DPI Longwall Hydraulic Hazard Workshop

Longwall Pump station review

Presented by Jerry Hessenberger

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Introduction

Due to random failures on the longwall pump station systems, Illawarra Coal and Longwall Hydraulics agreed to undertake an independently facilitated design review of the systems.

The intention of the review was to:

- analyse the system and the key failures;
- review the suitability of the system for the purpose of the application;
- make appropriate recommendations for improvement or redesign as appropriate.

Examples of failures:

- Pump input shaft failure
- Motor fan failure
- Coupling element failure
- Code 62 fitting failure
- Wet head failure
- Detected pressure overshoot when unloading

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Toshiba 350 kW Motor Fan Failure

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Motor Fan and Hydraulic Pump Input Shaft Failure

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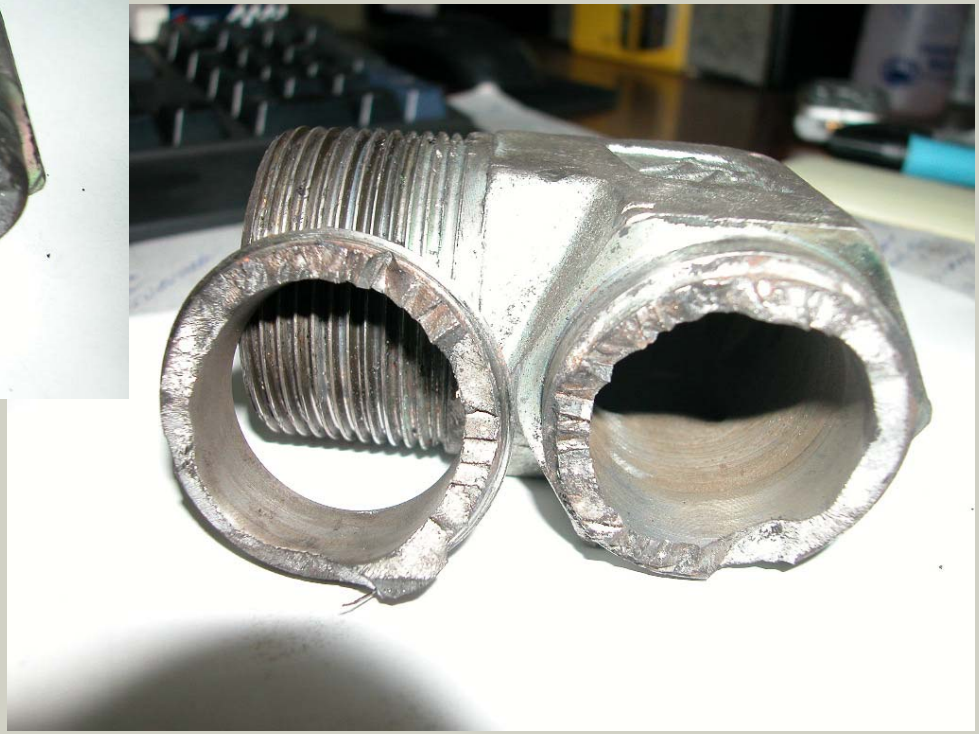
Hydraulic Fitting Failure



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Pump Station Configuration Overview

Pump series: Kamat 3500 with Toshiba 350kW motor. **The 3500 series pumps lead the market as the highest capacity Longwall pumps installed in an Australian Coal Mine to date.**

West Cliff Mine:

Pump sleds are equipped with the following Kamat pumps:

- 2 x 3500 Series 523 l/min system pumps operating @ 350 bar
- 1 x 232 l/min high set pump operating @ 380 bar
- 1 x 3500 Series 523 l/min shearer water pump operating @ 50 bar

Dendrobium Mine:

- 2 x 3500 Series 523 l/min system pump operating @ 350 bar
- 2 x 232 l/min high set pump operating @ 380 bar
- 1 x 2500 Series 458 l/min Shearer water pump on tank cart

Operational strategy:

- West Cliff mine operates with two pump systems which are “leapfrogged”
- Dendrobium Mine operates with 1 Pump system for 100% operation
- Maintenance carried out during out of service period (eg “leapfrog period”)
- Expect 99.8% reliability

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Review Team and Roles

Main team

• Process facilitator :	Hatch – Ian King
• Reliability Engineer:	Hatch – Reg Taylor
• System & design consultant:	Russell Smith - WBM
• System & design consultant:	Clayton McLellan - CMA
• Kamat Pump Specialist: Kamat Germany –	Jan Sprackel and Dr Andreas Wahl
• Pump System Design Engineer:	David Saint - LW Hydraulics
• Pump System Service Manager:–	Tony Kitching - LW Hydraulics
• Illawarra Coal Project Engineer:	Jerry Hessenberger
• Illawarra Coal Project Manager:	Robert Gordon

2 x Mine teams (West Cliff and Dendrobium)

- LW Engineer
- Mechanical & Electrical Senior Technicians
- Fitters (x2)
- Electricians (x 2)
- Operator
- Longwall engineers from Appin

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FMEA Process

- It was stressed to all workshop participants, that the FMEA process was not a “finger pointing” or “blaming” exercise.
- Once this was established and accepted by all the participation and sharing rate improved to the point where everyone was committed and freely contributed to the process.

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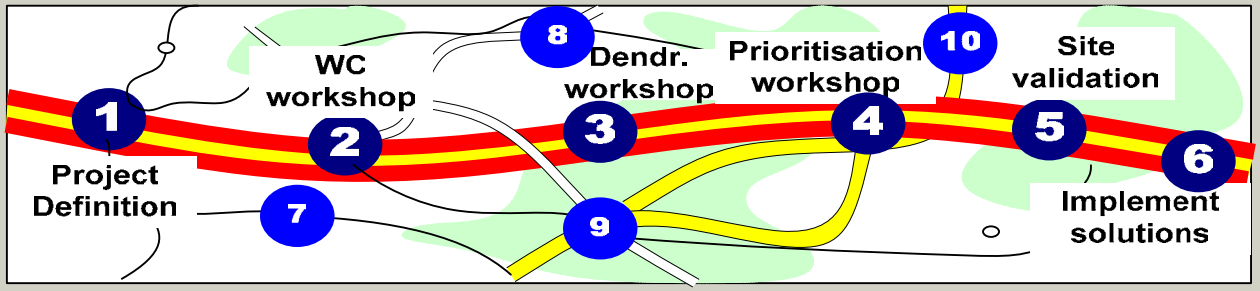
Process Followed



1. Project definition
2. West Cliff FMEA workshop (FMEA= Failure Mode and Effect Analysis)
3. Dendrobium FMEA workshop
4. Combined prioritisation workshop
5. Site validation of recommendations
6. Implement solutions

Specialised consultants:

7. Failure history analysis by Hatch
8. System modulation study by WBM
9. FEA on structures and components by WBM & CMA (FEA = Finite Element Analysis)
10. Overall design review by Kamat Germany & Longwall Hydraulics

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Outcome From Mine Site FMEA Workshops

- Process facilitated by Hatch
- Each FMEA Workshop defined on a component level, the function, functional failures and perceived basic cause for each of the failures
- The FMEA workshops identified 260 ***potential*** functional issues on the pump station system.
- The above FMEA potential issues were all analysed and reduced to only 7 issues which needed to be further addressed.

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Outcome From Mine Site FMEA Workshops

Site	Functional Failures identified	Root Cause Statistics		
		Identified	High Priority	Safety Risk
West Cliff	18	213	29	12
Dendrobium	29	260	13	20

Note: It should be clearly noted that of all of the above **potential** items identified and investigated in the FMEA process, only 7 issues were identified to require further action.

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WBM – Pump Station Modelling

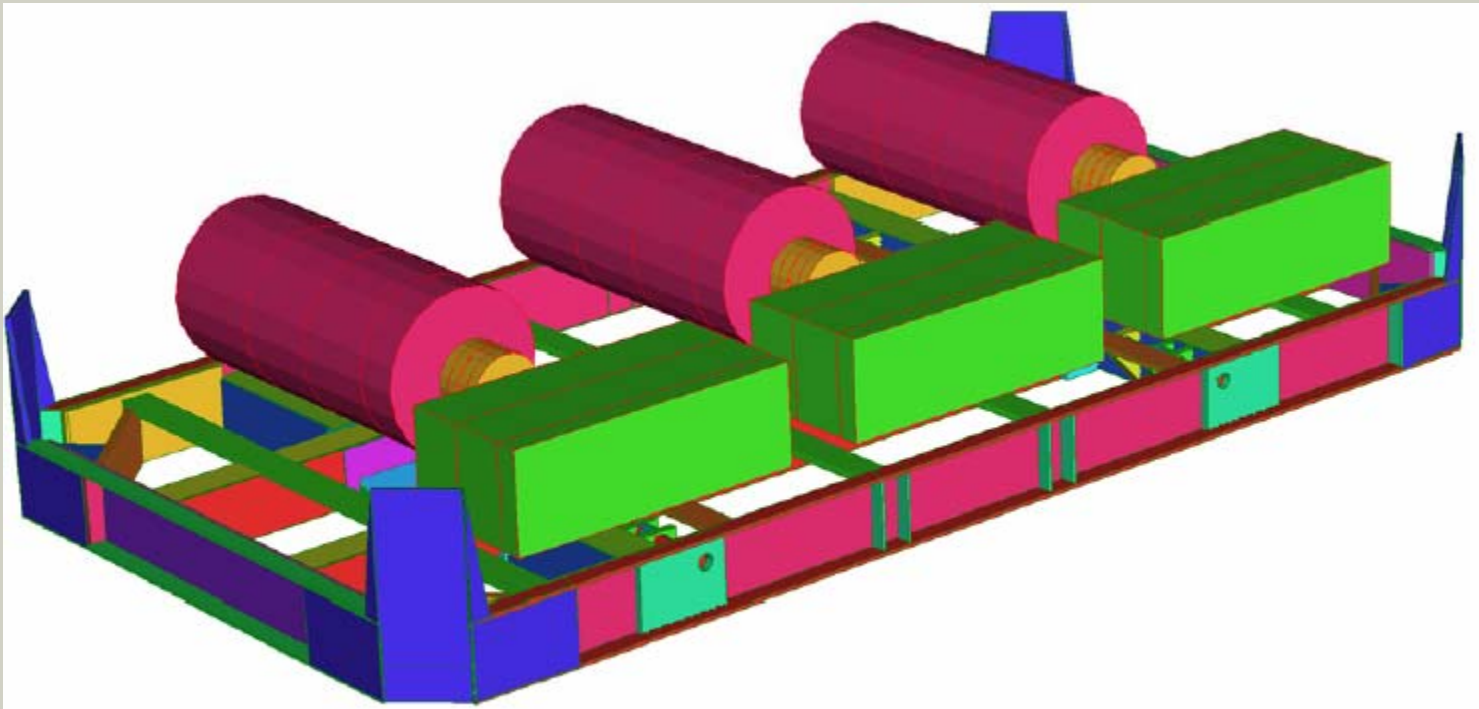

Figure 1 Model Details

- Modelling to simulate misalignment as a cause of coupling rubber and pump input shaft failures

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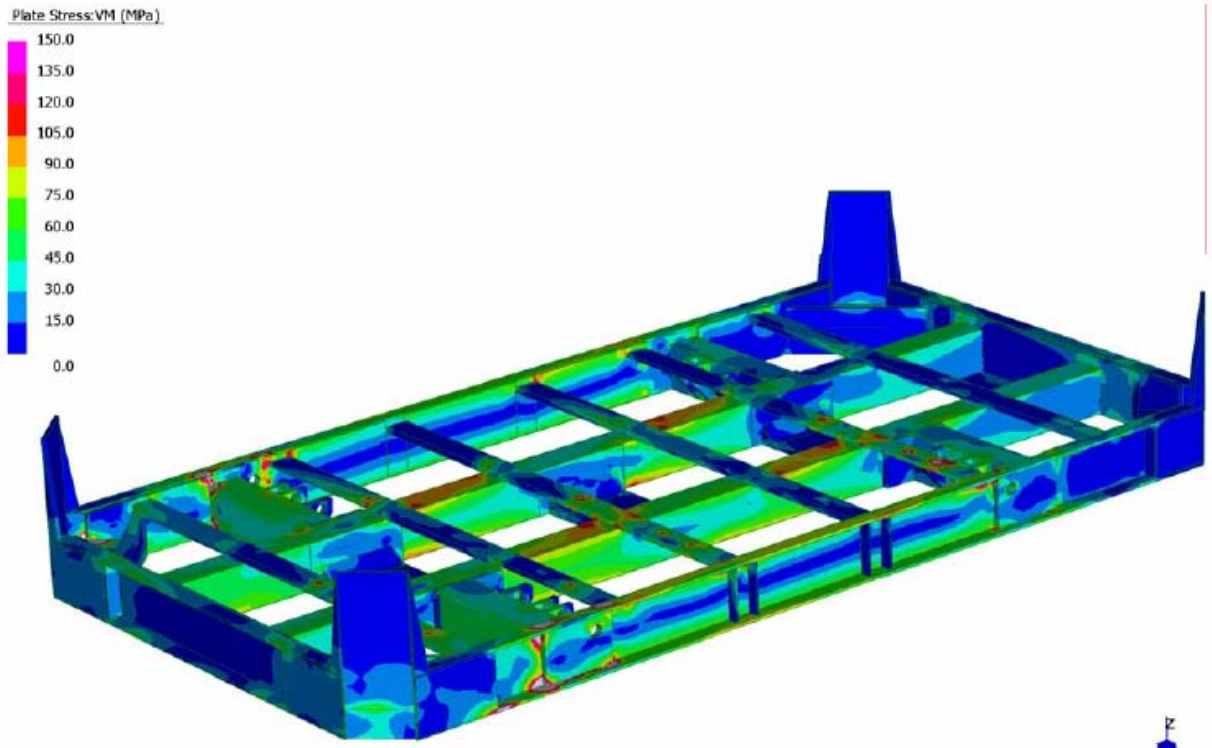
FEA Modelling for Extreme Support Conditions

STRESS RESULTS - Strength

Stress results for an extreme support condition are presented in Figure 2.



- Found isolated regions with stresses above commonly acceptable strength criteria (150 mPa). These local hot spots are not expected to represent strength problems

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Stress Results - Fatigue

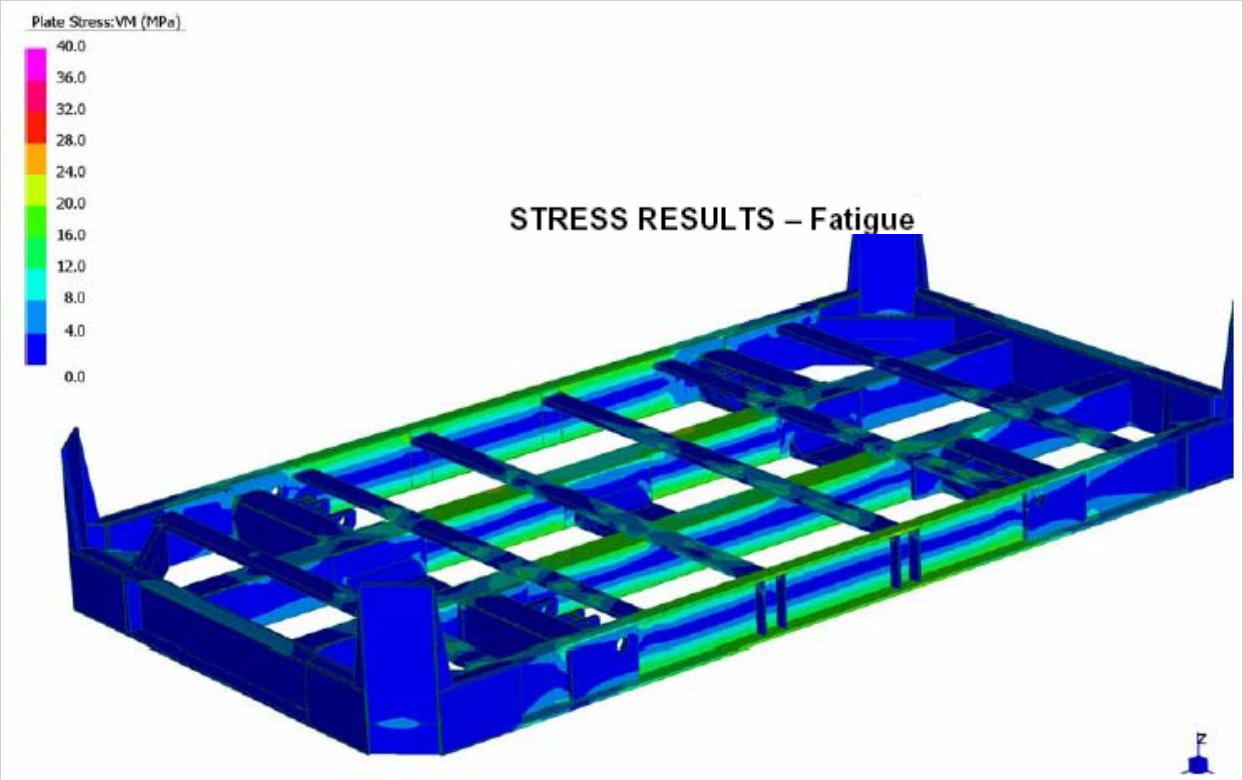

Figure 3 Fatigue Results (4 point support ~ +/- 0.125g)

- This loading is based on the approximate operating deflexion observed at West Cliff. There do not appear to be any areas where stress ranges exceed commonly acceptable values for the weld details used (40mPa).

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Outcome from System Modulation by WBM

- Of the 59 different support conditions modelled only 1 case was of concern, where it may be possible for above acceptable coupling deflection to be generated.
- Prior to any redesign work, WBM recommended that this case be checked in situ underground during a downtime period.

  To-date this has not been possible due to site operational constraints.

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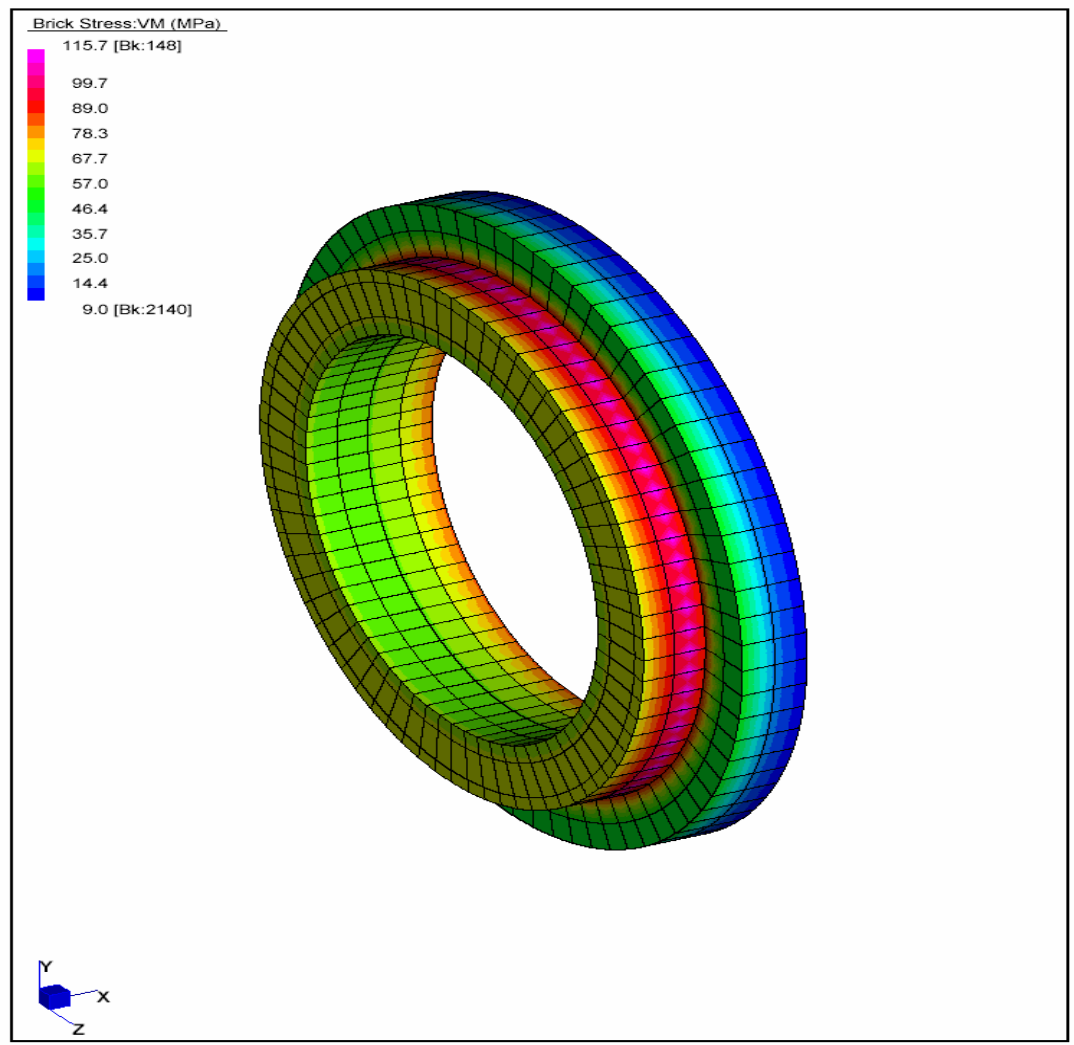
Code 62 Flange FEA



- The end of the SAE Code 62 flange was reviewed using a pressure of 350 bar with a load of 100kg on the end of the "pipe“, 300mm from the flange
- Using mild steel flanges - cycling with only hydraulic pressure and occasional external load is OK,
- Cycling with an external load on the flange is not adequate.

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Longwall Hydraulic System Review - WBM

- WBM was contracted to carry out a survey of the existing Dendrobium and West Cliff Longwall Systems to assess the perceived pressure overshoot problem.
- The survey aimed to verify the existing hydraulic system during the operation of the longwall and to determine the suitability of the pump stations for safe and reliable operation.
- The site testing was undertaken and used to establish the relevant flow resistances and provide information for calibration of WBM's longwall hydraulics simulation model

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Example of WBM's Longwall Hydraulic Supply Modelling

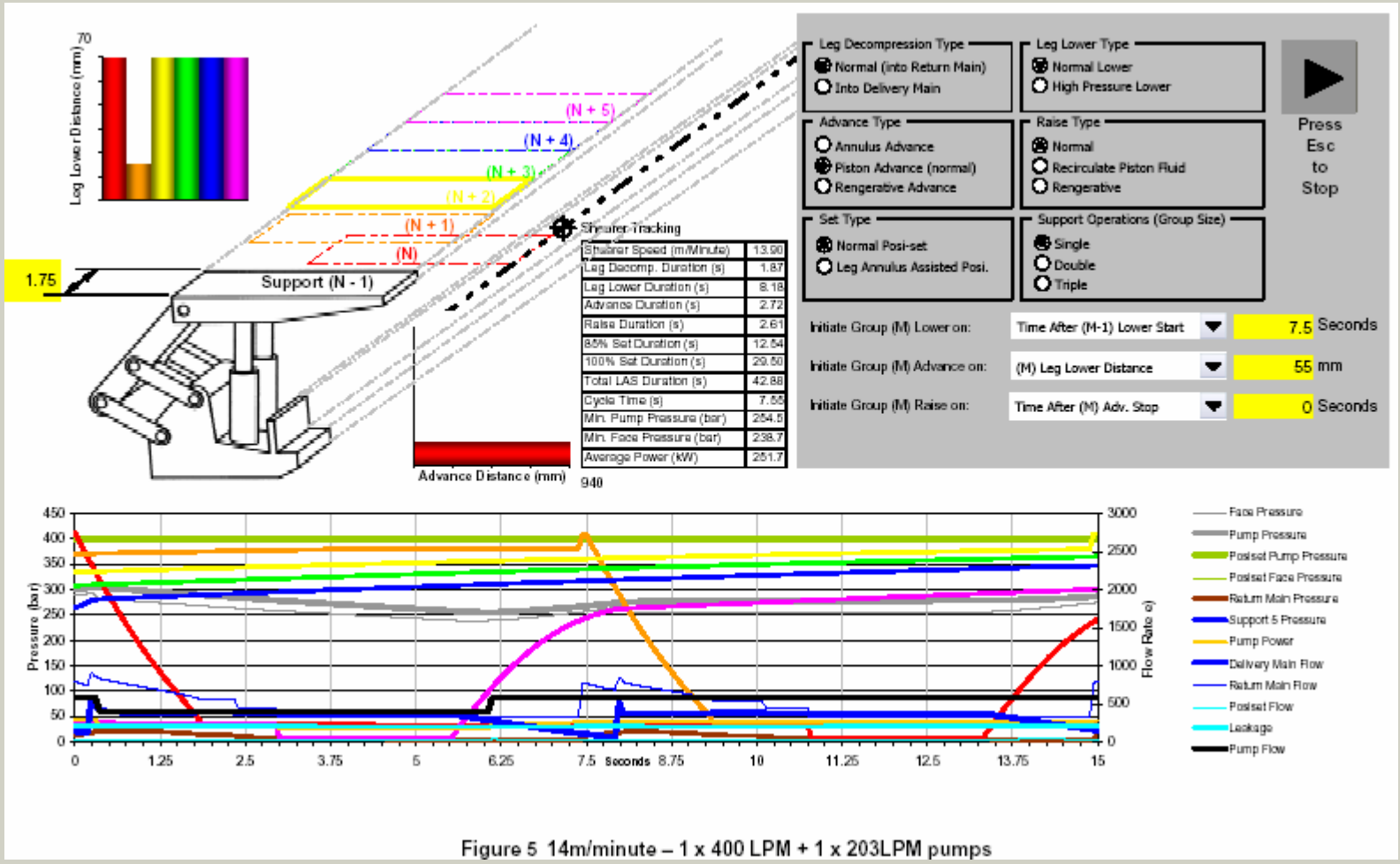

Figure 5 14m/minute – 1 x 400 LPM + 1 x 203LPM pumps

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WBM Review Recommendations:-

- Suspected unloader delays at Dendrobium should be further investigated.
- Abnormal unloader delay may be the result of unloader malfunction.
- Unloader redesign may be required to improve the unloader performance
- Review option for using smaller 400 l/min pumps to reduce pressure overshoot, cycle times, pressure pulsations and fluid borne vibration, water hammer and shock related problems

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System Pump Size versus Performance

- WBM had suggested that smaller 400 l/min capacity pumps may meet current productivity demands of the Longwall System.
- However, due to operational requirements such as “3 – shield in parallel” operation, bank pushing and the design parameters of the AFC auto chain tensioning system, the smaller pumps would not be adequate to supply system volume to maintain system pressure above 150 bar (as required by Joy) during longwall operation

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Recommendations from DFMEA and OEM Review

- **Unloader Valve** – Regular maintenance inspections to establish optimal overhaul frequency rate
- To increase lifetime of pump head wear parts – Install **new type low pressure suction boost pump.**
- To improve pump on-load/off-load timing and system stability (improved system pressure overshoot) – provide **extra accumulation to Main System and High- Set Circuits**
- To prevent Taper-Lock coupling movement – **Fit keyed and heat-shrunk style couplings to pumps and motors**
- **Redesigned, Relocated and Optimised mounting and quantity of Hydraulic Connectors, Valves and Manifolds** - to improve safety and reliability.
- **NDT of all cart frames** – To confirm structural integrity

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Additional Changes Implemented to System

Modified the hardware:

- Replaced fabricated motor fans with Cast units. (Prior to this review)
- Fans and rotors balanced during overhaul (Dendrobium).

Reviewed maintenance procedures:

- Open and inspect unloader valve every 28 weeks and overhaul initially at 48 weeks. Change over to condition based strategy once obtaining more information of deterioration rate.
- Record unloader reaction time weekly (target < 600ms)
- Additional pressure and temperature recordings to detect changes in the system
- Shortened replacement frequency of unloader pilot filter (monthly)

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Summary

- Didn't find a single "silver bullet" to solve the problems.
- The system was improved by the combined effect of a few relatively small changes.
- The system design is new and detailed condition monitoring is required to predict future system performance.
- The system design, as originally specified, has remained unchanged.
- Early observations so far indicate that the changes implemented have had a positive effect on the system performance - time will tell.
- All the learnings from this process have been **successfully** implemented on the Company's latest Douglas Longwall pump station system.

- **The success of this process was only possible due to open sharing of information and good teamwork by mine site personnel, consultants and OEM's.**

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