Reliability Centered Maintenance: Applying an Aviation Philosophy to Oil & Gas

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Introduction

From: Northern Ireland, UK
Studied: MEng Electronic Engineering

Work:
10+ years with Schlumberger in 4 countries
Operations, Engineering, Management, Maintenance

RCM trained since 2014
Reliability Maintenance and Managing Risk Conference 2019

A Brief History of Maintenance
- Corrective
- Preventive
- Third Generation

The Aviation Industry
- Reliability Study
- Interesting Findings
- Introduction of RCM

What is MWD?
- Theory of Operation
- Reliability Matters

Performing an RCM study
- Preparation
- Selecting the Team
- Holding the Event

The Results
- Implementation
- The Successes
- Conclusion
A brief history of Maintenance

• Pre-WW2: **CORRECTIVE MAINTENANCE**

  - **Prevention of equipment failures was low priority**
  - **Equipment was simple and easy to repair**
  - **Lower skills required; labor readily available**

  - Industry not very highly mechanized; Downtime did not matter as much
  - Customers had to be patient!!

  "**FIX IT WHEN IT BREAKS**"
A brief history of Maintenance

- **WW2-1960’s: PREVENTIVE MAINTENANCE**

  **Machines were numerous and becoming more complex**
  **Industry began to depend on machines → the consequences of failure became greater**
  **Downtime came into sharper focus.**
  **Idea: Equipment failures could and should be prevented!!**

1950’s

- Wartime pressures increased demand for goods; Supply of industrial manpower dropped sharply; Increased mechanization

1960’s

- PM consisted of equipment overhauls done at fixed intervals; Cost of maintenance rising sharply relative to other operating costs

“**FIX IT BEFORE IT BREAKS!!**”
A brief history of Maintenance

• 1970’s onwards: THIRD GENERATION MAINTENANCE

New Expectations:
• Asset availability
• Reliability
• Safety
• Product quality
• Environment
• Equipment life
• Cost

New Research:
• 6 patterns of Failure*

New Techniques:
• Decision Support Tools (FMEA)
• Condition monitoring
• Considering Reliability & Maintainability from the design stage

“FIX IT AT THE RIGHT TIME”
What about the Aviation Industry?

1950’s

1958: Maintenance must be more scientifically designed. Federal Aviation Act passed: specify WHAT tasks, but also WHY

A high proportion of crashes were caused by equipment failure

Airline industry expanding → expansion threatened by reliability record

1960’s

1960: Maintenance must be more scientifically designed.

Assumed “Right Age” Model was correct

Resnikoff Conundrum: in order to collect failure data, there must be equipment failures

Reliability was not improving and the FAA was becoming more and more concerned

1975

DOD contracted United Airlines to document criteria for efficient scheduled maintenance...

FAA/Industry Reliability Program
- $100m study
- Operators, Maintainers, Manufacturers, Regulators
- Objective: explore the relationship between equipment age and reliability

RCM was born
Historical belief: there is a “right age” at which maintenance is necessary to ensure future reliability.

What if this assumption is wrong??
The studies proved that the fundamental assumption of design engineers and maintenance was wrong in nearly every specific example in a complex modern jet airliner.

It is very important to understand the failure pattern of your asset to avoid performing potentially harmful maintenance.

So, what were the findings?

The 6 patterns of Failure:
- Bathtub: 4%
- Life: 2%
- Increasing: 5%
- Honeymoon: 7%
- Random: 14%
- Infant: 68%
How is it going for Aviation?

Accident Rates and Onboard Fatalities by Year
Worldwide Commercial Jet Fleet, 1959-2014

Fatality rate in 1958:
60 per million take-offs
DC-8: 4 million man-hrs maintenance

Fatality rate in 1998:
1 in 30 million take-offs
747: 66,000 man-hrs maintenance

There is a process for implementing successful RCM practices…

…Let’s first turn our attention to the Oil & Gas Industry
What is MWD?

Logging While Drilling (MWD) Tool

Measurements While Drilling (MWD) Tool

Directional Drilling Tool

Modulator/Pulser

Power System (batteries, turbine)

Control Electronics

Gamma Ray Sensors & Electronics

Directional Sensors & Electronics
Why is MWD Reliability Important?

SAFETY
Anti-collision

LEGAL
Prevent crossing lease-lines, boundaries, or borders

FINANCIAL
Hit the Target to maximize production

BUSINESS
Reputation, Revenue

Consequences of Failure
Preparation is Key!

Before the RCM Study, perform a “Data Mine” to gather information

Types of Data:
- Current Maintenance procedures and triggers
- Operational reliability metrics
- Common failure modes, Pareto charts*
- Manufacturing FPY
- Activity
- Fleet size
- Locations
- Performance at high temperature
- Sales, including M&S
- Comparisons to similar products
- Functional block diagram of product*

*Keep some of this info posted on wall during Workshop
What is this data used for?

- To measure the current performance – reliability, efficiency
- To understand the failure modes
- To identify the biggest potential impacts
- To determine how the product is used/operated/maintained
- To choose team members
- To focus RCM Workshop

Runs by Temperature Range

<table>
<thead>
<tr>
<th>Temperature Range (degC)</th>
<th>Runs</th>
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<tbody>
<tr>
<td>-20-10</td>
<td>10%</td>
</tr>
<tr>
<td>10-20</td>
<td>27%</td>
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<tr>
<td>20-40</td>
<td>26%</td>
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<tr>
<td>40-60</td>
<td>17%</td>
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<tr>
<td>60-80</td>
<td>9%</td>
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<tr>
<td>80-100</td>
<td>8%</td>
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<td>100-120</td>
<td>2%</td>
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<td>0%</td>
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<tr>
<td>140-160</td>
<td>0%</td>
</tr>
<tr>
<td>160-180</td>
<td>0%</td>
</tr>
<tr>
<td>180-200</td>
<td>0%</td>
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</tbody>
</table>

~80% runs <100C
4% runs >135C

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Activity by location

- NAL 62%
- MEA 17%
- SAM 11%
- ASA 4%
- EAF 6%

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Preparation is Key!
Selecting the Team

Why choose a diverse team?
- For a complete knowledge set

Tips for a successful workshop:
- Choose the right personalities
- Energetic, motivated facilitator
- Team building activities
- Hold the event at an outside venue to remove distractions

RCM Workshop Team:
- 1 Facilitator (outsider?)
- Varied Functions: Maintenance, Engineering, Service Quality, Operations Support, Experts
- Varied Disciplines: Electrical, Mechanical, Reliability, Maintenance
- Varied Locations: USA, Australia
The 7 Questions

**RCM:** a process to determine what must be done to ensure an asset continues to do what its users want it to do in its present operating context

1. Functions
2. Functional Failures
3. Failure Mechanisms
4. Failure Effects
5. Criticality/Consequences
6. Task: Predict or Prevent?
7. Task: Alternative?

Similar to a traditional FMEA
1. Functions
   - Determine what the users want it to do, & ensure it can do that!
   - List primary & secondary functions.

2. Functional Failures
   - What constitutes a failure (partial, total)?

3. Failure Modes / Mechanisms
   - Why did it fail to function or operate?

4. Failure Effects
   - How did this failure affect the product locally/at system level?

5. Criticality / Consequences
   - How much does this failure matter?

6. Task: Predict or Prevent?
   - Is it possible (or worthwhile) to try to predict or prevent this failure?

7. Task: Alternative?
   - If not, what else can we do (if anything) about this failure?
## The Workshop

<table>
<thead>
<tr>
<th>WEEK 1</th>
<th>DAY</th>
<th>TIME</th>
<th>AGENDA</th>
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<tbody>
<tr>
<td>Day 1-3</td>
<td>Mon - Wed AM</td>
<td>Introduction &amp; L1 Course for Field participants</td>
<td></td>
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<tr>
<td>Day 3</td>
<td>Wed PM</td>
<td></td>
<td>Review Operating Context and Functions</td>
</tr>
<tr>
<td>Day 3</td>
<td><strong>Wed evening</strong></td>
<td></td>
<td>Course Participants Team Dinner (with Management)</td>
</tr>
<tr>
<td>Day 4</td>
<td>Thurs AM</td>
<td></td>
<td>Review of Data Harvest</td>
</tr>
<tr>
<td>Day 4-6</td>
<td>Thurs PM - Fri</td>
<td></td>
<td>Failure Modes, Effects,</td>
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<table>
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<tr>
<th>WEEK 2</th>
<th>DAY</th>
<th>TIME</th>
<th>AGENDA</th>
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</thead>
<tbody>
<tr>
<td>Day 6</td>
<td>Mon AM</td>
<td></td>
<td>Failure Modes, Effects, continued</td>
</tr>
<tr>
<td>Day 6-8</td>
<td>Mon PM - Wed</td>
<td></td>
<td>Consequences and Failure Management Policies</td>
</tr>
<tr>
<td>Day 8</td>
<td><strong>Wed evening</strong></td>
<td></td>
<td>Course Participants Team Dinner</td>
</tr>
<tr>
<td>Day 9</td>
<td>Thurs</td>
<td></td>
<td>Consolidation, Criticality, &amp; Estimated Timescales. Review of Implementation Challenges.</td>
</tr>
<tr>
<td>Day 10</td>
<td>Fri</td>
<td></td>
<td>Review, Create Draft Summary, Present Draft Summary to Managers @3pm</td>
</tr>
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The Outcome

25 Functions with 36 Failure modes

216 Unique Failure Mechanisms

102 Tasks $\rightarrow$ Combined to 74

Internal Review: 11 Tasks rejected $\rightarrow$ 63 Actions to be completed

Presented to Upper Management for Approval

Count of Actions by Responsible Team

- Service Quality/Reliability: 27%
- Electrical, Mechanical, Firmware Engineering: 16%
- Documentation: 11%
- Surface Systems Team: 9%
- Operations Support Team: 8%
- Sustaining: Investigation: 8%
- Maintenance: 7%
- Operations: 3%
- Engineering, Manufacturing, Supply Chain: 3%
- Sales, Marketing, Customer Support: 2%
Create the Action Plan with:

- Assigned responsible person
- Target completion dates
- Estimated efforts/resources required
- Use major project milestones to keep project on track
- Track your progress
- Monitor your metrics for motivation
Reliability Maintenance and Managing Risk Conference 2019

The Success: Reliability

Design: O-rings
- $962k
- NO failures on new parts in field testing

Human: Maintenance & Field SWIs, Operating Guidelines
- Reduced Workshop errors by 85% and Field errors by 60% from 2014-2015!

Operations: Downhole Filter Sub
- Debris #1 failure mode for Pulser:
- Reduced failures by 72% from 2014-2015!

Design: Data Display
- Visual use of recorder data to help determine root cause of failures and hence reduce NFFs
The Success: Reliability

- RCM Workshop takes place in Katy TX, 22 Sep - 3 Oct 2014.
- Sep 2014 Reliability
- January 2016 Reliability: Increased by 53%!
The Success: Cost Reduction

Maintenance: Condition-based Maintenance

SL1 – environmental triggers rather than pump hours. Field Test showed a 67% reduction in SL1s, no failures.

Global Savings: $4.6m

Maintenance: Streamlined Prescribed Maintenance

- ~20 steps cut from Pulser SLs – saving 60 minutes per SL1 ($220k labor)
- Replaced invasive Calibration Test with Gamma Verification test (50% time reduction)
- SL2 trigger hours extended from 500 to 1500 hrs for Electronics
- Redundant checks removed

Maintenance: Wear Criteria

Extend the wear limits of frequently replaced mechanical parts to reduce cost.

Savings during Field Test: $95k
The Success: Cost Reduction

Monthly Cost of Service Delivery Trend

- RCM Workshop takes place in Katy TX, 22 Sep - 3 Oct 2014.
- Anomalies due to Business Climate
- January COSD: Reduced by 50%!
- September COSD

Cost of Service Delivery
Summary

- History of Maintenance
- RCM & the 7 Questions
- Key tips & tricks for a successful RCM

Understand the failure pattern of your asset & the biggest failure modes

Preparation is key: Gather your data! Post important data on the wall
Choose your team & venue carefully
Define the Criticality rankings beforehand
Creating the Action Plan is just the beginning – keep the commitment for the implementation by tracking the wins
More Information

- Reliability-Centered Maintenance; F.S. Nolan et al, United Airlines, 1978
- MIL-STD-3034, RELIABILITY-CENTERED MAINTENANCE (RCM) PROCESS, Department of Defense, 2011
Contact Information

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Thank you!

Questions?