HOISTING SYSTEM MAINTENANCE - A RISK BASED APPROACH FOR ESTABLISHING SAFE & EFFICIENT STRATEGIES

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ABSTRACT

Hoisting systems are continually pushing the limits of material strength, system speed, capacity and depth. Failure of a hoisting system can have catastrophic consequences and while technology developments have improved the inherent safety of these systems, ongoing risk management systems need to be employed. In addition to sound design practices, the implementation of a comprehensive and robust maintenance program is key to a safe and productive operation. Developing maintenance strategies for such critical systems can be a complex and sometimes daunting task. There is typically conflict between downtime to complete offline maintenance activities and the minimum run time required to meet mine production commitments. Legislation varies widely across Australia with most states adopting programs from existing operations in combination with risk management strategies. However, with limited definition surrounding minimum maintenance requirements, finding an optimum balance can be challenging. This often results in excessive downtime or ineffective maintenance regimes being conducted which can have detrimental impacts to safety, operating cost and revenue. At Ernest Henry Mine (EHM), a risk-based review of the site hoisting system maintenance plan was conducted. This paper provides a case study overview of the maintenance program development and the refinement process utilised, the tools used to collect reliability data to support and validate these plans and procedures, along with key examples showing the benefits of employing strong data collection and analysis practices. The same process can be applied to any operation to develop new or refine existing hoisting system maintenance programs to safely maximise system availability and throughput.

KEYWORDS

Winder, Maintenance, Hoist, Ropes, Risk management, Legislation, Standards, Condition monitoring, Ernest henry mine, Safe work instruction, Production, Downtime, Preventative maintenance

INTRODUCTION

Vertical haulage systems are an efficient means of transporting men and material quickly between the surface and underground mine workings. Today, these systems typically operate at depths between 500 m and 2000 m, lifting payloads up to 60 t, at speeds up to 18 m/s and incorporating 1 to 6 supporting ropes depending on the type of winder selected. If failure occurs within systems operating at these limits, the consequences can be catastrophic. This drives the importance of implementing system and equipment maintenance strategies capable at providing early detection of approaching problems. The high-risk nature of these systems combined with limited legislative guidance for maintenance regimes within Australia, can often lead to a tendency of ‘over-maintaining’.

Production hoists are required to operate at full capacity continually and are often the mine's sole method of mineral transport and subsequent revenue generation. Increasing the instantaneous throughput of a hoisting system can be difficult once already in operation. Unless the system had prior consideration to upgrade, large-scale equipment replacement and structural modification is typically required. The most effective way of increasing system throughput is to maximise the available run time. To do this, a robust yet efficient maintenance strategy is necessary.

It can be difficult to establish maintenance plans for greenfield operations. Within Australia, there is limited direction provided by Regulations and Legislation regarding what constitutes an acceptable maintenance plan. Specific maintenance tasks for inclusion into a 'compliant' maintenance schedule are generally not detailed. This can lead to organisations adopting strategies from other operations without fully understanding the reasons why certain tasks have been included and their corresponding execution frequencies selected. Regularly, site-specific tasks are implemented after a near miss, earlier failure or isolated incident, the failure mechanisms of which may not be present in every installation. The maintenance plan developed at EHM prior to commissioning the hoist in 2014 exhibited some of these traits and underwent an overhaul in 2017 to rectify.

This paper provides a case study around the process established by EHM to increase the hoisting plant availability. To support this increase, a risk-based review of the maintenance plan was conducted to ensure safety was not compromised. Included in this paper is data quantifying the nominal increase in availability along with a summary of the final maintenance strategy implemented. This strategy could be used as a starting point for systems utilising a similar hoist configuration, particularly within Queensland, Australia.

Key to supporting the review process was maintenance data collected from the initial operating years. An overview of some of these data collection tools and systems is provided, showcasing the communication methods used to connect the requirements of condition monitoring systems to the maintenance team operating on the floor. Included are specific examples of how methodical and accurate data collection supported system troubleshooting and the maintenance planning process.

ABOUT ERNEST HENRY MINE

EHM is a copper and gold mining and processing operation located 38 kilometres North East of Cloncurry in North West Queensland, Australia. EHM started as an open pit operation and transitioned to underground mining in 2011 to extend the mine life to at least 2026.

The underground mine uses sub level caving techniques and a series of ore passes to connect the production levels to the primary crushing station. The primary crushing operation utilises a direct tip gyratory crusher to size Run Of Mine (ROM) material such that is suitable for transport on the underground conveying system. The crushed product in transported to the surface via the vertical hoisting shaft and onto the site concentrator for processing. The EHM shaft haulage system comprises a tower mounted friction winder in a skip-skip configuration. The key hoisting system specifications are outlined in Table 1, with the headframe and winder building depicted in Figure 1.

Table 1. EHM Hoisting System Specifications

Parameter	Description
Shaft	Diameter 7m – concrete lined
Winder Configuration	Tower mounted, 4-rope friction
Depth of Wind	921 m
Instantaneous Throughput Capacity	1010 tph
Nominal Annual Capacity	6,000,000 t
Hoisting Speed	16 m/s

Parameter	Description
Skip Payload	32 t
Motor Capacity	5,000 kW
Braking System	Hydraulic, Disc
Drive Configuration	Direct drive, Synchronous motor
Conveyance Guidance System	Rope guided, hydraulic tensioned
Head Ropes	4 x 46 mm, Stranded
Tail Ropes	4 x 46 mm, Stranded
Guide Ropes	4 x 45 mm, Half Lock Coil

Figure 1. Ernest Henry Mine headframe and skyshaft

HOW TO DEVELOP A SAFE AND EFFICIENT MAINTENANCE STRATEGY

The 2017 winder maintenance overhaul raised questions surrounding what defined a safe and efficient maintenance strategy. The key objectives underpinning the review process included:

- Ensure compliance with regulatory and governing bodies.
- Minimise personnel risk exposure during system operation and completion of the maintenance tasks.
- Ensure maintenance tasks will detect the failure modes they are intending to address.
- Completion of the tasks shall reduce the probability of failure occurrence.
- Ensure task execution frequency is as low as practical such that the probability of a failure occurring does not increase from the current baseline plan.

To support these objectives, the maintenance strategy was conducted following a five-step process:

- Step 1 - Literature review.
- Step 2 - Benchmarking.
- Step 3 - Failure mode and effect analysis.
- Step 4 - Maintenance task and failure mechanism risk assessment.
- Step 5 - Scheduling and implementation.

Step 1 - Literature review

To ensure that any maintenance plan developed from this process maintained regulatory compliance, a review was conducted of all legislation applicable to mining operations within Australia, along with published literature such as standards and guidelines associated with hoisting system inspection, operation and maintenance. It is noted that the EHM site operates under the Queensland Mining and Quarrying Act and complies with the requirements of this act.

The review focussed on locating any prescriptive maintenance requirements within these documents, either legislated or recommended, in order to build the foundations for the maintenance plan. Over 30 documents were reviewed through this step however most documents only provided generalised statements surrounding the necessity to have systems in place to ensure system integrity and safety. Some of the key documents identified as having prescriptive maintenance information, applicable to the EHM hoisting system are listed in Table 2 for reference. Note that some of the documents listed are now superseded.

Table 2. Literature review – summary of documentation with prescriptive maintenance information

Document Title
NSW Mine Design Guideline MDG33.3 - Mine winders - Vertical shaft winders (draft)
NSW Mine Design Guideline MDG33.5 - Mine winders - Friction winders (draft)
NSW Mine Design Guideline MDG33.7 - Mine winders - Examination, testing and retirement of ropes (draft)
Safe Work Australia Code of Practice - Underground winding systems (draft)
Western Australia - Mines safety and inspection regulations - 1995
Australian Standard 3637.1:2005 - Underground mining - Winding suspension equipment - Part 1 - General Requirements
Australian Standard 3637.3:1997 - Underground mining - Winding suspension equipment – Part 3 - Rope cappings
Australian Standard 3785.6:1992 – Underground mining shaft equipment - Part 6 - Guides and rubbing ropes for conveyances
Australian Standard 4812:2003 – Non-destructive examination and discard criteria for wire ropes in mine winding systems

An example of a prescriptive maintenance requirement regarding tail rope non-destructive testing, taken from AS4812 Clause 2.4.3 'NDE frequency shall not exceed 12 months'. This provides clear recommendation on the type of testing to be conducted and the test frequency. Definitive and clear statements such as this were compared to the existing maintenance plan as a compliance review. This also set the foundation for development of the new maintenance strategy.

When applying these prescriptive maintenance requirements, it is important to understand the context in which they are intended and make judgement of their application. For example, a requirement to 'inspect head ropes daily' is a clear statement, however in this example the context surrounded the use of man riding conveyances and was not specifically intended for application to production hoisting systems in Queensland.

Step 2 - Benchmarking

The second step involved reviewing maintenance plans of similar operating sites as a benchmarking exercise. The following primary aspects of each plan were compared:

- Duration to complete each maintenance task.
- Frequency of maintenance task execution.
- Maintenance task list including activities completed as part of the task and data recorded.

This review combined the scheduled task list, task duration and task frequency components of the benchmarking exercise. A comparison between weekly scheduled downtime over a typical one month period at EHM and the average of the sites encompassing the review is shown in Table 3. This identified that EHM was scheduling an additional 70% downtime compared to the average across these sites. The reasons justifying this difference were quantified as part of the process.

Table 3. Scheduled downtime comparison - benchmarking

Site	Week 1	Week 2	Week 3	Week 4	Total	Comparison
EHM	8 h	19 h	9 h	21 h	57 h	1.7
Average	9.5 h	8 h	8 h	8 h	33.5 h	1

A qualitative approach was taken to evaluate the perceived ‘quality’ of the maintenance task procedures and data recording. This was completed through review of the ‘Standard Jobs’ to identify any gaps or areas for improvement when conducting each task. This exercise identified potential sections within the plan that would benefit from further scrutiny.

Step 3 - Failure modes and effects analysis

The fundamental purpose of condition monitoring or predictive maintenance is to provide early detection of a deteriorating condition or pending failure of plant and equipment. This third step focussed on the failure mechanism and modes contributing to this deterioration. It is important to understand the detail of each maintenance task procedure, what data is collected, how the data provides indication of failure and how the detection of the failure mechanism relates to the frequency of inspection.

For each maintenance task related to the analysis or inspection of a particular component within the hoisting system, the corresponding component failure mechanisms were identified, along with their failure mode. The effects of such failures were also quantified. For consistency, the failure modes were summarised into the following four categories:

- Steady Aging - gradually increasing failure rate over time.
- Infant Mortality - high initial failure rate followed by a more random level of failures.
- Random – consistent level of random failures over time.
- Worst Old - increasing rate of failure towards end of life.

Understanding the link between what failure mechanism the maintenance task can detect and the associated failure modes is key to evaluating the task frequency required to maintain an acceptable risk level. For example, short interval or frequent tasks corresponding to failure mechanisms characterised as ‘steady aging’ were challenged; if indications of pending failure were typically predictable and gradual, no benefit is realised by frequent inspection. These cases could have their inspection frequency increased later in life once an issue was identified.

To get maximum benefit out of the next step (step 4) of the process, identification of the effect and consequence of each failure mode listed in step 3 was mediated to target the most credible or likely outcome, not necessarily the worst conceivable. With the complicated nature of hoisting systems, failure of any component can often cascade to catastrophe under certain conditions. However, there are typically other measures in place to prevent such escalation. For example, if core failure of one head rope was to occur, the rope would develop considerable slack creating excessive rope movement during hoisting cycle which would be detected during the operator online inspection which was completed each shift. If every maintenance task failure mechanism had a catastrophic event associated with it, the risk review process would struggle to identify any areas for improvement.

Two examples of maintenance tasks, their failure mechanisms, failure modes and effects are summarised in Table 4 and Table 5. The ‘Head Rope Measurement’ maintenance task involves taking a series of rope diameter and lay length measurements to monitor the condition of each rope. These are taken in specific areas subject to the highest fatigue loading. The ‘Winder Brake Inspection’ maintenance task involves visual inspection of the winder brake discs, callipers and hydraulic system.

Table 4. Maintenance task - head rope measurement failure mechanism, mode and effect summary

Failure Mechanism	Failure Mode	Effect / Consequence
Rope core failure	Worst Old	Overload remaining ropes causing excessive rope stretch. Production loss due to unscheduled downtime for rope change
Rope excessive corrosion	Steady Aging	Reduced rope life; cost of early replacement and associated production loss for rope change downtime

Table 5. Maintenance task - winder brake inspection failure mechanism, mode and effect summary

Failure Mechanism	Failure Mode	Effect / Consequence
Hydraulic pipe failure	Random / Worst Old	Brakes will not lift leading to production loss.
Hydraulic pump failure	Steady Aging	Brakes apply and winder cannot move if failure occurs leading to production loss (failsafe).
Hydraulic valving failure	Steady Aging	
Fastener failure	Random	Damage to winder drum/disc/callipers leading to equipment damage from reduced braking force.
Pad damage	Steady Aging	
Braking surface contamination	Random	Braking force reduced however system exceeds minimum braking force requirements.
Control system failure	Random	
Electric sensor failure	Random	Winder held out due to missing electrical signal leading to production loss

Step 4 - Maintenance task risk assessment

With the failure modes and effects now identified in step 3 for each maintenance task, this step involved conducting a site-specific risk assessment. The objective of the assessment was to define the overall ‘risk rating’ associated with the failure mechanisms, at the current task frequency. This process was completed again for the maintenance tasks at a second, revised frequency. The criteria for an acceptable frequency was such that that the overall risk rating would not increase from the existing baseline.

Typical of many remote mining operations within Australia, the fixed plant maintenance team consisted of four different work crews to provide day and night shift coverage, seven days a week. With any new maintenance strategy, it is crucial to obtain buy in from all stakeholder’s associated with the asset. Supporting this philosophy, four independent risk assessments were conducted, one per crew, over a one-month period. Attendance to these assessments included operators, tradesman, supervisors, engineers and managers from both electrical and mechanical disciplines with background in design, operation and maintenance of these systems.

The results from each assessment were tabulated, analysed and compared, with clear alignment obtained for most of the maintenance tasks across the crews. Those which lacked consistency either in revised task frequency or overall risk rating were revisited and rationalised to a single consolidated outcome.

Developing a maintenance program using a risk-based approach requires confidence in the reasons supporting acceptance of the risk level. Prior to completion of the maintenance review, EHM amassed over two years of data from methodical collection and recording of information generated from each maintenance task. This provided vital insight into site specific behaviour and issues relating to the plant, creating a certain level of assurance when revising the maintenance plan. This was particularly prevalent when assessing failure mechanisms identified with corresponding 'random' failure modes. For example, head rope inspections visually scan the rope for abnormalities, one of which being mechanical damage. Mechanical damage is typically caused from material spillage and is considered random. There is nothing to say that the very next hoisting cycle after an inspection is completed that this damage may not occur; so why isn't the inspection completed after every cycle? The historical data related to items such as mechanical rope damage helped to inform some of the maintenance frequency decisions.

Important to note is that during the risk assessments, the consequence of the failure mechanisms rarely changed by completion of the maintenance task. Primarily likelihood was the driving factor when determining the revised risk rating. Not all maintenance task frequencies were extended. If the risk rating increased at a frequency other than that currently in place, the strategy did not change for those tasks. Keeping consistency with the previous maintenance task examples, an example of the risk assessment output is summarised in Table 6.

Table 6. Output from the risk assessment including risk ranking and task frequency comparison

Maintenance Task	Current Frequency (week/s)	Consequence Rating	Likelihood Rating	Risk Rating	Revised Frequency (week/s)	Consequence Rating	Likelihood Rating	Risk Rating
Head Rope Measurement	1	4	E	10	2	4	E	10
Winder Brake Inspection	1	1	D	2	3	1	D	2

Step 5 - Scheduling and implementation

After completion of the first four steps of the maintenance strategy development, the planned downtime schedule required adjustment. A summary of the time-based offline maintenance tasks, their planned duration, original and revised execution frequencies are provided in Table 7.

Table 7. EHM maintenance task summary with task duration and frequency comparison

Maintenance Task Description	Task Duration (hour/s)	Original Frequency (week/s)	Revised Frequency (week/s)
Shaft Inspection	1.5	1	3
Winder Inspection	1	1	1
Head Rope Inspection	1	1	1
Tail Rope Inspection	0.5	1	6
Head Rope Measurement	0.75	1	2

Maintenance Task Description	Task Duration (hour/s)	Original Frequency (week/s)	Revised Frequency (week/s)
Winder Tread Length	1.5	1	2
Winder Tread Depth and Profile Measurement	0.5	1	2
Skip Grease	0.5	1	1
Skip Inspection	1	1	1
Head Rope Attachment Inspection	1	1	3
Tail Rope Attachment Inspection	1	1	3
Deflection Sheave Inspection	0.25	1	1
Deflection Sheave Lubrication	0.25	1	1
Winder Brake System Inspection	0.75	1	3
Winder Brake Test	1	1	1
Winder Protection System Testing	3	1	1
Drum Wedge Block Bolt Inspection	1	1	13
Motor Cooling Fan Inspection	1	1	3
Shaft Bottom Equipment & Steelwork Inspection	2	1	3
Guide Rope Insp and Grease (Lower Half)	2	2	3
Guide Rope Insp and Grease (Upper Half)	2	2	6
Shaft Water Ring Clean	6	2	3
Emergency Egress Platform Test	2	7	7
Emergency Egress System Testing	2	7	13
Shaft Bottom Clean	Shutdown	13	13
Midshaft Clean	Shutdown	13	13
In-shaft Steelwork Inspection	Shutdown	13	13
Pony Drive Test	Shutdown	13	13
Skip Tub Change	Shutdown	13	13
Head Rope Lubrication	Shutdown	-	13
Arrestor Inspection (offline)	Shutdown	13	13
Safety Catch Inspection (offline)	Shutdown	13	13
Head Rope NDT	6	26	26
Tail Rope Measurement	Shutdown	52	52
Guide Rope Measurement	Shutdown	52	52
Tail Rope NDT	Shutdown	52	52
Guide Rope NDT	Shutdown	52	52
Bridle NDT	Shutdown	52	52
Winder NDT	Shutdown	52	52

With a well-founded and robust maintenance strategy now developed, how the strategy was implemented meant the difference between a good plan and a great plan. With the minimum task frequencies now identified, a rescheduling exercise was undertaken. Figure 2 shows the planned maintenance downtime allocation each day over a 13-week period. Note week 20 represents a scheduled shutdown.

Maintaining consistency in the week to week plan built an expectation of the normal downtime cycle both upstream of the materials handling system (mine production team) and downstream (process plant). In summary:

- Sunday and Tuesdays had larger shutdowns scheduled, nominally 6 hours.

- Thursdays were consistent with 3 hours.
- Wednesday was typically a short day with 1 to 2 hours.

The four crews mentioned in the preceding sections operated on day/night shifts with an eight days on, six days off rotating roster. Maintenance efficiency was reduced on Wednesday due to personnel movements with the crews changing over throughout the day, hence the least maintenance was scheduled. It is impossible to have an identical plan each week with the varying task frequencies, however the trends put in place provided all stakeholders with anticipation of daily downtime. This supported their maintenance and scheduling processes, maximising maintenance overlap across the site.

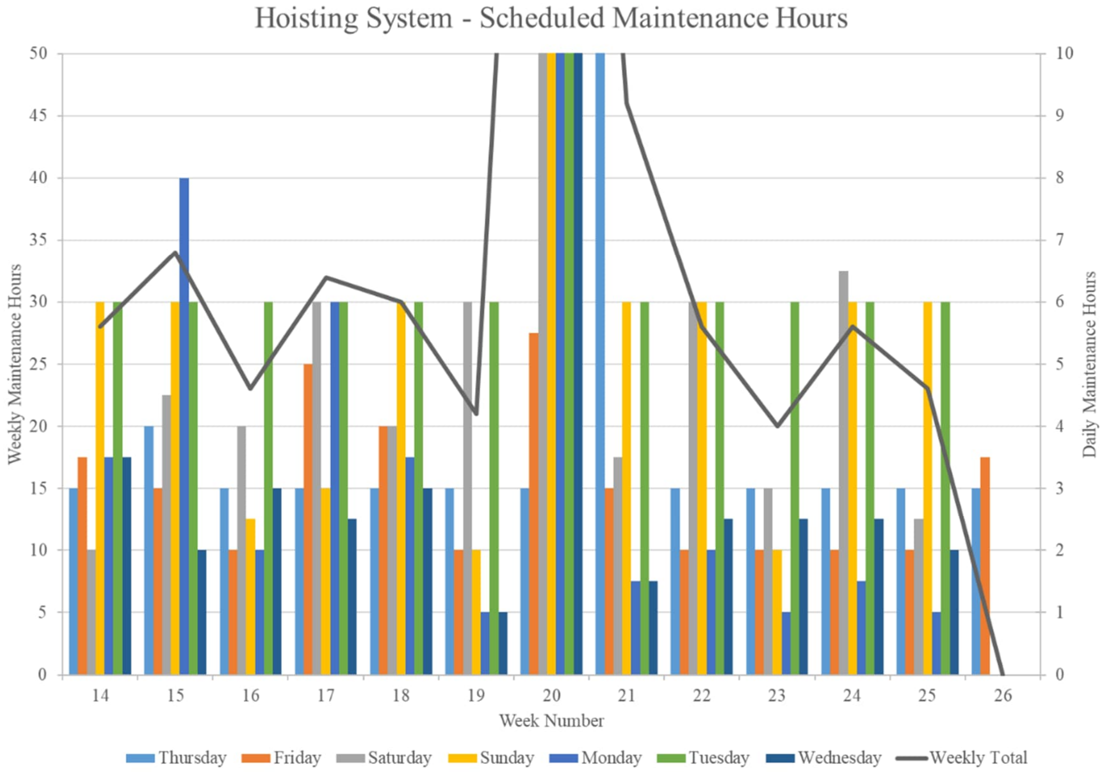

Figure 2. Scheduled maintenance downtime summary by day and week

BENEFITS FROM THE NEW MAINTENANCE PLAN

The result, primarily driven by the revised task frequency, was a reduction in downtime for completion of scheduled maintenance activities, summarised in Table 8.

Table 8. Scheduled minimum downtime and availability summary

Description	Original	Revised
Annualised planned maintenance downtime (excluding shutdowns)	1316 h	806 h
Weekly minimum planned maintenance downtime	25.3 h	15.5 h
Availability improvement	-	5.8 %
Potential annual throughput increases	-	515, 100 t

At EHM this additional availability or run time (510 hours annually) was transformed into a combination of increased production as well as available time for execution of system improvement projects within the shaft. It has also been used as an artificial stockpile or buffer to help offset loss from any unforeseen system breakdown or circumstance where production ceases. It was recently used to recover from a large wet weather event where production had to stop to liberate power to run the emergency dewatering system. This new maintenance plan is one of the key improvements made to the EHM hoisting system, contributing to the 7 Mtpa average throughput currently and sustainably being produced, well above the original 6 Mtpa nameplate. A large portion of hoisting system maintenance tasks involve working around or within the shaft, whereby personnel are exposed to hazards such as working at heights, energy isolation and dropped objects. By reducing the planned maintenance, a reduction in personnel exposure time to these hazards was also achieved.

THE HOIST MAINTENANCE TOOLBOX

As identified earlier, key to the success of this maintenance strategy development process was data collection. When detailing maintenance standard procedures, it is important to have a clear objective and plan for the data being collected, along with understanding the influences on accuracy and consistency of the data. Once this is established, measures can be built in to protect against them using both the procedure and maintenance schedule. For example, at EHM, useful data for head rope diameter and lay length was greatly inhibited from minor variances in measurements. Initial trending emphasized this issue with sporadic variances shown in measurements taken between personnel across different crews. To limit this influence, the head rope measurement maintenance task was scheduled so that the same crew and personnel could execute each time, improving data consistency.

Safe work instructions

At EHM, maintenance tasks requiring specific measurements and processes to be followed were documented in Safe Work Instructions (SWI's). Each SWI detailed step by step instructions to complete the task. Excerpts from these SWI's are shown in Figure 3 and Figure 4.

TASK STEPS

2.0 Head Rope Measurement – South Skip at Loading Station

2.1 Position measurement crew on the Guide Rope Tensioning Level in the Skyshaft.

2.2 Instruct the Winder Driver to position the South skip at a wind depth of 928m

2.3 Isolate the Winder at SSCP 3. Winder driver to verify isolation.

2.4 Lower the NDT platform in the North compartment, then open the guard doors.

2.5 Measure all four Head Rope lay lengths and diameters approximately 1500mm above floor level as per the **INFORMATION AND FEEDBACK – Measurements**:

Section 1 – Standard Rope Lay Length and Diameter Measurement Process.

Section 2 – South Skip Load Position – Deflection Sheave – 928m

Rope	Lay Length	Diameter (North/South)	Diameter (East/West)	Initials	Supervisor Initials
East					
East Inner					
West Inner					
West					

Section 3 – South Skip Load Position – South Drum – 907m

Rope	Lay Length	Diameter (North/South)	Diameter (East/West)	Initials	Supervisor Initials
East					
East Inner					
West Inner					
West					

2.6 Record measurements in the **INFORMATION AND FEEDBACK – Measurements:**

Section 2 – South Skip Load Position – Deflection Sheave – 928m

RECORD MEASUREMENTS

Figure 3. Excerpt from the head rope measurement SWI

Section 1 – Tread Length Measurement

Maximum Allowable Deviation – 10mm

Rope	Deviation – 1st Check	Deviation – 2nd Check	Initials	Supervisor Initials
West	mm	mm		
West Inner	mm	mm		
East Inner	mm	mm		
East	mm	mm		

Section 2 – Tread Profile & Depth Check (Prior to Cut)

Maximum Permissible Depth – 80mm
Permissible Contact Angle Range – 120 deg to 150 deg
Permissible Diameter Range – 48.5mm to 49.5mm

Rope	Depth Location 1	Depth Location 2	Depth Location 3	Nominal Diameter	Contact Angle	Initials	Supervisor Initials
West	mm	mm	mm	mm	deg		
West Inner	mm	mm	mm	mm	deg		
East Inner	mm	mm	mm	mm	deg		
East	mm	mm	mm	mm	deg		

Figure 4. Excerpt from the winder tread length and profile SWI

Onsite data bank – the 'Winder Rope Cycle Book'

With over 40 different maintenance tasks being completed throughout the year, some on a weekly basis, an enormous amount of data is generated. To realise the long-term benefits of this data the 'Winder Rope Cycle Book' was developed as a central repository for all information recorded by the SWI's. Each week the maintenance and reliability team conducted a review of the work orders and would enter the data into the Winder Rope Cycle Book. Figure 5 shows an example of how the data collected from the SWI in Figure 4 is recorded.

	EAST Tread - Collar to Collar Variance (mm)	EAST INNER Tread - Collar to Collar Variance (mm)	WEST INNER Tread - Collar to Collar Variance (mm)	WEST Tread - Collar to Collar Variance (mm)	Tread cut	Tread Profile cut down to 130 degrees.	EAST - Rope Contact Angle (Deg)	EAST INNER - Rope Contact Angle (Deg)	WEST INNER - Rope Contact Angle (Deg	WEST - Rope Contact Angle (Deg)	EAST - Insert Depth (mm)	EAST INNER - Insert Depth (mm)	WEST INNER - Insert Depth (mm)	WEST - Insert Depth (mm)	Distance Inside Tipping Window	EAST - Rope Tension	EAST INNER -	WEST I	
4/11/2015	0	4	10	1	no	no	150	140	150	130	56	56	56	56	350	16.0	15.7	16.0	15.7
11/11/2015	3	6	10	0	no	no	150	150	150	150	56.5	57	56.5	57	350	16.2	15.8	16.4	15.9
18/11/2015							145	150	140	145					750	15.9	15.8	15.9	16.2
25/11/2015	5	9	10	0	no	no	145	150	150	150	56.5	57.5	57.5	56.5	750	16.0	15.7	16.0	16.3
2/12/2015	0	0	0	0	no	yes	120	120	125	120	57	58.5	58.2	58.2	1000	16.2	15.9	16.6	16.3
9/12/2015	3	0	3	4	no	no	125	125	125	125	56.7	58	57	58.5		15.7	15.4	15.7	16.1
16/12/2015	0	0	0	1	no	no	150	140	140	130	61	60	61	59.5		15.9	15.8	15.8	16.3
23/12/2015	0	0	2	0	no	yes	120	120	130	120	59	59	62	59.5	800	16.4	16.0	16.2	16.5
30/12/2015	0	0	0	0	no	no	150	150	150	130	62	63	63.5	62.5	1050	16.4	15.8	16.2	16.6
6/01/2016	0	7	7	4	yes	yes	130	130	130	130	65	65.5	65	65		16.2	15.7	16.3	16.6
13/01/2016	0	4	8	7	no	no	130	140	140	120	65	65	65	65		16.0	16.6	16.0	16.0

Figure 5. Winder rope cycle book tread length and profile measurements

Figure 6 shows a trend of the winder tread depth and contact angles, making up the tread profile, recorded over the life of one tread set. Time based data recording supports trending of these parameters for early identification of issues. For example, between December 2014 and March 2015, the condition of the treads rapidly deteriorated and required regular machining to maintain an acceptable running profile for the head ropes. The tread depth increased at a rate of 10mm per month for those three months, then settled for the balance of the year. The graph also shows that at the same time the following year, the condition reappeared and regular tread cutting commenced once more, leading to the requirement to change the treads.

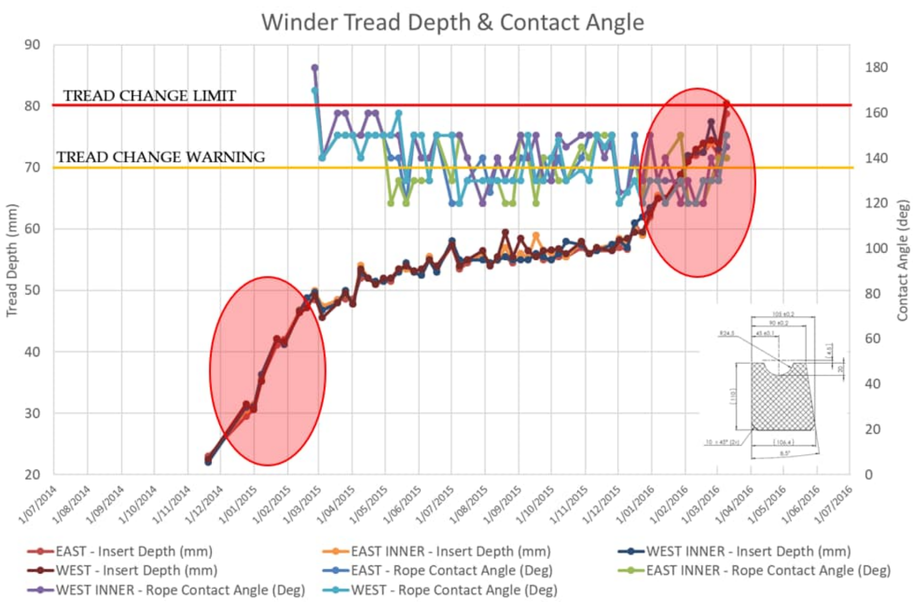

Figure 6. Winder tread depth and contact angle

In the case of the winder treads, having this data supported the diagnosis of the cause of this issue as well as forecasting the remaining tread life to allow alignment with a scheduled shutdown for replacement.

Figure 7 shows an example of permanent head rope stretch measured over time. This trend was developed from recorded rope pull up data along with position monitoring of each hydraulic adjustment link installed on the southern capels. This graph was used to monitor the head rope health, looking for indication the rope may be nearing end of life. These ropes exhibited typical initial stretch behaviour and steady elongation thereafter. In this instance the ropes were changed for other reasons prior to exhibiting the distinctive end of life characteristics.

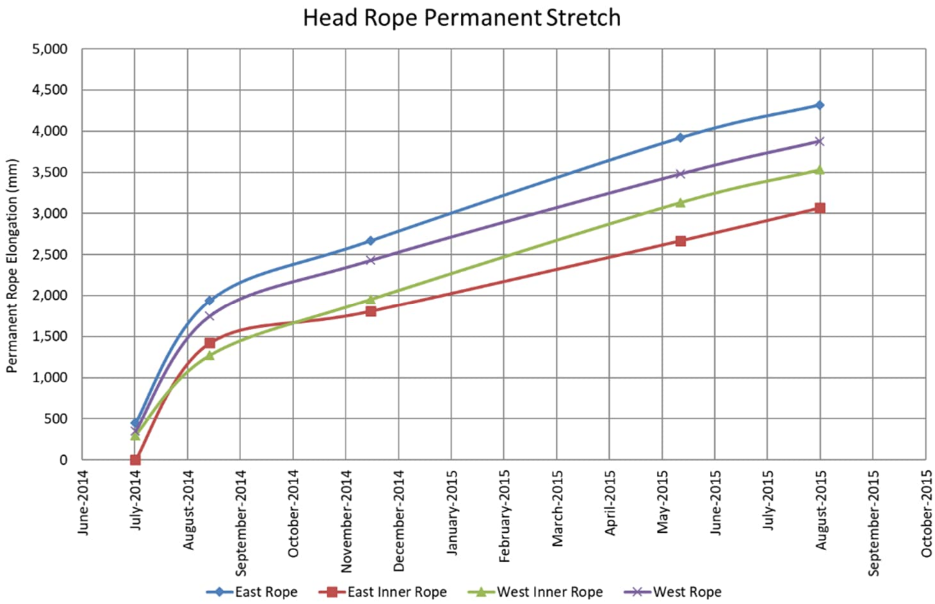

Figure 7. Permanent head rope stretch

CONCLUSION

This paper is not intended to describe a standard ‘one size fits all’ maintenance program for hoisting systems utilising tower mounted friction winders. Its objective is to describe a methodical and rational process that can be employed to optimise maintenance programs for any hoisting system. Following this process can assist in managing the balance between production commitments and maintenance without compromising personnel safety or system integrity. This review process should be repeated periodically to ensure maintenance regimes keep in touch with the plant and its current condition.

The task list and frequency defined within this paper could be used as a starting point for the establishment of a greenfield friction winder maintenance plan and assist commencement of site-specific data collection systems to support a future maintenance system overhaul such as the one described. It is important to always challenge maintenance plans and procedures to ensure the reasons behind the maintenance task are valid and the failure mechanism it is trying to protect against will be detected from completion of that task at its nominated frequency.

The documenting of this process may help in facilitating future reviews on other hoisting systems, as it lists the thinking that goes into establishment of each aspect of the maintenance plan. Also demonstrated are the benefits of having disciplined and accurate maintenance procedures, data collection and analysis systems in place to monitor plant health and provide early detection of developing issues.