TITLE:

Reliability Improvement of End Suction Pump in Severe Service through Engineered Component Upgrade

ABSTRACT:

An end suction pump for amine service at an Ammonia plant was successfully upgraded by improvement of its components.

Two 290 kW (390 HP) pumps, turbine/motor driven, rated for 262 m³/hr (1,153 gpm) and 271 m (889 ft), operate in severe service conditions due low NPSHA and part-load operation. The equipment exhibited rough operation with high vibration and an elevated repair frequency by recurrent fatigue failure of shaft, severe wear ring rubs, impeller corrosion/erosion, mechanical seal leakage and bearing damages..

After a catastrophic failure, involving pump and electric motor, that caused an emergency plant shutdown, an upgrade for the pumps was engineered. The objective was to overcome design weaknesses and incorporate features to increase reliability. Impeller deficiencies were identified and corrected and its metallurgy improved to endure severe cavitation/recirculation damage. The power end was completely redesigned, incorporating larger shaft and bearing housing stiffness, together with a material upgrade, oversized bearings and lubrication enhancements.

As a result, a failure frequency as large as 9 a year has been eliminated since the upgrade and the pump presently accumulates 3 years of continuous operation. An outstanding improvement in reliability was obtained together with considerable savings in investment & maintenance costs.

AUTHOR:

César A. Morales Casanova
Rotating Equipment Specialist
PDVSA – Pequiven
Morón Petrochemical Complex
Edo. Carabobo
Venezuela
RELIABILITY IMPROVEMENT OF END SUCTION PUMP IN SEVERE SERVICE THROUGH ENGINEERED COMPONENT UPGRADE

César A. Morales Casanova
Rotating Equipment Specialist
PDVSA - Pequiven
Edo. Carabobo - Venezuela
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• Objective
• Conditions of service – Amine recovery system
• Pump failures
  Experience of continued low reliability
  Problem areas – Original design
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  Catastrophic failure – 1998
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• Problem analysis
  Factors associated to low reliability
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  Objectives
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  Summary of main improvements
• Upgraded pump test
  Objectives
  Results of performance testing
  Test conclusions
• Upgrade results
  Cost – lead time comparison
  Current upgrade progress – end 2002
  Reliability improvement
• Conclusions
• Lessons learned
• References
A successful experience of reliability improvement of two process pumps, through the application of a cost-effective, “in-house” engineered component upgrade is presented.

The solution can be used as a reference to yield better mechanical performance of existing equipment in similar services.
**SITUATION OVERVIEW**

**PUMP RATINGS:**

- **Q:** 262 m³/hr (1,153 GPM)
- **H:** 271 m (889 ft)
- **N:** 3550 RPM
- **P:** 290 kW (390 HP)

**MAIN PUMP “A”**
- Turbine Driven

**STAND-BY PUMP “B”**
- Motor Driven

**AMINE RECOVERY SERVICE**
PUMP FAILURES

EXPERIENCE OF CONTINUED LOW RELIABILITY

OPERATION PROBLEMS:
- High Vibration
- Low Capacity
- Product Leakage

FAILED COMPONENTS:
- Impeller
- Wear Rings
- Shaft
- Bearings
- Mechanical Seal
PUMP FAILURES

PROBLEM AREAS - ORIGINAL DESIGN
PUMP FAILURES

PROBLEM AREAS - ORIGINAL DESIGN

SEVERE RUBBING AT WEAR RINGS - 1996
PUMP FAILURES

PROBLEM AREAS - ORIGINAL DESIGN

SHAFT FAILURE AT IMPELLER END - 1992
PUMP FAILURES

PROBLEM AREAS - ORIGINAL DESIGN

WEAR RINGS
SHAFT
IMPELLER
PUMP FAILURES

PROBLEM AREAS - ORIGINAL DESIGN

SEVERE IMPELLER FAILURE - 1992
PUMP FAILURES

PROBLEM AREAS - ORIGINAL DESIGN

WEAR RINGS

SHAFT

IMPELLER

MECH. SEAL
PUMP FAILURES

PROBLEM AREAS - ORIGINAL DESIGN

WEAR RINGS
SHAFT
IMPELLER
MECH. SEAL
BEARINGS
# PUMP FAILURES

## REMEDIAL ACTIONS – HYSTORICAL REVIEW

<table>
<thead>
<tr>
<th>YEAR</th>
<th>COMPONENT</th>
<th>ACTION</th>
</tr>
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<tbody>
<tr>
<td>1980</td>
<td>Impeller</td>
<td>Installed pins between shrouds</td>
</tr>
<tr>
<td>1986</td>
<td>Shaft</td>
<td>Impeller capscrew replaced to fine thread</td>
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<tr>
<td>1991</td>
<td>Impeller</td>
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</tr>
<tr>
<td>1995</td>
<td>Impeller</td>
<td>Incorporation of 3 partial vanes</td>
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<td>1996</td>
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<td>1997</td>
<td>Impeller</td>
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</tr>
<tr>
<td></td>
<td>Bearings</td>
<td>5313 thrust bearing replaced by 7313</td>
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</table>
# PUMP FAILURES

## REMEDIAL ACTIONS – HISTORICAL REVIEW

<table>
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<tr>
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<tr>
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<td>Impeller</td>
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PUMP FAILURES

REMEDIAL ACTIONS – HYSTORICAL REVIEW

1980

PINS INSTALLED BETWEEN IMPELLER SHROUDS
## PUMP FAILURES

### REMEDIAL ACTIONS – HISTORICAL REVIEW

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PUMP FAILURES

REMEDIAL ACTIONS – HISTORICAL REVIEW

1986

CAPSCREW M 24
NC TO NF
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PUMP FAILURES

REMEDIAL ACTIONS – HISTORICAL REVIEW 1992

IMPELLER NUT M 38 NF

CAPSCRW M 24 NF
PUMP FAILURES

REMEDIAL ACTIONS – HISTORICAL REVIEW

Pump “B”

SHAFT FAILURE AT IMPELLER END - MAY 1999
## PUMP FAILURES

### REMEDIAL ACTIONS – HISTORICAL REVIEW

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<td>Incorporation of 3 partial vanes</td>
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</table>
PUMP FAILURES

REMEDIAL ACTIONS – HISTORICAL REVIEW

1995

IMPELLER PATTERN WITH 3 PARTIAL VANES ADDED

EROSION CONTINUED
## PUMP FAILURES

### REMEDIAL ACTIONS – HISTORICAL REVIEW

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</table>
IMPELLER TRIM OF STAND-BY PUMP “B”
PUMP FAILURES

REMEDIAL ACTIONS – HYSTORICAL REVIEW

1996

IMPELLER TRIM OF STAND-BY PUMP “B”
## PUMP FAILURES

### REMEDIAL ACTIONS – HISTORICAL REVIEW

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<td>1997</td>
<td>Impeller</td>
<td>Trimming of vanes at inlet</td>
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PUMP FAILURES

REMEDIAL ACTIONS – HYSTORICAL REVIEW

VANE TRIM AT IMPELLER INLET TO REDUCE NPSHR

1997

IMPROPERLY EFFECTED
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<th>COMPONENT</th>
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<td>Bearings</td>
<td>5313 thrust bearing replaced by 7313 BG</td>
</tr>
</tbody>
</table>
PUMP FAILURES

REMEDIAL ACTIONS – HISTORICAL REVIEW

1997

THRUST BEARING UPGRADE FROM 3313 TO 7313 BG
PUMP FAILURES

CATASTROPHIC FAILURE – PUMP “B”
SEPT 1998
Unsuccessful efforts to improve reliability.

Solutions mainly focused in the consequences rather than the causes for the problems.

Improper procedures contribute to failures.

Complex problem with multiple correlated causes and failure modes.

Global solution required.
PROBLEM ANALYSIS

FACTORS ASSOCIATED TO LOW RELIABILITY

SEPTEMBER 1999

OPERATIONAL

• Low NPSHA
PROBLEM ANALYSIS

FACTORS ASSOCIATED TO LOW RELIABILITY
SUCTION CONDITIONS - 1999

PLUGGING OF PLATE COOLER

TEMP INCREASE & REDUCTION OF SUCTION PRESSURE

MEA RECOVERY SYSTEM
# Problem Analysis

## Suction Conditions - 1999

### Factors Associated to Low Reliability

<table>
<thead>
<tr>
<th></th>
<th>Design 20% MEA</th>
<th>Revised 1997 30% MEA</th>
<th>Measured 30% MEA</th>
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<tr>
<td>Fluid</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Temp [°C]</td>
<td>92</td>
<td>95 – 99</td>
<td>99</td>
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<tr>
<td>SG</td>
<td>0.965</td>
<td>1.015</td>
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<tr>
<td>VP [kg/cm² a]</td>
<td>0.78</td>
<td>1.05</td>
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<tr>
<td>Suct. Press. [kg/cm² g]</td>
<td>0.60</td>
<td>0.50</td>
<td>0.25 – 0.60</td>
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<tr>
<td>Flow [m³/hr]</td>
<td>228 – 262</td>
<td>200 – 220</td>
<td>200 – 220</td>
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<td>NPSH A [m]</td>
<td>9.00</td>
<td>4.90</td>
<td>2.45 – 5.90</td>
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<td>NPSH R [m]</td>
<td>6.50</td>
<td>4.00 ?</td>
<td>4.00 ?</td>
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<tr>
<td>NPSH Margin</td>
<td>38%</td>
<td>INSUFFICIENT</td>
<td>NONE</td>
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</table>
## PROBLEM ANALYSIS

### FACTORS ASSOCIATED TO LOW RELIABILITY SUCTION CONDITIONS - 1999

<table>
<thead>
<tr>
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<th>DESIGN</th>
<th>REVISED 1997</th>
<th>MEASURED</th>
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<tr>
<td>Fluid</td>
<td>20% MEA</td>
<td>30% MEA</td>
<td>30% MEA</td>
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<tr>
<td>Temp [°F]</td>
<td>198</td>
<td>203 – 210</td>
<td>210</td>
</tr>
<tr>
<td>SG</td>
<td>0.965</td>
<td>1.015</td>
<td></td>
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<tr>
<td>VP [psia]</td>
<td>11.1</td>
<td>14.9</td>
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<tr>
<td>Suct. Press. [psia]</td>
<td>8.5</td>
<td>7.1</td>
<td>3.5 – 8.5</td>
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<td>Flow [GPM]</td>
<td>1000 – 1153</td>
<td>880 – 970</td>
<td>880 – 970</td>
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<tr>
<td>NPSH A [ft]</td>
<td>29.5</td>
<td>16.0</td>
<td>8.0 – 19.3</td>
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<tr>
<td>NPSH MARGIN</td>
<td>38%</td>
<td>INSUFFICIENT</td>
<td>NONE</td>
</tr>
</tbody>
</table>
PROBLEM ANALYSIS

FACTORS ASSOCIATED TO LOW RELIABILITY
SEPT 1999

OPERATIONAL

• Low NPSHA
• Part load operation
PROBLEM ANALYSIS

FACTORS ASSOCIATED TO LOW RELIABILITY
PART LOAD OPERATION - 1999

EROSION & SHROUD SEPARATION

EVIDENCES OF RECIRCULATION AT DISCHARGE
PROBLEM ANALYSIS

FACTORS ASSOCIATED TO LOW RELIABILITY
SEPT 1999

OPERATIONAL

- Low NPSHA
- Part load operation
- Process disturbances (flow/pressure surges)

MAINTENANCE

- Inoperative pipe supports
  - Transmission of pipe forces
  - Excessive deflection

MAY CONTINUE
PROBLEM ANALYSIS

FACTORS ASSOCIATED TO LOW RELIABILITY
MAINTENANCE PROBLEMS - 1999

INOPERATIVE PIPE SUPPORTS
**PROBLEM ANALYSIS**

**FACTORS ASSOCIATED TO LOW RELIABILITY**

**SEPT 1999**

**OPERATIONAL**
- Low NPSHA
- Part load operation
- Process disturbances (flow/pressure surges)

**MAINTENANCE**
- Inoperative pipe supports
  - Transmission of pipe forces
  - Excessive deflection
- Improper procedures

*May continue easily corrected*
PROBLEM ANALYSIS

FACTORS ASSOCIATED TO LOW RELIABILITY

SEPT 1999

MANUFACTURING DEFICIENCIES
- Shaft (own shop)
- Impeller (local mfr)

DESIGN WEAKNESSES
- Dated 1969
- Hydraulics
- Component Stiffness
- Choice of Materials

PUMP UPGRADE
## Problem Analysis

### Correlation of Causes for Low Reliability

<table>
<thead>
<tr>
<th>MAIN CAUSES</th>
<th>IMMEDIATE EFFECTS</th>
<th>CONSEQUENCES</th>
<th>NOTICEABLE EFFECTS</th>
<th>EXPECTED FAILURE</th>
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<tbody>
<tr>
<td><strong>Operation</strong></td>
<td>Plugged Filters / Coolers</td>
<td>CAVITATION</td>
<td>IMPELLER EROSION</td>
<td>IMPELLER</td>
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<tr>
<td></td>
<td>Too low NPSHA</td>
<td>INTERNAL RECIRCULATION</td>
<td>IMBALANCE</td>
<td>WEAR RINGS</td>
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<tr>
<td></td>
<td>Part load operation</td>
<td>TURBULENCE</td>
<td>LARGE LOADS</td>
<td>SHAFT</td>
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<td>Process disturbances</td>
<td>VIBRATION</td>
<td>LARGE STRESSES</td>
<td>BEARINGS</td>
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<td><strong>Maintenance</strong></td>
<td>Inoperative pipe supports</td>
<td>INCREASE OF NPSHR</td>
<td>LARGE DEFLECTIONS</td>
<td>MECH. SEAL</td>
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<td></td>
<td>Improper wear ring materials</td>
<td>PIPE FORCES</td>
<td>SEVERE RUBS</td>
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<tr>
<td></td>
<td>Improper vane trim at inlet</td>
<td>STRESS RISERS</td>
<td>LOSS OF RUNNING CLEARANCES</td>
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<tr>
<td><strong>Manufacture</strong></td>
<td>Improper part. vane position</td>
<td>INSUFFICIENT MAT PROPERTIES</td>
<td>SHAFT FATIGUE</td>
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</tr>
<tr>
<td></td>
<td>Insufficient shaft fillet radii</td>
<td>MAT OF SIMILAR GALLING TENDENCY</td>
<td>LOSS OF FUNCTION</td>
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<td><strong>Design</strong></td>
<td>Deficiencies in hydraulics</td>
<td>VIBRATION INCREASE</td>
<td>VIBRATION</td>
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<tr>
<td></td>
<td>Insufficient stiffness</td>
<td>NOISE</td>
<td>NOISE</td>
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<td></td>
<td>Inadequate shaft end design</td>
<td>LOSS OF CAPACITY</td>
<td>LOSS OF CAPACITY</td>
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<td>Choice of materials</td>
<td>SEAL LEAKAGE</td>
<td>SEAL LEAKAGE</td>
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OBJECTIVES:

- Identify & solve design weaknesses.
- Correct component manufacturing deficiencies.
- Incorporate modifications for improved reliability.
- Withstand tough operating conditions with low NPSHA.
- Manufacture of new parts, pump refurbishment, stand testing & performance adjustment to requirements by a qualified supplier.
PUMP UPGRADE

AREAS OF ATTENTION
PUMP UPGRADE

IMPELLER IMPROVEMENT

BEFORE

AFTER

VANE CORRECTIONS
PUMP UPGRADE

IMPELLER IMPROVEMENT

VANE LEADING EDGE / MATERIAL IMPROVEMENT

MANUFACTURING MATERIAL:

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<th>NEW</th>
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<td>AISI 304</td>
<td>18Cr-16Mn</td>
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PUMP UPGRADE

AREAS OF ATTENTION

IMPELLER

WEAR RINGS
## PUMP UPGRADE

### WEAR RINGS IMPROVEMENT

### MANUFACTURING MATERIALS:

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<thead>
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<th>DESIGN</th>
<th>IN USE (1999)</th>
<th>NEW</th>
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<td></td>
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<tr>
<td>IMPELLER</td>
<td>AISI 304</td>
<td>AISI 304</td>
<td>AISI 304 + Cr. Plating</td>
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<td>Stellitted</td>
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<td>18Cr-16Mn</td>
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<tr>
<td>CASING</td>
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### WEAR RINGS MATERIALS
PUMP UPGRADE

AREAS OF ATTENTION

IMPELLER
WEAR RINGS
SHAFT
# PUMP UPGRADE

## SHAFT IMPROVEMENT

### SHAFT FLEXIBILITY COMPARISON

<table>
<thead>
<tr>
<th>API 610 Ed.</th>
<th>DESIGN (1969)</th>
<th>SAME MFR 7th</th>
<th>MFR 2 8th</th>
<th>MFR 3 8th</th>
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<tr>
<td>L [in]</td>
<td>10.91</td>
<td>12.25</td>
<td>11.25</td>
<td>11.50</td>
<td>11.18</td>
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<tr>
<td>D [in]</td>
<td>2.480</td>
<td>2.937</td>
<td>2.625</td>
<td>2.440</td>
<td>2.953</td>
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<tr>
<td>$L^3 / D^4$</td>
<td>34.3</td>
<td>24.7</td>
<td>30</td>
<td>43</td>
<td>18.4</td>
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<td>Improvement</td>
<td>–</td>
<td>39%</td>
<td>14%</td>
<td>– 20%</td>
<td>86%</td>
</tr>
</tbody>
</table>
PUMP UPGRADE

SHAFT IMPROVEMENT

MANUFACTURING MATERIAL:

<table>
<thead>
<tr>
<th>ORIGINAL</th>
<th>NEW</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISI 304</td>
<td>AISI 420</td>
</tr>
</tbody>
</table>

SHAFT END / MATERIAL IMPROVEMENT

R 5/32"
R 1/4"
R 1/32"

INCREASED TO M48x2 FROM M38x2

KEYWAY CORNER RADIUS
PUMP UPGRADE

AREAS OF ATTENTION

IMPELLER

WEAR RINGS

BEARING HOUSING

SHAFT
PUMP UPGRADE

BEARING HOUSING IMPROVEMENT

<table>
<thead>
<tr>
<th>ORIGINAL</th>
<th>NEW</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAST IRON</td>
<td>A216 WCB</td>
</tr>
</tbody>
</table>

1" NEW

5/8" ORIGINAL
PUMP UPGRADE

BEARING HOUSING IMPROVEMENT

IMPROVED BEARING HOUSING
PUMP UPGRADE

AREAS OF ATTENTION

IMPELLER

WEAR RINGS

BEARING HOUSING

BEARINGS & LUBRICATION

SHAFT
PUMP UPGRADE

BEARINGS & LUBRICATION IMPROVEMENT

6216 M
HSG BORE TOL: +0.06 / +0.04 mm
FINISH GROUND

7314 BECBM
HSG BORE TOL: +0.045 / +0.025 mm
AREAS OF ATTENTION

- Pump Upgrade
- Stuf. Box Cooling
- Bearings & Lubrication
- Impeller
- Wear Rings
- Bearing Housing
- Shaft
## PUMP UPGRADE

### SUMMARY OF MAIN IMPROVEMENTS

<table>
<thead>
<tr>
<th>Component</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IMPELLER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial Vanes</td>
<td>Mispositioned</td>
<td>Extended &amp; Corrected</td>
</tr>
<tr>
<td>Main Vanes at inlet</td>
<td>Improper Trim</td>
<td>Trimmed in pattern</td>
</tr>
<tr>
<td>Vane Leading Edges (All)</td>
<td></td>
<td>Rounded &amp; Thinned in Pattern</td>
</tr>
<tr>
<td>Material</td>
<td>AISI 304</td>
<td>18 Cr – 16 Mn</td>
</tr>
<tr>
<td><strong>WEAR RINGS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impeller / Casing</td>
<td>AISI 304 / AISI 304</td>
<td>1  AISI 304 + Cr / 18Cr-16 Mn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2  18 Cr-16 Mn / AISI 304</td>
</tr>
<tr>
<td><strong>SHAFT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3/D4</td>
<td>34.3</td>
<td>18.4</td>
</tr>
<tr>
<td>End Thread Size / Fillet Radius</td>
<td>M38 + Fill. Rad. 3/32”</td>
<td>M48 + Fillet Radius 5/32”</td>
</tr>
<tr>
<td>Radii at Shoulders / Corners</td>
<td>3/32” AT END / SHARP KW</td>
<td>1/4” AT END / 1/32” AT KW</td>
</tr>
<tr>
<td>Material</td>
<td>AISI 304</td>
<td>AISI 420</td>
</tr>
<tr>
<td><strong>BEARING HSG</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness at transition piece</td>
<td>16 mm (5/8”)</td>
<td>25 mm (1.0”)</td>
</tr>
<tr>
<td>Material</td>
<td>CAST IRON</td>
<td>CAST STEEL A216 WCB</td>
</tr>
<tr>
<td><strong>BEARINGS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radial / Thrust</td>
<td>6215 / 7313 BG</td>
<td>6216 M / 7314 BGM</td>
</tr>
<tr>
<td><strong>LUBRICATION</strong></td>
<td></td>
<td>Enhanced / Circulating</td>
</tr>
<tr>
<td><strong>MECH. SEAL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stuff. Box Cooling</td>
<td>NO</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>COUPLING</strong></td>
<td>Gear/Lubricated</td>
<td>Disc Pack / Non-Lubr.</td>
</tr>
</tbody>
</table>
UPGRADED PUMP TEST

STAND-TESTING OF UPGRADED PUMP

OBJECTIVES:

- Determine actual performance for modified impeller.
- Quantify actual NPSHR.
- Reduce effects of adverse operating conditions:
  - Trim impeller of pump “B” to reduce part load operation.
  - Rework impeller, if required, to help prevent cavitation.
- Guarantee trouble-free operation at the plant.
UPGRADED PUMP TEST

RESULTS OF PERFORMANCE TESTING

HEAD VS FLOW – FULL SIZE IMPELLER
UPGRADED PUMP TEST

RESULTS OF PERFORMANCE TESTING

PWR & EFF VS FLOW – FULL SIZE IMPELLER
UPGRADED PUMP TEST

RESULTS OF PERFORMANCE TESTING

HEAD VS FLOW – TRIMMED IMPELLER

3550 rpm φ 385 mm

3550 rpm φ 350 mm

Publ Head
Test Head

ORIGINAL RATED POINT
REVISED RATED POINT
OPERATING RANGE

Q [m³/hr]
H [m]

Q [GPM]
H [ft]
UPGRADED PUMP TEST

RESULTS OF PERFORMANCE TESTING

NPSHR 3% = 3,4 m (11 ft)

MIN REQ’D = 0,50 kgf/cm² g
(7,1 psig)

60% MARGIN

3% DROP

3550 rpm φ 350 mm

NPSHR @ 220 m³/h (970 GPM) – TRIMMED IMPELLER
UPGRADED PUMP TEST

TEST CONCLUSIONS

Performance of modified impeller was determined

Head: Larger due to partial vanes
BEP: Coincident at 300 m³/hr (1320 GPM)
Efficiency: Coincident with original
NPSHR: 15% lower than expected

Adjustments for revised conditions of service:

Pump “A”: Full-size impeller @ 3150 rpm
Pump “B”: 91% dia impeller @ 3550 rpm
Min suct. press.: 0.5 kgf/cm² g (7.1 psig)
Required NPSH Margin: 60%
UPGRADED PUMP “A”

MAIN PUMP INSTALLED SEPT 1999

PUMP IN SERVICE – MAY 2000
UPGRADED PUMP “A”

PUMP IN SERVICE – MARCH 2002

MAIN PUMP INSTALLED SEPT 1999
## UPGRADE RESULTS

### COST – LEAD TIME COMPARISON

<table>
<thead>
<tr>
<th>PROS - CONS</th>
<th>COST &amp; LEAD TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PUMP REPLACEMENT</strong></td>
<td>• ENGINEERING $3,0 K</td>
</tr>
<tr>
<td></td>
<td>• 1 PUMP &amp; DRIVER $90,0 K</td>
</tr>
<tr>
<td></td>
<td>• 2 YR SPARE PARTS $5,0 K</td>
</tr>
<tr>
<td></td>
<td>• FOUND. &amp; PIPING $10,0 K</td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL: $108 K</strong></td>
</tr>
<tr>
<td></td>
<td>11 MONTH ON SITE</td>
</tr>
<tr>
<td><strong>PUMP UPGRADE</strong></td>
<td>• ENGINEERING $5,0 K</td>
</tr>
<tr>
<td></td>
<td>• BRG HSG PATTERN $5,0 K</td>
</tr>
<tr>
<td></td>
<td>• MAIN PARTS $17,0 K</td>
</tr>
<tr>
<td></td>
<td>• MFG, ASSY &amp; TEST $12,0 K</td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL: $39 K</strong></td>
</tr>
<tr>
<td></td>
<td>11 MONTH FINISHED</td>
</tr>
</tbody>
</table>
UPGRADE RESULTS

CURRENT UPGRADE PROGRESS – END 2002

MAIN PUMP “A”

Fully upgraded

STAND-BY PUMP “B”

Partially upgraded

• Impeller & wear rings
• Shaft end design & material

Impeller size increased from 91% to 96% (370 mm)

• Flow requirement not reached
• Measured suct. press.: ≈ 0.25 kgf/cm² g (3.6 psig)
• Full cavitation, NPSH margin < 0
**UPGRADE RESULTS**

**RELIABILITY IMPROVEMENT – END 2002**

- **MAIN PUMP “A”**
  - Fully upgraded
  - No failures

- **STAND-BY PUMP “B”**
  - Partially upgraded
  - Failures at brgs & seal only

*Projected savings over 10 years: US$ 900 K*

**FAILURE HISTORY BEFORE AND AFTER THE UPGRADE**
Pump upgrade objectives were successfully achieved.

Upgrade of existing pump was the best choice for a cost-effective solution.

In-house engineering allowed a custom design with some features exceeding current mfr. specs.

Impeller revised configuration is not an optimum solution, but provided a remarkable service life improvement.

Detected design deficiencies played an important role on low reliability, but not on catastrophic failures.
LESSONS LEARNED

In general, improvement of existing equipment represents lower investment and lead time.

Check your equipment for upgrade opportunities, specially if they exhibit low reliability.
REFERENCES

RELIABILITY IMPROVEMENT OF END SUCTION PUMP IN SEVERE SERVICE
THRU ENGINEERED COMPONENT UPGRADE


- Bloch, Heinz P. *Pump Reliability Improvement Program*. Pump Failure Reduction Programs. PRIME Seminar notes


THANK YOU!