500 centrifugal pump failures prevented using new prevention strategy

Bladimir Gomez
Supervisor,
Rotating Equipment Engineering
PDVSA CRP Refinery
Bladimir Gómez, MBA, ME - Bladimir is the Superintendent of Rotating Equipment Engineering at the PDVSA CRP Refinery Complex with 12 years of experience providing expertise for all rotating equipment from new specifications, to troubleshooting, and repair strategies.

Bladimir has a Mechanical Engineer degree and an MBA with focus on management of quality and productivity from Francisco de Miranda University, Venezuela.
The Problem

In a major refinery there was excessive failures of centrifugal pumps, that cost the company millions of dollars every year.

A new failure prevention strategy was developed to reduce the high cost of failures.
Centrifugal Pumps Failures and Repair Costs for 2011-2012

- Failures: 1056 in 2011, 1168 in 2012
- Repair Cost: 6,336,000.00 in 2011, 7,008,000.00 in 2012
Centrifugal Pumps Failure by Component

- Mechanical Seals: 60%
- Bearings: 22%
- Shaft: 8%
- Wear rings: 8%
- Couplings: 2%

Legend:
- Mechanical Seals
- Bearings
- Shaft
- Wear rings
- Couplings
Centrifugal Pump Failure Causes

- Improper operation: 45%
- Off-design: 24%
- Assembly or installation defects: 14%
- Maintenance deficiencies: 17%

Diagram showing the percentage of failure causes for centrifugal pumps.
ELEMENTS OF THE NEW STRATEGY (The Solution)

• A New Definition of Failure
• Use of Failure Progression Model
• Development of Three Levels of Inspections
The oil and gas industry defines failure using the Potential-Functional (P-F) Failure Curve. The notion is that a piece of equipment, at some point in time, will begin to exhibit decreased performance. This is labeled the Potential Failure. If allowed to progress, the performance will continue to decrease until the point of Functional Failure.
New Definition of Failure

The new definition of failure is the point of Potential Failure.

This is a paradigm shift in thinking and creates an entirely new approach to preventing failures. We designed inspection programs to identify the Conditions, Factors, Errors, and Violations which cause the Events that lead to the Potential Failures.
The Failure Progression Model

Contributing Factors that Influence Human Performance

1. Process deviations
2. Human interactions
The Top Twelve Contributing Factors

1. Miscommunication
2. Complacency
3. Distraction
4. Pressure
5. Resource Allocation
6. Lack of knowledge
7. Lack of awareness
8. Stress
9. Fatigue
10. Lack of assertiveness
11. Lack of teamwork
12. Norms [normalization of deviance]

The Dirty Dozen

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PREVENT FAILURES

Behavior Management
Level III Behavior Inspections

Process Management
Level II Process Inspections

Asset Management
Level I Equipment Inspections
 Contributing Factors that Influence Human Performance

1. Process deviations
2. Human interactions
### Strategies Comparison (Before and After)

<table>
<thead>
<tr>
<th>Traditional Predictive Inspection</th>
<th>New failure Prevention Method</th>
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</thead>
<tbody>
<tr>
<td>Defined routes focus on detection of failures (stressed equipment)</td>
<td>Defined routes focus on stressed equipments, process events(*) and human error and/or violations</td>
</tr>
<tr>
<td>Report Anomalies</td>
<td>Report preventions</td>
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<tr>
<td>Activity done by the Predictive Inspector</td>
<td>Activity done by the unit team (Inspector, Engineers, Operators and PM personnel)</td>
</tr>
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<td>Use of conventional hardware, such as vibration portable data collectors, infrared thermometers, process monitoring and instrumentation systems.</td>
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Example: Mechanical seal failure prevention on a BB2 type centrifugal pump of a Cat Cracker Unit

API Pump type BB2

API Seal Code C2A3C54
Inpection strategy:

**Level 1 Inspections (Asset Management)**
Vibration monitoring – Rotating equipment inspector
Inpection strategy:

**Level 2 Inspection (Process Management)**

- Seal gland temperature – Plant Operator
- Oil temperature / outlet API Plan – Plant Operator
- Reservoir pressure – Plant Operator
Inpection strategy:

Level 3 Inspections (Behavior Management)
Contributing factors – Rotating equipment engineer
Mechanical Seal Conditions - API Plan 54 - Level 2 Inspection

- API Plan 54
- Level 2 Inspection

vs. inspection events

Oil Temperature (F)
Mechanical Seal Conditions - API Plan 54 - Level 2 Inspection

- Gland temperature
- Oil Outlet temperature
- Oil Inlet temperature

Each vs. inspection events
Inspection Results:

**Level 1 inspections analysis:** Vibration levels normal, no leaks at seal.

**Level 2 Inspections analysis:** Oil flow reduction across the system caused by problems with the flow regulation valve, determined by the level 2 inspections (IOW)

**Level 3 inspection analysis:** Miscommunication
**Actions Following Inspections**

**Risk assessment: High**

The monitoring of the flow regulation valve was not included in the existing Preventive Maintenance Program.

**Actions:**

- Replace flow regulation valve, include valve monitoring in the PM program and communicate to the personnel (training).

- Review of the rest of the API Plan 54 applications at the plant and check for the flow regulation valve monitoring.
Mechanical Seal Conditions - API Plan 54 - Level 2 Inspection

- vs. inspection events

Oil Temperature (F)
Mechanical Seal Conditions - API Plan 54 - Level 2 Inspection

- Gland temperature
- Oil Outlet temperature
- Oil Inlet temperature

Each vs. inspection events
Conclusion:

By expanding the inspections to the process conditions and contributing factors that occur prior to the potential failure, the equipment failure is prevented.

The three levels of inspection were applied to 4000+ centrifugal pumps in the refinery.

This resulted in a reduction of over 500 pump failures over two years of implementation, with savings of 4MM$.

No additional cost or resources were required.

To prevent failures, must reduce the contributing factors.
Centrifugal Pumps Failures and Repair Costs for 2011-2014
To prevent failures, one must reduce the contributing factors.