceBoss Parameters/Checks	Result	Actual Measured Result	Initial
18.1	Task: Review all FaceBoss parameters. Limit: Parameters as per list attached.			

This commissioning document was completed by two different people and on two different copies of the document.

A Joy service technician completed most of the sheets on 12 July 2017. He did not complete item 18.1

A Ulan West shift electrical trade supervisor completed the remainder of the sheet on 13 July 2017 and has initialled item 18.1 as “S” safe to use.

There is no specific line item in this commissioning document to test the interlock between the DMU advance and panel belt loop take-up winch.

Commissioning sheets were then signed by two development coordinators on 23 July 2017. (This is after the DMU was in service.)

The commission sheets were filed in the mine’s maintenance management system and the work order closed. No parameter sheet was found to be filed with these commissioning documents.

2.7.6. Events on 13 July 2017

On 13 July 2017 during the commissioning process, the interlock to the belt winch was tested and found to not work. The two workers undertaking the testing checked the DMU screen and concluded the interlock from the panel belt was stopping the advance.

A third worker was called to investigate and he found the wrong program was installed in the panel belt PLC in regards to winch control. This worker rectified the program issue and later another worker was able to advance the DMU.

This activity led the engineers involved to conclude that the interlock between the DMU and the winch was functional.

However, the parameter “BeltAdvanceModeEnabled” was still set to 0 (disabled) on this day so the reason the DMU would not advance is unknown. Joy Global reviewed the logs from this date and could not determine a reason.

2.7.7. Initial advance 16-20 July 2017

The installation of the FCT and DMU requires the DMU to be set up some distance back from the coal face to allow room to reverse the FCT onto the DMU.

The DMU with the FCT is then advanced into position to start normal production. This initial advance occurred over four days from 16 July 2017. During this advance period on 20 July 2017 there was an over-tension event. An operator was working on advancing the DMU.

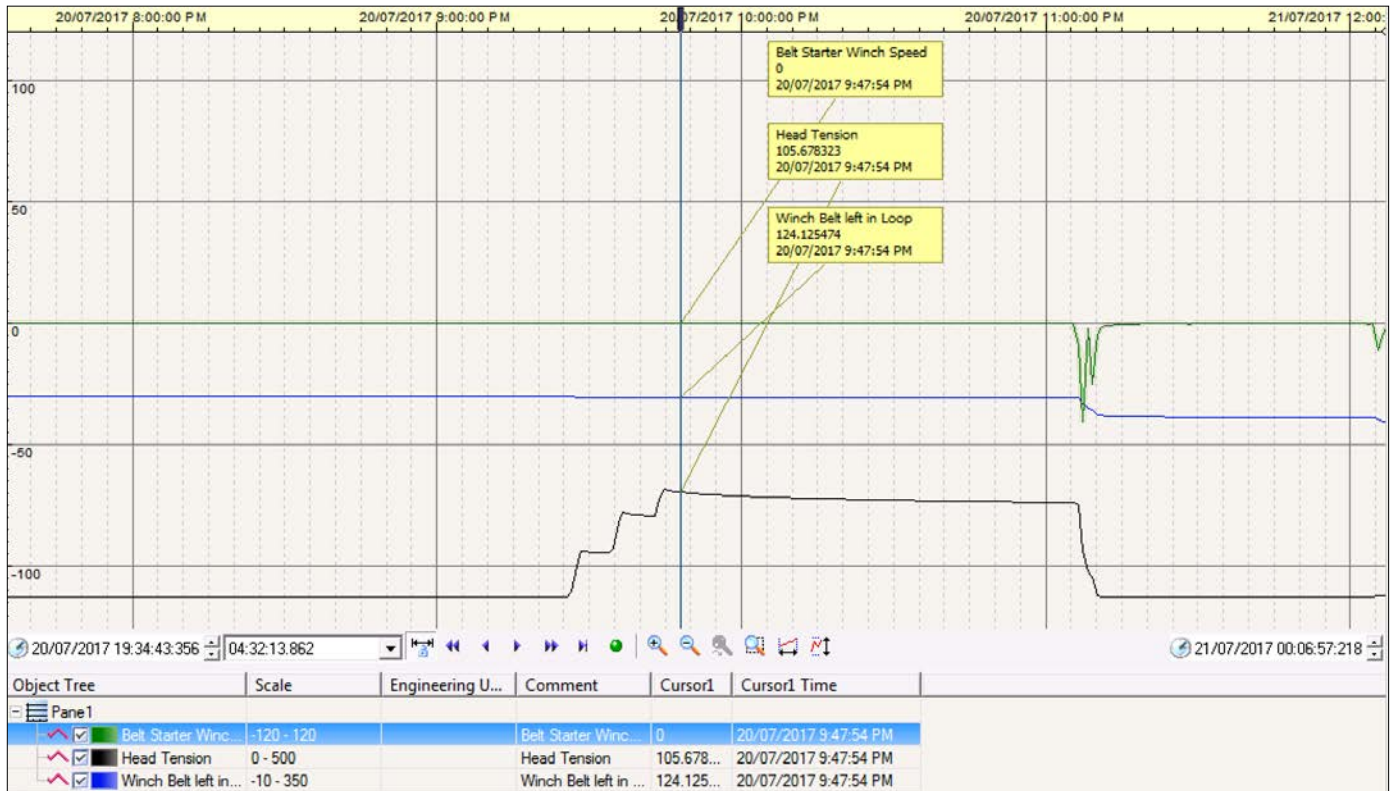
During the third advance, this operator arrived at the boot end and noticed that both the top and bottom belts were moving and stopped the job. During a normal advance, the top belt is stationary and the bottom belt moves. This operator told investigators that he did not know why both belts were moving and suggested that it may have been timber, used to pack the DMU, jammed in the bootend. As it was the end of the shift no-one on that shift investigated the trip or over-tension. A low oil trip was reset early on the next shift.

The fact that this trip occurred at the end of the shift was significant in regard to the lack of investigation into the fault. The next shift (night shift) started as normal by doing their isolation at the drive head. As they did not

know there was an over-tension issue they reset the winch low oil trip and then proceeded to the DMU to continue the advance as normal.

This over-tension incident on 20 July 2017 was raised verbally the next day (21 July 2017) by the operator from the previous day to mine supervisors. No formal hazard form was completed at this time. The supervisors discussed it and resolved to investigate during the next belt advance.

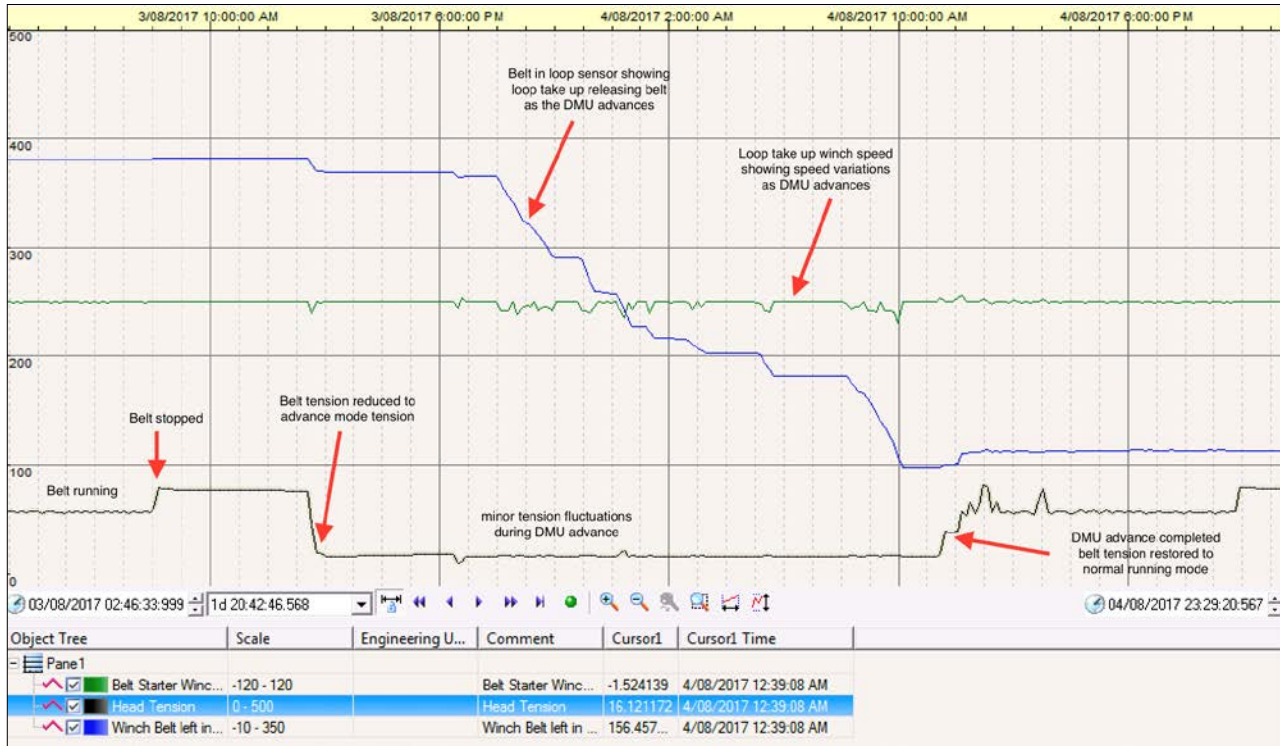
Figure 17: Panel conveyor trend for 20 July 2017.



After 20 July the MG5 section produced coal as normal.

2.7.7.1. Normal production with FCT/DMU

Figure 18: On 3 August 2017 the DMU was advanced as normal without issue.



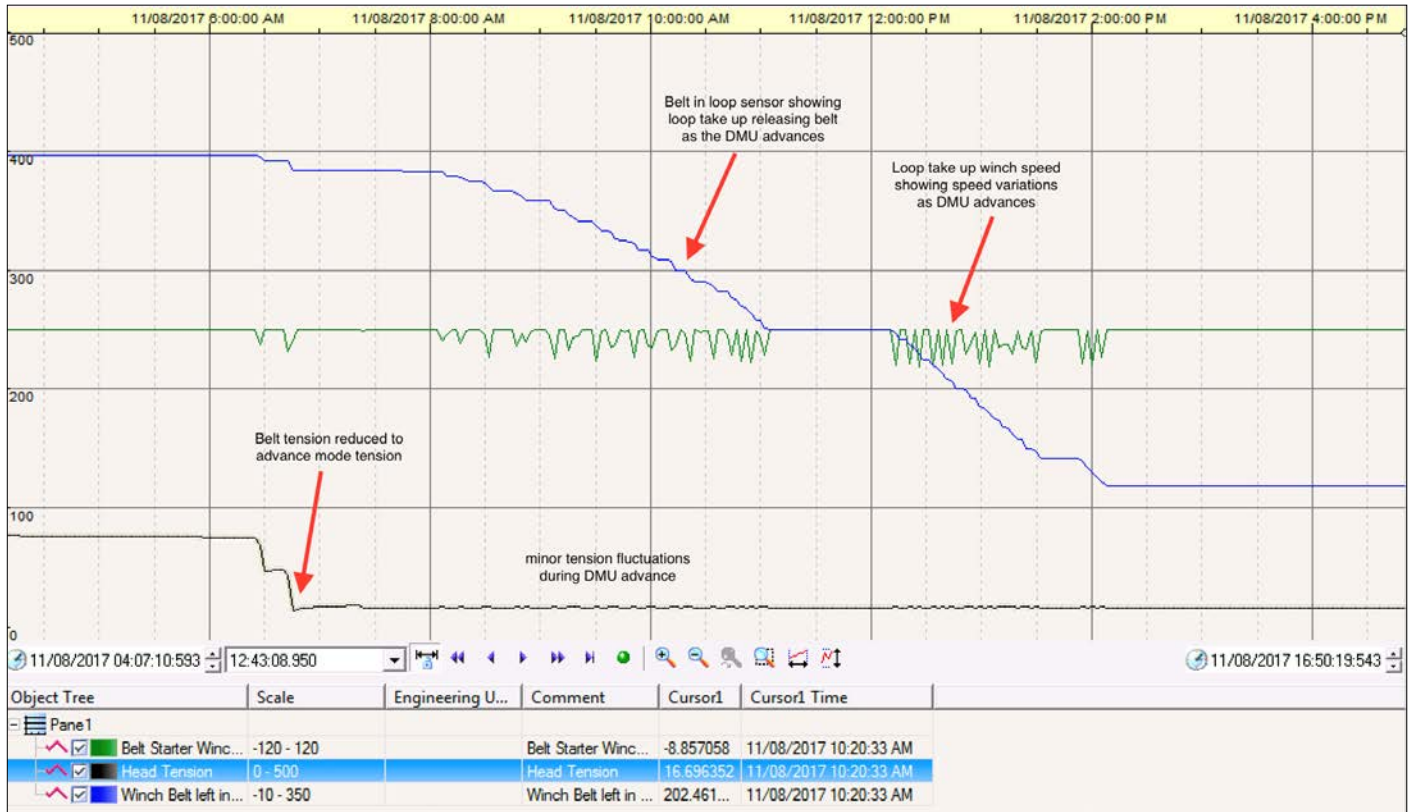
On 11 August 2017 a hazard form was completed and submitted by a supervisor in response to the reports from 20 July 2017 that the DMU was allowed to advance when the winch was faulty. Further testing was undertaken with two actions identified. The testing was completed before the hazard form was completed. The main purpose of completing the hazard form was to capture this incident and that the two actions could be tracked.

Action – Review belt move procedure and add step to check belt tension via BMA voice or control room if not confirmed. Each DMU move up - consult development crews. Completed 21 August 2017. Procedure update to version 14.

Action – Contact Joy OEM of DMU and raise potential issue of incorrect logic for winch faults causing high tension.

In progress at the time of the incident, a supervisor was in the process of collecting evidence to supply to Joy.

Figure 19: On 11 August the DMU advanced as normal without issue.



2.7.7.2. DMU advance procedure

Ulan West Operations has many procedures to perform routine tasks. Computers and printers are installed throughout the mine, and all procedures stored on the mine’s intranet are accessible from these computers.

A safe work procedure (*Belt extension using DMU and monorail*) was at version 15 at the time of the incident. The version history of this document is listed below. This document was updated regularly as improvements to the procedure were identified. If this procedure was followed step by step, on the day of the incident, it is unlikely the incident would have occurred as administrative controls and situational awareness, documented in the procedure, would have alerted the workers to equipment behaviour that was not consistent with the steps documented in the procedure.

Below is a summary of changes to this document. It is noted that the section in the document titled “Change Information” has not been updated to reflect this listing.

Table 8: The summary of procedure change information.

Version	Date published	Description of change
15	28-Aug-2017	Added step to lower ramp tip on last push to level floor
14	21-Aug-2017	Edits made in response to CMO action 1378254. Step 6 added the following words (highlighted in RED)

		<i>Confirm voice confirmation of belt tension every move- up. If voice confirmation not received, press the interrogate button on DAC to receive confirmation.</i>
13	17-Jul-2017	Update to pre task steps
12	1-Feb-2017	
11	13-Jan-2017	Added diagram and requirement to check that pump control switch is correct mode to allow the pump to start through radio and locally
10	11-Jan-2017	Added special conditions, Ramp tip must be flat on ground on final park up position remedial works to be done prior to tramming off DMU if not flat
9	28-Nov-2016	Added wording around location of ramp tip at completion of pan extension
8	21-Oct-2016	Added to monitor to warn on advance
7	5-Sep-2016	Include the requirement to have the correct colour of brackets facing the walkside
6	7-Jun-2016	Added Hazard and control with monorail interaction when accessing structure in the rib. Procedure to be adhered to with consideration of SWP Install ROC 1600 Gate Road Structure ULW ENG PRO 0602 B Bird
5	11-Mar-2016	Made changes to tools and equipment, special prep works, important requirements and grammar.
4	9-Aug-2015	Added page 3 to include checks to be done while advancing to avoid damage to the rails
3	26-May-2015	Added notes to special preparation works and step 6 to confirm safe length of advancing belt electrics
2	7-Nov-2014	Added controls to advancing DMU
1	29-Oct-2014	Initial document

Three copies of the procedure were found in the area of the incident.

- Version 15 – Printed in colour (stapled) found on the crib room table. (in the evidence bag from crib room) It is considered this procedure was printed on the surface and provided as part of the work instructions on the day of the incident.
- Version 12 – Printed in black and white (not stapled) found in the crib room area. (in the evidence bag from crib room)
- Version 12 – Printed in Black and white (stapled) found on the ground in the area between the DMU and the panel belt boot end.

This procedure is not linked to a work order and as such is not required to come out of the mine at the end of the shift.

Procedures are not always supplied to the work crew for the DMU advance. The workers relied on their experience to carry out routine tasks, which are part of the production cycle, such as the DMU advance and would normally only refer to the procedure if they were told it had changed. The procedure was not written to have each step signed when completed, it is a step-by-step procedure with text instructions and colour photos.

The procedure also references associated procedures:-

ULW-ENG-PRO-0150 (Joy conveyor mech isolation for belt extension)

ULW MIN PRO 0362 (SWP Layout Structure in FCT Development Panel)

ULW ENG PRO 0602 (SWP Install ROC 1600 Gate Road Structure)

There was no evidence of a formal tool box talk given to the crews about changes to this procedure on the day of the incident. During interviews, workers stated that they did not consider the 20-page procedure had changed because they did not receive a tool box talk on the changes, and did not review the procedure in detail before the job started. If the workers were formally notified that the SWP had changed and the importance of these changes, it was unlikely the incident would have occurred as administrative controls and situational awareness, documented in the procedure, would have alerted the workers to equipment behaviour that was not consistent with the steps documented in the procedure.

There was evidence that toolbox talks were regularly given to workers about changes.

2.7.7.3. Safe standing zones

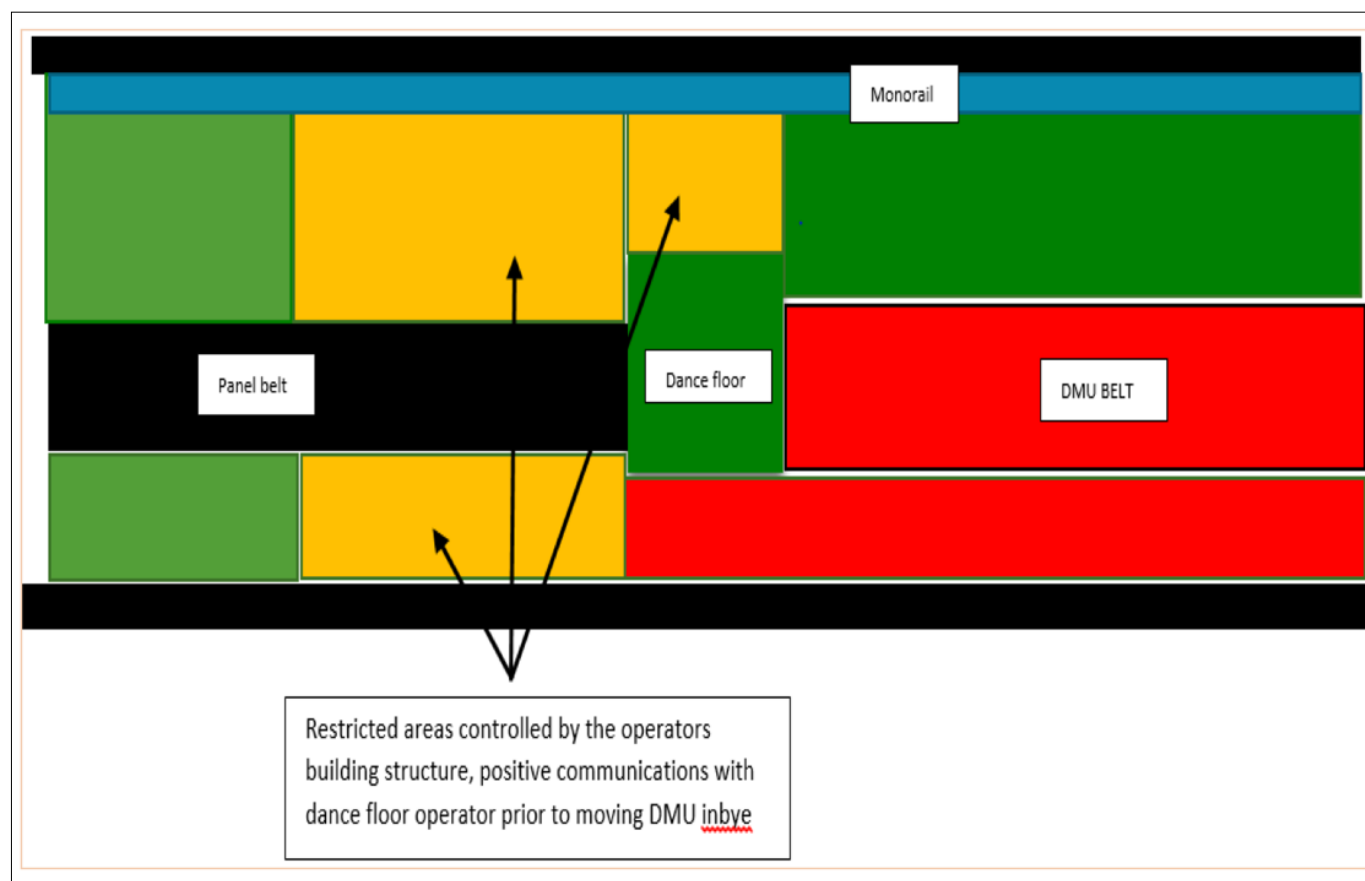
On the design and manufacture and supply of the FCT/DMU to Ulan West Operations, Joy supplied nominated safe standing zones for the operation of the FCT in the technical manual.

The mine has a development no go zone standard where the last two versions were viewed. Both were found in the crib room:

- Version 3 dated 28 October 2016 shows no standing area to build the structure outbye the boot end frame and dance floor.
- Version 4 dated 14 July 2017 shows the area outbye the boot end frame and dance floor is a restricted area to build structure during DMU advance mode. This change came through a hazard form that was processed through the mine's system.

The workers on the day of the incident were following the mine's development no go zone standard version 4.

Figure 20: Extract from document ULW MIN STD 009.



2.7.7.4. Events on the day of the incident

A normal section advance was to occur on 29 August 2017.

Refer to Appendix B for a timeline of events leading up to the incident.

The workers isolated the panel belt as normal by following the mine's isolation procedure for belt extension, which includes a group isolation permit.

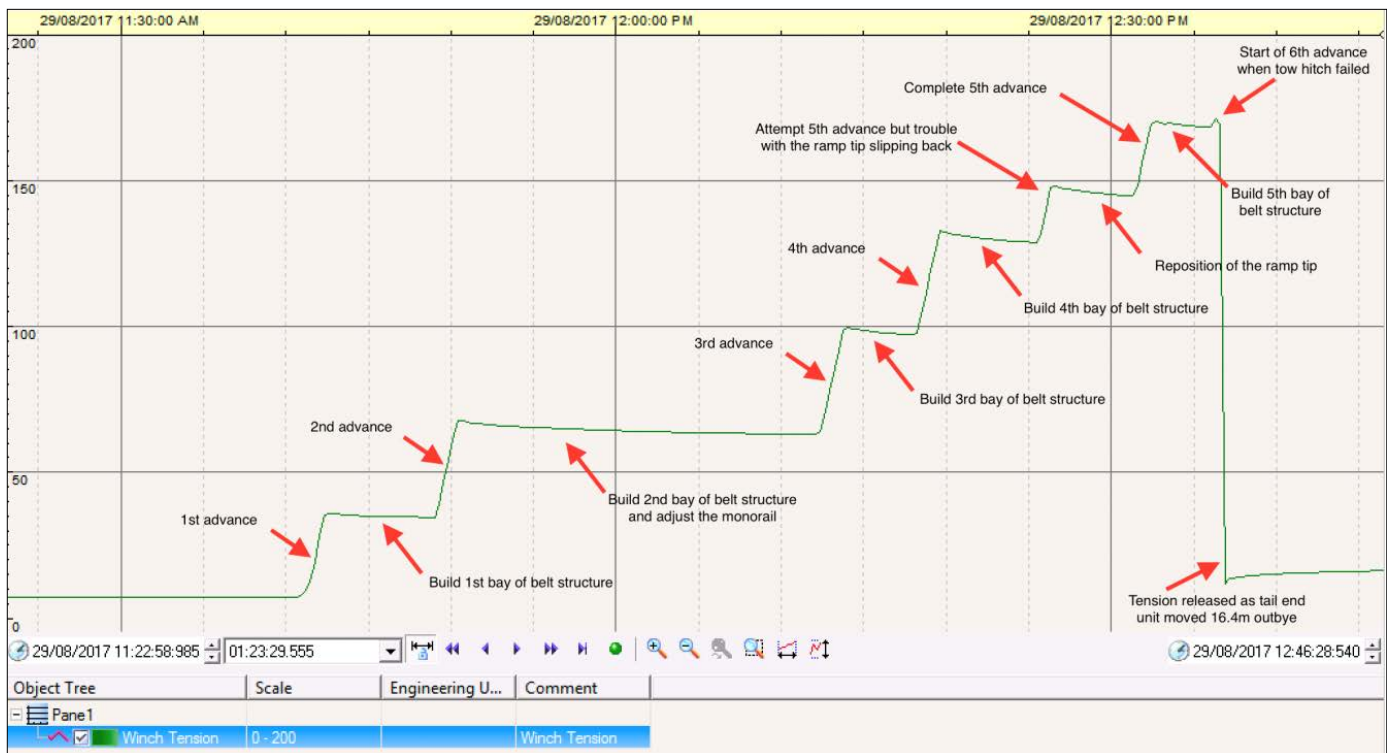
At 9.33 am power (11kV) to the entire panel was tripped by an unrelated event. Power was restored to the panel but power to the panel belt loop take up winch motor was not restored. Power was restored to the winch control and monitoring system.

At 11.41 am the DMU advance started and the crew installed belt structure on the outbye side of the tail end unit. The first four advances proceeded as normal.

During the fifth advance, the DMU operator had trouble with the ramp tip slipping back while advancing the DMU. He repositioned the ramp tip and completed the advance. Note that this operator was at the inbye end of the DMU some 220 m from the failure.

The fifth bay of belt structure was installed and the sixth advance started. During this advance, the tow hitch between the DMU and the tail end unit failed allowing the stored energy in the conveyor belting to propel the tail end unit 16.4 m outbye, in less than two seconds, crushing the five bays of structure.

Table 9: Annotated trend diagram of panel belt winch tension. During a normal advance the winch will maintain belt tension at 12kN. On the day on the incident the winch tension achieved 181kN just before the tow hitch failed.



2.7.7.5. Other DMU incidents

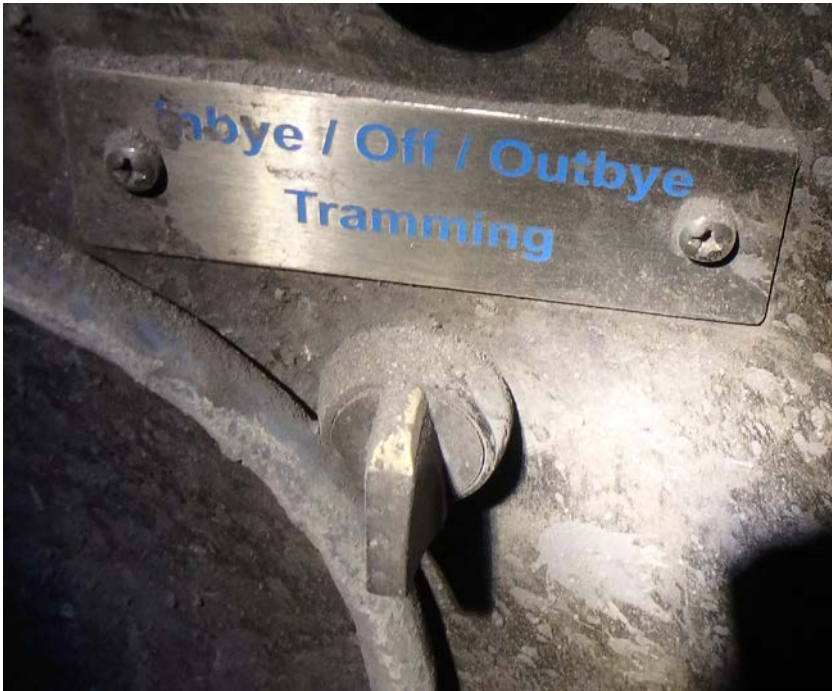
No other failures of this type have occurred at Ulan West Operations. The investigation team discovered only one similar incident which occurred in NSW.

Further investigation into the incident identified a manual bypass switch was operated in the control system, which bypassed the interlocking system. The equipment failure on this incident was a failure of the brake on the loop take up winch.

2.7.7.6. Tail end unit tramming switch

On a small electrical panel on the DMU there is a three-position switch: inbye / off / outbye. After the incident this switch was identified to be in the off position.

Figure 21: The three-position switch.



The function of this switch is to signal the panel belt loop take up winch that the DMU is to move and in which direction it is going to move. Once inbye or outbye are selected the target tension at the panel belt loop take up winch is set to low value of 12kN for inbye and 50kN for outbye. Investigations revealed that this switch was set to off. The procedure states the switch is to be set to inbye.

The tension for the winch was manually changed by the section electrician before each panel advance in MG5 panel as required in the procedure.

The tramming switch is integral to the operation of the interlock between the panel belt loop take up winch and DMU advance.

The outbye mode is not used at Ulan West Operations with the DMU as the Ulan West Operations DMU cannot tram outbye by design.

Figure 22 - Mode switch from procedure.



Figure 23 - Mode switch post incident.



The mode selector switch was to be placed in move-up mode (inbye) to enable belt advance (move-up).

The switch was observed in the vertical position (figure 8) (production mode) on enclosure 5 on the DMU ramp area on the inbye end of the DMU. “DMS – DMU mode switch” was tested following this incident, identifying that this switch and the switch activation was firm, confirming the switch would remain in position following selection of mode.

During testing, it was identified that the switch position and switch position labels do not align. This is shown in figure 8 where the switch is in move-up mode.

Figure 7 is included within the site belt extension safe work procedure using DMU [ULW MIN PRO 0365, V15] which indicates the correct switch position corrected using additional markings.

On further investigation it is understood that this switch was supplied in this condition (reference Joy Global training documents in MG5 crib room).

3. Key causal factors

3.1. Mechanical design

If uncontrolled, the DMU advancing cylinders have enough force to break the boot end frame from the DMU.

3.2. Parameter management

The “BeltAdvanceModeEnable” parameter was changed to “0”, on Saturday 29 April 2017. This disabled the DMU advance to belt loop take up winch interlock. Commissioning of the DMU parameters failed to highlight that the “BeltAdvanceModeEnable” parameter was incorrectly set.

Joy Global’s policy on password security was not adhered to.

There are parameters in Joy equipment that can only be viewed by Joy engineers that do not allow mines to validate that all parameters are set correctly at the machine. Including, in this case, the “BeltAdvanceModeEnable” parameter.

3.3. Procedures and systems of work

The safe work procedure for the DMU advance was available but not all steps were followed. Changes to procedures were not communicated.

4. Other contributing factors

Based on the evidence at the time of writing, the causal investigation team made the following findings with consideration to organisation, task/environmental and individual/team factors and absent or failed defences to be the primary contributing factors to this incident: Refer to appendix 2.

4.1. Mechanical design

A change in the FCT/DMU design was undertaken to accommodate Ulan West Operations' specification on how the mine was to use the FCT/DMU at the mine. This included the modification of the DMU to be its own belt with belt drive and separate boot end for the panel conveyor.

Due to the design change to have its own belt, a side shift mechanism was required on the boot end to allow belt alignment. This side shift mechanism became the point of failure.

No mechanical force analysis of the DMU structure conducted at the design stage by the OEM as the consequences of over tension were considered as minor, such as a broken clip in the belt.

With a change of a parameter allowing the DMU to move up without releasing more belt, the maximum force from the cylinders could then be exerted on to the hitch that was not designed or intended to handle this force. The electrical interlock between the DMU and belt was designed to only allow the DMU to advance when the belt tension at the winch was less than 30kN.

The FCT/DMU and the panel conveyor belt system were not fully assessed by the OEM and site as a complete system.

4.2. Parameter management

The software management form was not completed for the parameter change done on 29 April 2017.

Supervision documentation on 29 April 2017 did cover working on the DMU on the surface. The worker on the DMU was given work instructions verbally.

Checking of parameters during commissioning was less than adequate.

Within the development department of Ulan West Operations, software parameters were changed rarely and as such the software change system was rarely used. By contrast, the longwall department changed parameters regularly and the consequences of unintended movement of equipment is better understood. The last software change form for the DMU was in March 2016.

Periodic checking of parameters on the DMU was not included in the planned maintenance system.

Joy security on passwords appeared to be robust however, the Joy USEngineer password was known outside of Joy.

The interlock between the panel belt loop take up winch and the DMU advance was not identified as critical on the functional safety assessment as it was believed the conveyor belting would break.

4.3. Procedures and systems of work

No overall coordination was evident regarding who would perform which steps of the SWP for belt extension using DMU and monorail.

The people building the belt structure did not think they needed to know and understand the DMU advance procedure.

The tramming switch was found after the incident to be in the incorrect (off) position, which prevented the conveyor intercom system from broadcasting the belt tension.

While there was evidence of the use of the hazard reporting system there were a number of opportunities for hazards to be formally raised but those involved used verbal comments to supervisors.

Communication regarding changes to procedures was not formally controlled.

Even though the procedure was available on the job, it was not followed.

Investigation into the over-tension event on 20 July 2017 was not complete and the consequences of the over tension was not foreseen as a mechanical failure of the tow hitch. The consequences were considered to be minor, such as a belt clip pulling apart.

5. Key learnings

The investigation highlighted a number of key learnings that are covered in the body of the report.

Even though the design review process for the equipment was extensive, the consequences of the over tension of the panel belt was underestimated by the investigation team. This underestimation led to a lower level of engineering analysis being applied to the design of the mechanical structure and the integrity of the electrical control system interlock between the DMU advance and the panel belt winch.

Passwords to control parameters in various OEM equipment were widely known across the industry, allowing the security to be compromised.

Where safe work procedures have been developed, workers should guard against normalising the risks involved in the task by their experience of doing the task many times, and periodically take the time to step through the procedure on the job, particularly after any changes have been made to procedures or environment.

When safety controls are updated into safe work procedures, these safety features need to be clearly and concisely communicated to the workers in a formal manner. The importance of the introduced safety controls should be emphasised to workers.

6. Recommendations

The recommendations address the (state contributing factors categories involved, e.g. Absent or Failed Defences) identified as key findings of the investigation.

6.1. Mechanical design

- The OEM is to review the design of the DMU and conveyor system using standard engineering methods to assess the structural design versus the input force of the propulsion cylinders of the system and the functional safety of any interlocks taking into account scenario's that could lead to a catastrophic failure, such as multiple fatalities, during a DMU advance.

6.2. Software parameter management

- Sites need periodic or event-triggered parameter audits of all parameters as part of equipment maintenance procedures.
- All parameters need to be able to be viewed by the mine.
- When commissioning equipment, discipline is required to complete every line item to an effective standard and if a line item cannot be done processes must be followed to identify and investigate the discrepancy.
- OEMs should review the security of parameter control systems and implement appropriate parameter management controls.
- Where parameters allow the bypass of safety functions, OEMs should consider automatic resetting of the parameter to a safe state at power up.
- All relevant employees and contractors should be made aware of the intent and application of the software change process.

6.3. Procedures and systems of work

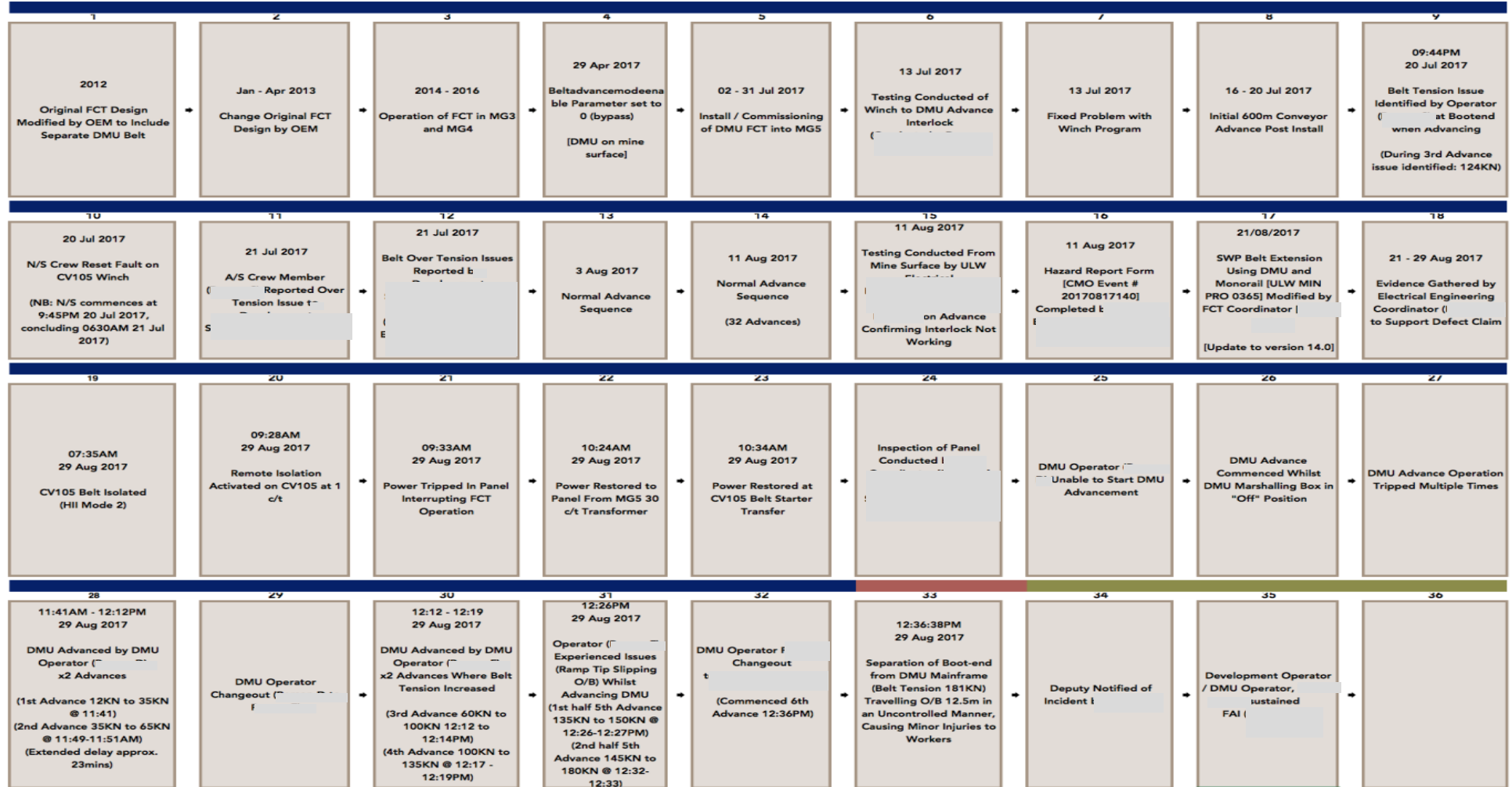
- Where safe work procedures have been developed, workers should guard against normalising the risks involved in the task by their experience of doing the task many times, and periodically take the time to step through the procedure on the job and particularly after any changes to procedures or environment.
- Communicate changes to procedures effectively to all parties affected.
- When safe work procedures are used on regular tasks, a process is required to capture compliance to the procedure and feedback from the work crew on the effectiveness of the procedure.
- Previous printed versions of documents should be removed from the active working area.
- Encourage employees to use hazard reporting systems and provide feedback in a timely manner.
- Owners of FCT/DMU systems should include outcomes from this incident in equipment training.

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Authorised by	Anthony Keon, Chief Compliance Officer

7. Appendices

A.1 ICAM timeline

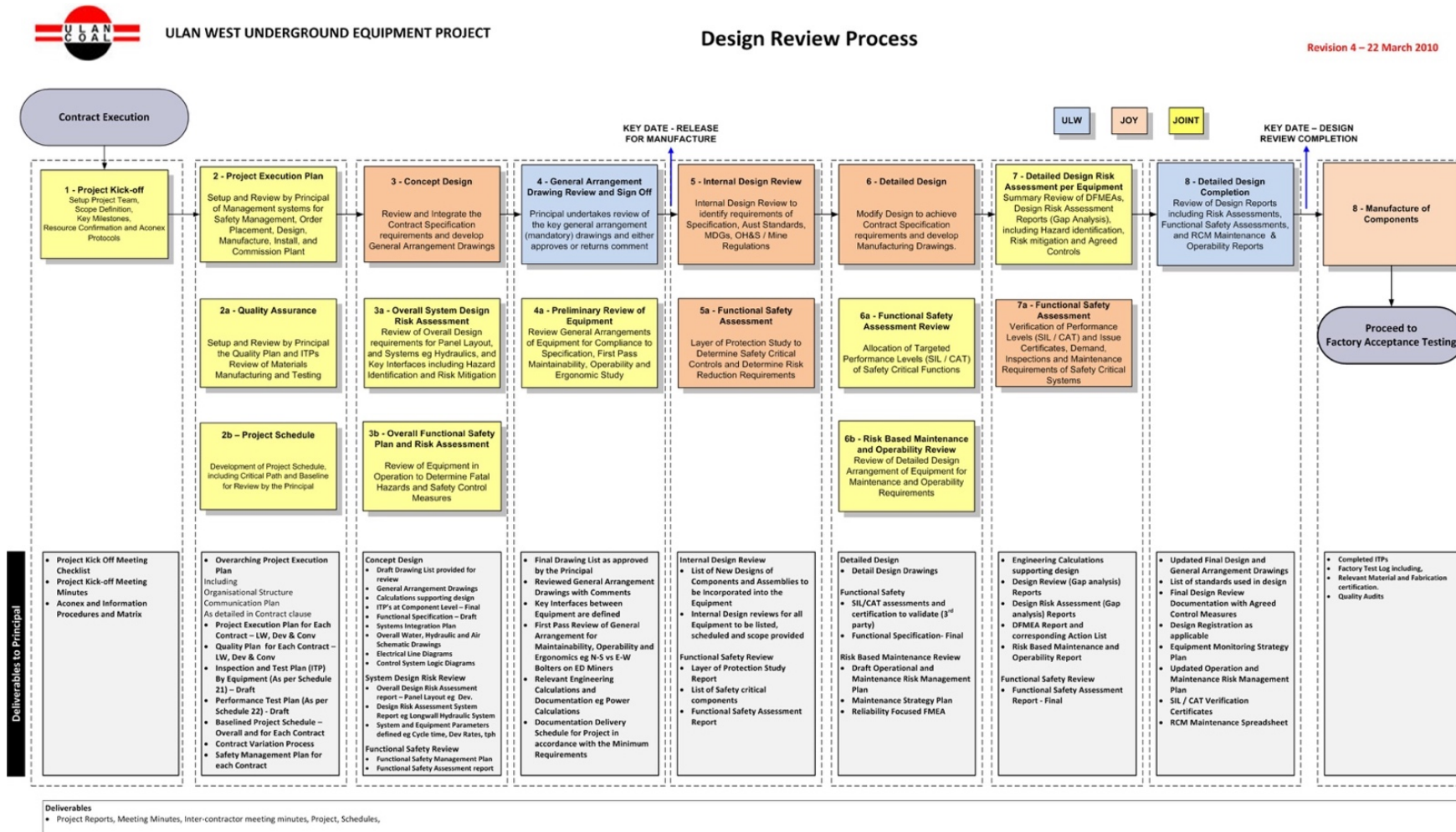
Underground DMU boot-end separated from mainframe



A.2 ICAM chart

Organisational/ System Factors	Task/ Environmental Conditions	Individual and Team Actions	Absent and failed defences	Incident
The commissioning check sheets were inadequate to identify a failure on the Loop Take-up to DMU interlocking facility.	Mechanical Design: The DMU has enough force to pull itself in half	Safe Work Procedure for Belt Advance was available but not all steps were followed	DMU and Conveyor Software Advance Logic: Change to Beltadvancemodeenable Parameter (set to 0) disabling the DMU advance to belt loop take-up interlock.	29 Aug 2017, 12:36:38PM Separation of Boot-end from DMU Mainframe (Belt Tension 181KN) Travelling O/B 12.5m in an Uncontrolled Manner, Causing Minor Injuries to Workers
Inadequate Communication - inadequate handover of hazards between shifts	Inclusion of side shift mechanism with no mechanical force analysis of the DMU structure conducted at the design stage by OEM	DMU tramping switch was found after the incident to be in the incorrect (OFF) position.	LTU Winch Belt DAC not actively announcing belt tensions	
Inadequate Management of Change - poor communication of change to SWP Belt Extension Using DMU and Monorail by FCT Coordinator to Shift Deputies and Workers	Inadequate communication of hazard relating to belt tension issues	The inbye mode switch (production/move-up) was found in the down position which indicates Production.	LTA Parameter Checks - Commissioning and Periodic	
Inadequate use of Software Management Change Form and System Impairment Permit.	Inadequate communication of hazard relating to belt tension issues	Inadequate communication of changes to SWP Belt Extension Using DMU and Monorail by FCT Coordinator to Shift Deputies and Workers		
Certain parameters not visible to personnel outside of Joy, where there is no process in place by OEM to manage these hidden parameters	LTU Winch was not powered, preventing the belt from paying out during belt advance	DMU and Conveyor Software Advance Logic: Change to Beltadvancemodeenable Parameter (set to 0) using high level OEM password during commissioning		
The FCT/DMU and the panel conveyor belt system not fully assessed by the OEM and site as a complete system.				
LTA Parameter Checks - Commissioning and Periodic				
Joy USEngineer password is known and used by people across the industry in an adhoc manner.				

A.3 Design review process



A.4 Survey of the incident location

