RELIABILITY IMPROVEMENT AT PETROTRIN REFINERY – PUMPS AT NO. 8 CDU. 1997 to 2003

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Problem – To Improve Pump Reliability on Twelve Bad Actors

- Mean Time Between Overhauls (MTBO) was low at 13 months for pumps and 6 months for turbines (shop overhauls only).
- Plant production was occasionally disrupted by turbine breakdowns.
- Maintenance cost was high at US$ 9,380 per pump p.a. average.
Survey the maintenance records and cost data in the CMMS (1997 & 1998) and the SAP (1999 – 2000) for the 49 pumps at No. 8 CDU. Look for the pumps with the worst record.

Preliminary definition: “Bad actor” - any pump handling hydrocarbons with MTBO < 24 months or maintenance cost > US$ 7936 (TT$ 50,000) p.a. or MTBO < 15 months regardless of cost. Preliminary number of bad actors - 17.

Five pumps within the MTBO and cost criteria above were improved purely by quality assurance repairs without any engineering upgrade.

Final definition: “Bad actor” - any pump which must require some engineering upgrade to improve the above. Hence, final number of bad actors - 12.
IDENTIFY THE BAD ACTORS

Survey Maintenance Records, CMMS and SAP for all 49 Pumps over 1997 - 2000

ANNUAL

<table>
<thead>
<tr>
<th>MTBO (months)</th>
<th>M’TCE COSTS (US $,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 24</td>
<td>&lt; 7.9</td>
</tr>
<tr>
<td>&lt; 24 OR</td>
<td>&gt; 7.9</td>
</tr>
<tr>
<td>&lt; 15</td>
<td>Regardless of cost</td>
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</tbody>
</table>

For the 17 Bad Actors

Can Q.A. repair improve?

YES – 5 Bad Actors resolved.

NO – 12 Bad Actors require:

1. Failure Analysis whenever dismantling/repairs are done.

2. Engineering upgrade to resolve.
ANALYSIS METHOD

For all major incidents e.g. fire or equipment destruction, appoint a multi-disciplinary team to investigate and develop a detailed report.

For routine failures on the bad actors, the mechanical engineer should carry out a failure analysis.

The engineer obtains advice as required from other members of his asset team (Process Engineer, Operations Superintendent, Maintenance Supervisor, etc).
STEPS IN PROBLEM SOLVING – PROCESS RELATED

What were the process conditions? Adverse conditions will wreck mechanical seals.

Check suction tank for low level – problem!!

Is NPSHA less than NPSHR? – problem!!

Are there light ends in the liquid? Even small amounts can create havoc!!

Compare actual operating conditions vs design conditions.

These causes affected one pump (TT-2407) seriously and contributed to problems on three others (TT-3100/01/58).
Examine machine before, during/after dismantling.

- Identify all damaged/worn parts and parts with highest frequency of failure.
- Identify parts likely to be associated with the root cause – packing/sleeves, mechanical seals (faces and o-rings) and bearings/cooling systems.
- Reconcile with previous historical findings and other steps in problem solving (slides 6, 8, 9)
- Establish a pattern/mechanism of failure.
- In developing a solution, dovetail - obtain inputs from other departments and seek out a solution which addresses other problems as well.
STEPS IN PROBLEM SOLVING – RELATED TO EQUIPMENT DESIGN

Compare design of existing pump/turbine (40 years old) to modern design built to API standards.

Particularly, look for design issues which lead to bearing overheating. Also, how is the bearing mounted to the shaft? (refer to slide 13). Check for fretting & looseness of parts.

These causes affected four pumps (TT-3134/36/38/40) and twelve turbines seriously.

Can redesign be done in-house or should it be referred to the OEM?

Or should a new pump/turbine be bought?
Examine seal faces and o-rings. Check for cracked/worn faces and embrittled o-rings. 40 year old seal designs (stellite vs carbon faces) were suffering rapid wear/overheating. These causes affected 2 LPG pumps (TT-3100/01) and a gasoline pump (TT-3158).

On packed pumps, check for rapid grooving of sleeves. These causes affected 4 pumps (TT-3118/20/46/50). Cost of leakage – US$4,000. per pump p.a.
# STEPS IN PROBLEM SOLVING

<table>
<thead>
<tr>
<th>Process Related</th>
<th>Related To Shaft seal Design</th>
<th>Related To Equipment Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Presence of light hydrocarbons.</td>
<td>3. Replacement of Seals.</td>
<td>3. Redesign - In-house or OEM or Replacement of equipment.</td>
</tr>
<tr>
<td>4. Compare Operating vs. Design conditions.</td>
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</tbody>
</table>
RECOMMENDATIONS – PROCESS & SHAFT SEAL DESIGN

- At low suction pressure (2 psig), switch to another supply tank in order to avert onset of pump cavitation.

- For 4 pumps with packed glands, fit new mechanical seals (Silicon carbide vs carbon faces, alloy 718 bellows).

- For 2 LPG pumps and a gasoline pump, replace old seals by new tandem seals with outer seal in standby mode at atmospheric pressure. Multi-port flush. (Silicon carbide vs carbon faces - spring loaded).

- STATUS - All above completed except for the gasoline pump.
RECOMMENDATIONS – EQUIPMENT DESIGN

Replace 12 turbines (40 years old) by new machines (API-611). Design new turbines to consume excess LP (65 psig) steam instead of 450 psig steam.

STATUS – Completed.

OPTION CONSIDERED – upgrade of old turbines by the OEM is technically sound but the cost is about the same as for a new turbine.

Upgrade bearing/shaft design on 4 pumps to eliminate the adaptor which fitted as a sleeve between the radial ball bearing and the shaft.

Refer to slide 13. STATUS – 2 pumps completed.

OPTION CONSIDERED – Purchase of upgraded pump from the OEM is technically sound but the cost is much higher.
EXAMPLE OF EQUIPMENT REDESIGN
UPGRADE OF PUMP BEARING/SHAFT

OLD DESIGN

MODIFIED DESIGN

NOTE: SHAFT WITH ENLARGED BEARING
SEAT. ADAPTOR SLEEVE ELIMINATED.
BEARING HOUSING IS THE SAME
<table>
<thead>
<tr>
<th>TT NO.</th>
<th>SERVICE</th>
<th>MTBO (MONTHS)</th>
<th>MTCE COSTS TT$, 000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JAN '97 - AUG '00</td>
<td>SEPT '00 - AUG '03</td>
<td>1999</td>
</tr>
<tr>
<td>2407</td>
<td>Charge Booster West</td>
<td>11</td>
<td>36</td>
</tr>
<tr>
<td>3140</td>
<td>Heater Charge North</td>
<td>22</td>
<td>36</td>
</tr>
<tr>
<td>3138</td>
<td>Common Spare for Cold Crude Charge/Heater Charge</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td>3136</td>
<td>Cold Crude Charge South</td>
<td>14.7</td>
<td>36</td>
</tr>
<tr>
<td>3134</td>
<td>Cold Crude Charge North</td>
<td>14.7</td>
<td>36</td>
</tr>
<tr>
<td>3120</td>
<td>Reduced Crude South</td>
<td>14.7</td>
<td>36</td>
</tr>
<tr>
<td>3118</td>
<td>Reduced Crude North</td>
<td>14.7</td>
<td>36</td>
</tr>
<tr>
<td>3150</td>
<td>Kerosene to Storage South</td>
<td>14.7</td>
<td>36</td>
</tr>
<tr>
<td>3146</td>
<td>Light Gas Oil South</td>
<td>11</td>
<td>36</td>
</tr>
<tr>
<td>3158</td>
<td>Common Spare for Splitter Charge/Main Reflux</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>3100</td>
<td>Depropaniser Reflux North</td>
<td>4.4</td>
<td>* 12</td>
</tr>
<tr>
<td>3101</td>
<td>Depropaniser Reflux South</td>
<td>5.5</td>
<td>* 12</td>
</tr>
</tbody>
</table>

**AVERAGE MTBO**

13.4 MTHS  29 MTHS

**AVERAGE MAINTENANCE COST PER PUMP US$,000**

9.38  10.52  6.34  3.97

**INCULDE FOR INFLATION, 5% P.A. US$,000**

10.88  11.57  6.66  3.97

* Overhauls were done early in the period. Since then, MTBO has improved to over 24 months.
Results - Reduced Maintenance Costs For No. 8 CDU.
Average Cost Per Pump

<table>
<thead>
<tr>
<th>Year</th>
<th>bad actors - Qty 12</th>
<th>all pumps - Qty 49</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>8.0</td>
<td>4.0</td>
</tr>
<tr>
<td>2000</td>
<td>10.0</td>
<td>5.0</td>
</tr>
<tr>
<td>2001</td>
<td>6.0</td>
<td>3.0</td>
</tr>
<tr>
<td>2002</td>
<td>4.0</td>
<td>2.0</td>
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</table>
Obsolete Turbine
Barrier Tank on LPG Pump
Charge Pump TT-3140
Section of No. 8 CDU