A Structured Approach to Offshore Crane Maintenance

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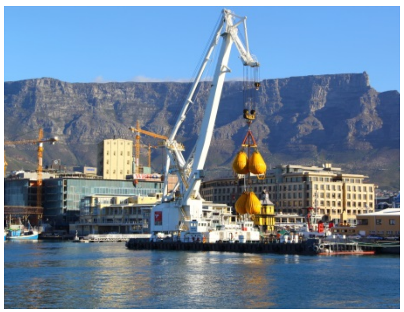







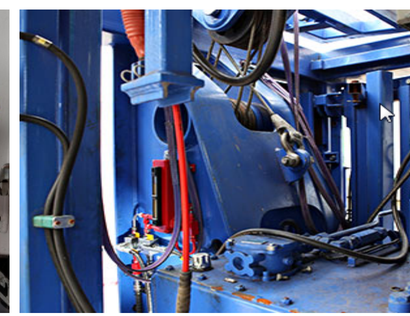

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Introduction To EnerMech

- Market leader in the provision of integrated mechanical, electrical and instrumentation service packages.
- Servicing the world-wide energy industry.
- Established in 2008 by an experienced team and backed by Lime Rock Partners.
- Heritage of over 40 years through key acquisitions.
- Track record of strong organic growth.
- Focused on providing a more competitive, responsive and better value service safely.
- Operates from over 40 facilities across Europe, Australia, Asia, Middle East / Caspian, Americas and Africa.
- c.2,500 employees, 2016 revenue £310m.

Provider of Integrated Services Across Asset Lifecycles

Pre-Commissioning

Asset Support

Late Life Support /Decommissioning

Mechanical Handling Services

Process, Industrial & Pipeline Services

Integrated Maintenance & Inspection Services

Electrical & Instrumentation

Provision of Specialist Services, Equipment and Personnel, Underpinned by a Strong Engineering Culture

Common Platforms, Shared Facilities & Equipment, Complementary Skill-Sets, Multi-Disciplined Teams

Customer Value Add: Increase Oilfield Efficiency, Improve Productivity and Asset Value In A Safe, Environmentally Friendly Manner

Agenda

1. Background
2. Crane Maintenance Strategies;
   - Time Based
   - Risk Based
   - Condition Based
3. Getting It Right
4. Case Study – Safety System Cause and Effect
5. Crane Condition Reports

Background

Crane Types;

- **1st Generation**
  - Not purpose built for the offshore environment.
  - Adapted land based crawler cranes.
  - Limited upgrade capabilities.

- **2nd Generation**
  - First purpose designed offshore cranes.
  - Simple hydrostatic transmissions.
  - Subject to continuous upgrade i.e. safety systems, load monitoring.

Background

Crane Types;

- **3rd Generation**
  - Modern purpose built offshore cranes.
  - Designed and built to current standards.
  - Extensive safety systems (AOPS/MOPS).
  - Data logging facilities.
  - Standardised components.

Background

Crane related incidents in perspective;

- Equipment failure due to pedestal crane design or technical specification faults is not a significant cause of incidents.
- 11% Equipment Failure / 89% Human Factors are Root cause.
- Of the High Potential incidents recorded over a 20 year period, 16% were associated with equipment failure.
- Single largest percentage of incidents remains those having Human Factors as their primary cause.

Background

Pedestal Crane Operations (30% of total)

- **Primary cause typical:**
  - Unsecured load/Incorrect positioning/Awareness of surroundings
- **Root cause:**
  - Slinging / banking error

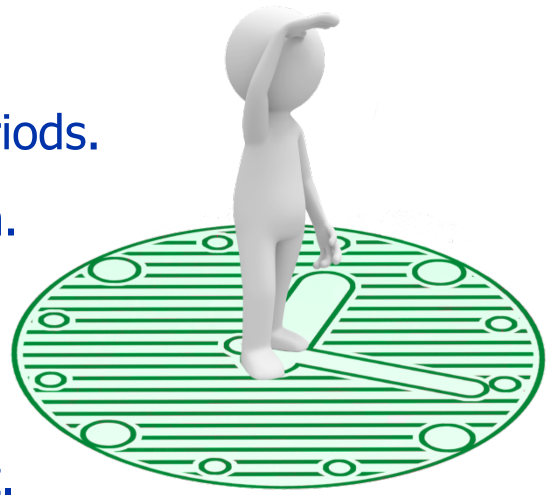
Pedestal Crane Maintenance (12% of total)

- **Primary cause typical**:
  - Hydraulic system failures
- **Root cause**:
  - Maintenance programme / Human factors

Crane Maintenance

Prescriptive – Time Based

- Prescriptive Legislation.
- Standards / Recommended Practises (RP) / Technical Guidance.
- Change out components irrespective of use.
- Relied heavily on OEM for guidance on change-out periods.
- Vendor recommendations were taken without question.
- Failure driven change-out frequency.
- Performance Standards.
- Practices & experience not based on operating context.
- Subjective “specialist” opinion.



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Crane Maintenance

What Can Still Go Wrong…

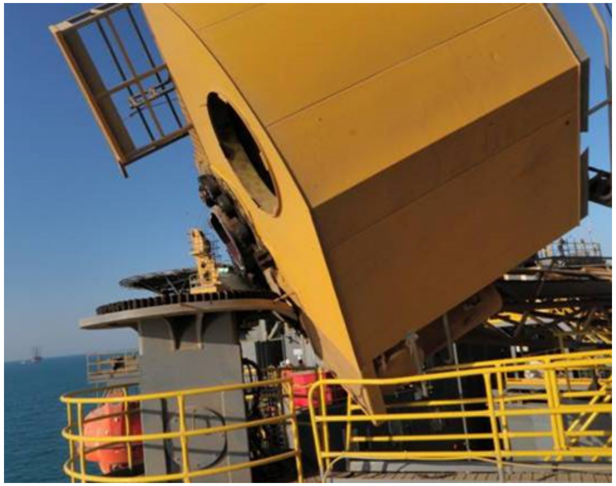
- The crane was 20 years old.
- There where maintenance procedures in place.
- The crane was regularly maintained by Competent personnel..
- The crane had recently been inspected by a Competent 3rd Party.

Single component failure was not understood.

Crane Maintenance

Risk Based – Predictive

- Management of crane safety and environmental integrity.
- Ensures an acceptable level of Reliability / Availability.
- Identifies single point failures.
- Provides an audit trail for maintenance selection and challenge of current regime's.
- Greater maintenance cost effectiveness - time and money is directed to maintenance tasks that make a real difference to integrity and reliability.
- Selection of appropriate maintenance tasks.
- Longer useful life of expensive items i.e. Booms, Slewrings



Crane Maintenance

What is RISK?

- "A situation involving exposure to danger"

  i.e. something which could go wrong.
- It is not always possible to totally eliminate it.
- ALARP.
- Is generally assessed;

  Risk = Probability x Severity

- We seek to understand it and maintain it within acceptable limits.

Crane Maintenance

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Risk Control

- Where possible re-design / design out;
  - ➢ Change the equipment, system or procedures to eliminate the failure or change its consequences
- When not possible;
  - ➢ Reduce the probability through planned maintenance
  - ➢ The type of maintenance required will be determined by the magnitude of risk.
- Demonstrate that Risk is assessed and managed;
  - ➢ Legislative compliance.

Crane Maintenance

Failure Mode & Effect Analysis (FMEA)

- A well proven systematic method used to identify and investigate potential system and component weaknesses before they occur.
- Focuses on preventing defects, enhancing safety.

- Breakdown crane into system/component level.
- What operation the component is expected to do.
- Looks at each failure and categorise it.
- Determine safe life of components.
- When carrying out FMEA the assumption is that no maintenance is done.

Crane Maintenance

Single Line Component Failure – Safety Critical

- A failure that will immediately result in the un-commanded movement of the crane boom and/or hook load or cause the crane to free slew, independent of the fact that the consequence of the event can be averted by operator intervention.

Fail Safe System – Production Critical

- The system design fails in a way that will cause no harm or at least a minimum of harm to other devices or danger to personnel e.g. any failure of equipment, process, or system does not propagate beyond the immediate environs of the failing entity.

Crane Maintenance

FMECA Process

- Important addition to include 'Criticality' analysis to predict the probability of failure against the severity of their consequences.
- Identifies whether risks are acceptable or not;
  - **The severity of the failures**
  - **The likelihood of occurrence**
  - **Compensating measures**
- Proposes redesign actions for failure modes that are inherently too high a risk.
- Assigns preventive maintenance actions appropriate and effective for those failures where the risk is considered manageable.

Crane Maintenance

Failure Mode Effect Analysis									
Ser	**Function**	**Functional Failure**	**Failure Mode**	**Local and System Effects**	**SPF**	**Likelihood**	**Severity**	**Risk**	**Cat**
1.01	Provide structure to support the forces applied during crane operations.	Unable to provide structure to support the forces applied during crane operation.	A-frame structural fail due to metal fatigue.	A-frame fractures. Collapse of A-frame and boom structure. Any attached load will fall. Probable injury to personnel, possible fatality. Secondary damage possible to platform equipment, structure and/or supply vessel. Loss of crane operational capability.	Y	1	4	4	B
2.01	Support and manoeuvre the load in a safe and efficient manner using the boom hoist system.	Unable to support and manoeuvre the load in a safe and efficient manner using the boom hoist system.	Boom hoist winch primary brake failure.	The boom hoist winch has a multi-plate disc brake system which is used as holding brake only, slowing down is controlled by the hydraulic system. A pawl lock energized when prime mover is stopped.	Y	2	2	4	B
3.01	Support and manoeuvre the load in a safe and efficient manner using the main and auxiliary hoist system.	Unable to support and manoeuvre the load in a safe and efficient manner using the main and auxiliary hoist system.	Main hoist winch primary brakes fail.	The main hoist winch has a multi-plate disc brake system which is used as holding brake only, slowing down is controlled by the hydraulic system. An external caliper disc brake energized when winch motion has stopped.	Y	2	2	4	B

Crane Maintenance

Failure Characteristic Analysis					
Incipient Condition	**LTTF**	**Safe Life**	**Useful Life**	**MTBF**	**Comments**
Cracks	8760				The failure interval is based on information from four years operation and maintenance of same or similar cranes. The approximate cranes operational running hours is 2700 per year. A review should be undertaken if there is a substantially change to the cranes operational duties or running hours.
Wear	8760				The failure interval is based on information from four years operation and maintenance of same or similar cranes. The approximate cranes operational running hours is 2700 per year. A review should be undertaken if there is a substantially change to the cranes operational duties or running hours.
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- **LTTF (Suitable for Safety and Non-safety Critical)**
- **Safe Life (Safety Critical Equipment)**
- **Useful Life (Non Safety Critical)**
- **MTBF (Not suitable for Safety Critical failure modes)**

Crane Maintenance

Planned Maintenance Routines

- **Failure Finding Task**: Test the item to ensure that it will function when required, e.g. test ringing the fire bells weekly.
- **On Condition Maintenance:** Monitor some incipient condition and undertake maintenance based on the results of monitoring, e.g. vibration monitoring on rotating equipment.
- **Scheduled Overhaul:** Undertake an overhaul based on an appropriate measure of item age.
- **Scheduled Replacement:** Replace the component based on an appropriate measure of age.
- **On Failure Maintenance:** Allow the item to fail then repair it.

Crane Maintenance

Planned Maintenance Routines

- **Task Description**: What maintenance task are we going to carry out
- **In Current PMR's**: Is it included in the current maintenance regime
- **Procedure/Work Instruction**: Is a detailed procedure required?
- **Interval**: What interval has been selected based on the failure characteristic?
- **Interval Selected**: If driven by another Failure Mode this may be different
- **Selection Criteria**: Whether LTTF, MTBF, Safe Life & Useful Life
- **System**: Hoist, Boom, Slew, Structure, Hydraulics, Pneumatics
- **Discipline**: Crane Operator, Crane Technician, NDT, CM Specialist etc.
- **Duration**: Minutes

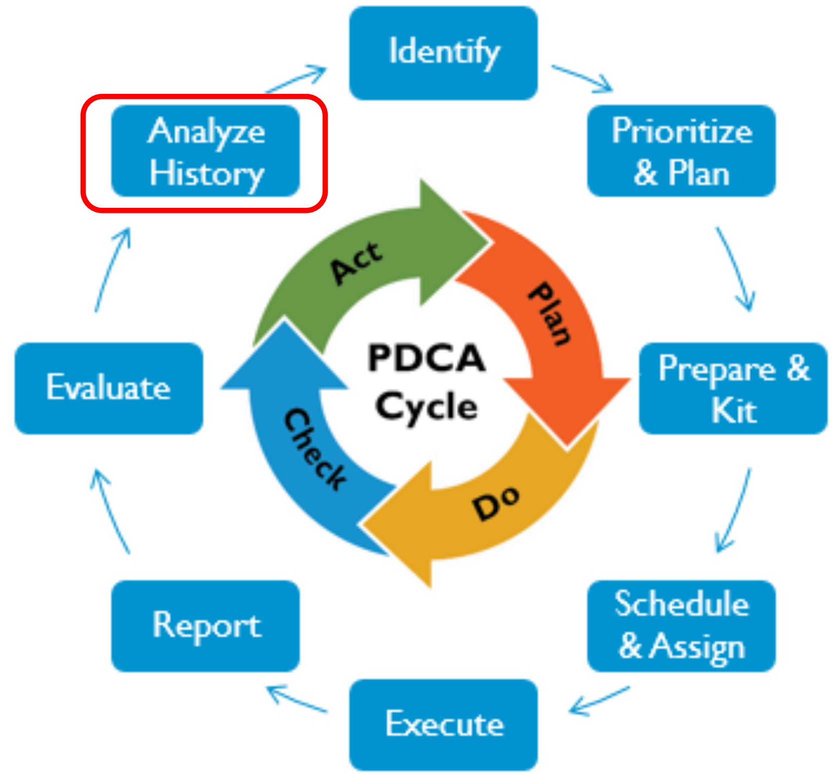
Crane Maintenance

Maintenance Strategy Selection										
MSS	Task Description	In current PMR's	Procedures/ Work Aid	Interval	Interval selected	Selection Criteria	System	Discipline	Duration (Mins)	Comments
B-OCM	Carry out a visual inspection of the A-frame structure for signs of deformation, corrosion & distortion.	Yes	No	6M	6M	Based on a LTTF interval of 12 months the recommended task interval is 6 months (1/2 LTTF interval).	Structure	Crane Op Maintainer	30	
B-OCM	Carry out a stall test of boom hoist circuit in the raise position by manually stroking boom hoist pump, and record pressure (350 Bar). Note: Boom to be in rest. Do not test for more than 3 seconds.	Yes	Yes	6M	6M	Based on a LTTF interval of 12 months the recommended task interval is 6 months (1/2 LTTF interval).	Boom Hoist	Crane Op Maintainer	30	
B-OCM	Carry out a stall test of the hydraulic main hoist circuit in the raise function using the joystick and record pressure (350 Bar). Note: Test input brakes separate from disc brake. Do not test for more than 3 seconds.	Yes	Yes	6M	6M	Based on a LTTF interval of 12 months the recommended task interval is 6 months (1/2 LTTF interval).	Main Hoist	Crane Op Maintainer	30	

Crane Maintenance

Condition Based - Future

- **Complete the Maintenance Cycle.**
- **Historically cycle limited to Report / Evaluate.**
- **CMMS – Free text data capture.**
  - Data unreliable – incomplete
  - Cannot be trended or analysed
- **Not linked to individual crane utilisation / load history.**



Crane Maintenance

Analyse History

- Not enough cranes in service with similar tasks with enough frequency to provide adequate statistics to fully evaluate further.
- Data capture to be robust, error free and repeatable.
- Empirical data is required to analyse;
  - Measure, trend, monitor
  - Take action at the appropriate alert level

Goal is in time to transition from a Risk Based, to truly Condition Based maintenance regime.

Getting It Right

What Do You Need to Do…

- **Always operate cranes within the safe operating design limits – sounds simple…**
  - Human behaviours – Crane Operator
  - Perceived job pressures
  - External factors - wind speed, radius vs load, sea - states etc.

Getting It Right

- **Keep fabric maintenance in good shape**
  - Maintain the basic structure.
  - If it's painted, it won't (or shouldn't) corrode.
- **Load Path – Mechanical Drive Train**
  - Ropes / Winches / Gearboxes / Pumps / Motors / Hooks / Prime mover
- **Reliable Control System & Limits**
  - Pneumatic, hydraulic, electrical-electronic
- **Record Keeping**
  - Avoid execution of maintenance by 'tick-box'.

Getting It Right

- **Limits – Don't always assume they work…**
  - HSE Bulletin: **ED 1-2016** (Crane Safety Systems) 17 November 2016.
  - Alert to remind Duty Holders of the requirement to have measures in place to verify the correct operation and the correct settings of all safety systems and limits on offshore cranes.
  - Two incidents have recently occurred on offshore pedestal cranes when the crane boom upper hoist limit systems have failed to prevent the crane booms from being hoisted up too far and against the boom backstops. The continued hoisting resulted eventual catastrophic failure of the booms.

Case Study

Response to HSE Bulletin: ED 1-2016 (Crane Safety Systems)

- Prepared a Cause & Effect Matrix for each crane.
- Determine the parameters and functionality of all OEM operational limits;
  - Boom / Load Hoist (raise & lower)
  - Ultimate
- Prove all functions by testing or suitable simulation method.
- Expanded analysis to included emergency / safety systems;
  - AOPS (GOP)
  - Constant Tension (CT)
  - Emergency Functions (Hoist/Boom/Slew)
  - Low Boost Pressure
  - Engine safety devices

Case Study

Crane Manf : **Stothert & Pitt**
Crane Model : **OS100**
Platform : **ABCD**
Revision R00 **15/02/2017**

Cause / Effect

IDENT. No.	CAUSE	COMMENT	PROCEDURE REF	EFFECT	Warning horn sounds outside cab	Warning horn sounds in cab	Warning whistle sounds in cab	Visual alarm on annunciator	Alarm stops at limit	Hoist winch stops (pumps centred & brakes applied)	Hoist winch (lowering) available	Hoist winch (raise) available	AGOP ram extends/boom lowers, then ram retracts	AGOP load release cylinders triggered	AGOP / CT Reduced hoist rope tension	AGOP / CT Hoist brakes automatically released	AGOP / CT Hoist motors switched into hi	Boom speed reduction (Hyd ran	Boom winch stops (pu	Boom (loweri	Boo
1	**LIMITS**																				
1.1	Hoist raise pre-limit warning (250) activated	(~6m below boom tip) note 1					x	x													
1.2	Hoist raise limit (253) activated - 3 fall (Foot pedal o/ride)	(~5m below boom tip) note 1							x	x	x										
1.3	Hoist raise limit (251) activated - 1 fall (no o/ride)	~2.5m below boom tip 1-fall							x	x	x										
1.4	Ultimate hoist raise limit	Not fitted																			
1.5	Hoist lower pre-limit warning (255) activated	9 coils - Note 3					x	x													
1.6	Hoist lower limit (256) activated	6 coils - Note 3							x	x		x									
1.7	Hoist winch slack rope detection	Not fitted																			
1.8	Boom minimum radius approach (23) - speed reduction	~70^0 (Speed slows to ~10%)																x			
1.9	Boom minimum radius pre-limit warning (258) activated	~75^0 (15m, 1 fall)					x	x													
1.10	Boom minimum radius limit (260) activated	81^0 (10.4m, 1 fall) - note 2							x										x	x	
1.11	Boom ultimate minimum radius limit (257) activated * note5	81.5^0 (10.1m, 1 fall) no o/ride																	x	x	
1.12	Boom maximum radius warning limit activated						x	x													
1.13	Boom maximum radius limit activated (no override)								x										x		x
1.14	110% overload boom out inhibit (239) activated	Solenoid on Mipeg (note 4)			x						x	x							x		x
1.15	Slew limit activated	Not fitted																			
2	**EMERGENCY / SAFETY SYSTEMS**																				
2.1	Automatic Gross Overload Protection (AGOP) stage 1	Main ram extends											x								
2.2	AGOP - stage 2	Load release												x	x	x	x				
2.3	Manual Overload Protection System (MOPS)	Not fitted																			
2.4	Constant Tension (CT) System selected	1-fall only & min 4 Te load													x	x	x				
2.5	Emergency Load Lowering system	Procedure available																			
2.6	Emergency Boom Lowering system	Not available																			
2.7	Emergency Slewing system	Procedure available																			

Crane Condition Reports

Compliance Inspections

- A structured approach to check and validate the crane condition and the effectiveness of maintenance being conducted.
- Experienced Crane Inspection Engineers.
- Validation of legislative examinations and compliance.
- Auditable process to demonstrate risk management.

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