Pump Monitoring & Rebuild Program

Luz E. Penilla, Associate Engineer (Civil), Vibration Analyst: ISO Category III

BAYWORK

November 14, 2018
FY17 Results
Pump & Motor Rebuild Program – Condition Monitoring

Predictive Maintenance
Vibration Condition Ratings as of June 2017
(49 Units Surveyed)

<table>
<thead>
<tr>
<th>Condition Ratings</th>
<th>Machines Evaluated</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOOD (Low Risk)</td>
<td>36</td>
</tr>
<tr>
<td>Fair (Moderate Risk)</td>
<td>3</td>
</tr>
<tr>
<td>Alarm 1 (High Risk)</td>
<td>4</td>
</tr>
<tr>
<td>Alarm 2 (Very High Risk)</td>
<td>6</td>
</tr>
</tbody>
</table>

Pump Monitoring Report (PG. 1)
District’s Mission

Provide Silicon Valley safe, clean water for a healthy life, environment and economy
Facts About SCVWD

- 10 Dams & Reservoirs
- 114 Miles Raw & Treated Pipelines
- 3 Portable Water Treatment Plants
- 1 Recycled Water Treatment Plant
- 3 District Pump Stations

- Serves 2 million people
- 756 Employees
Pump & Motor Rebuild Program

Pump and Motor Rebuild Stages

1. RISK INDICATORS

2. GENERAL SCOPE OF WORK (SOW)

3. REBUILD PROCESS & ROLES

4. TRAINING

5. RECORDS MANAGEMENT
Data Collected for Critical Assets

- Identify critical units >50 Hp
- Data from drawings & name plate
- Bearings, HP, speed, configuration
- Stages, setting length, material, weight
- Etc.

Pump performance curves

Pump & Motor Rebuild Program

---

ANCHOR BOLT DETAIL

1. **DESCRIPTION**: ELECTRIC 1.5 x 90 DEG
2. **CONNECTION**: POMPA
3. **DRIVER PRINT FOR DIMENSIONS**: MECHANICAL SEAL
4. **DIMENSIONS ARE IN MILLIMETERS**: PUMP 1.250 x 1900
5. **MECHANICAL SEAL**: 1.00 GROUT
6. **1.250 x 1900 x 18.00**: 1.00 GROUT
7. **FOUNDATION HOLES**: 4 x 1.250 x 18.00
8. **SUPPLIED BY VENDOR**: ANCHOR BOLTS/NUTS/WASHERS
9. **GRADE 316 STAINLESS STEEL**: ANCHOR BOLTS/NUTS/WASHERS

---

**Customer Data**

- **Pump No.**
- **Motor No.**
- **RUHREPUMPEN DEALER No.**

---

**Drawing Title**: 16C277 S STAGE VTP OUTLINE

---

**Revisions**

- 

---

**REVISIONS**
RISK INDICATORS: Purpose of Vibration Monitoring

Pump & Motor Rebuild Program - Condition Monitoring

- Vibration Detects
  - Bent Shaft
  - Misalignment
  - Hydraulic Performance
  - Bearing damage
  - Electrical damage
  - Resonance
  - Mass Unbalance
  - Gear Damage
Pump & Motor Rebuild Program

Vibration Contract

Qualifications

- ISO or ANST certified vibration analyst

Scope of Work

Schedule

Minimum Requirements

Report Requirements
Data Collected

Condition Monitoring

► Vibration **Velocity** *(in/sec RMS)*

► Vibration **Acceleration** *(g’s peak-to-peak)*

► Vibration **Displacement** *(mils)*
Test Data for Assigned Risk Indicators (ARI)

Pump & Motor Rebuild Program - Condition Monitoring

- Vibration Velocity (in/sec RMS)
  - DFI = Dynamic Factor Indicator

- Vibration Acceleration (g’s peak-to-peak)
  - B = Bearing Wear Stage

\[ \text{ARI} = \sqrt{\text{DFI}^2 + B^2} \]

Standards – Motor Uncoupled

Acceptance Testing - Limits

EASA/NEMA MG-1 700

0.15 in/sec pk = 0.10 in/sec RMS

For rigid mounting, multiply 0.10 in/sec RMS by 0.8 = 0.08 in/sec RMS
Standards - Motor Test Points

Acceptance Testing

ISO 10816-3:2009(E)
Measuring points for a vertically mounted machine
Acceptance Testing - Limits

ANSI/Hydraulic Institute 9.6.4 Pump Class VS
Assigned Risk Indicator Equation

\[ ARI = \sqrt{DFI^2 + B^2} \]

- **Dynamic Factor Indicator (DFI)**
  - 1  if Vibration < HI Limit
  - 2  “      = < HI Limit
  - 3  “      = 1.5x HI Limit
  - 4  “      = 2x HI Limit
### Bearing Wear Identification

**Bearing wear stage for maximum time-waveform peak-to-peak magnitude versus shaft rotational speed**

<table>
<thead>
<tr>
<th>Revolutions per minute</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0.16</td>
<td>0.32</td>
<td>0.64</td>
<td>1.28</td>
</tr>
<tr>
<td>100</td>
<td>0.26</td>
<td>0.52</td>
<td>1.02</td>
<td>2.04</td>
</tr>
<tr>
<td>200</td>
<td>0.50</td>
<td>1.00</td>
<td>2.00</td>
<td>4.00</td>
</tr>
<tr>
<td>300</td>
<td>0.75</td>
<td>1.50</td>
<td>3.00</td>
<td>6.00</td>
</tr>
<tr>
<td>450</td>
<td>0.88</td>
<td>1.75</td>
<td>3.50</td>
<td>7.00</td>
</tr>
<tr>
<td>600</td>
<td>1.00</td>
<td>2.00</td>
<td>4.00</td>
<td>8.00</td>
</tr>
<tr>
<td>900</td>
<td>1.70</td>
<td>3.40</td>
<td>6.90</td>
<td>13.60</td>
</tr>
<tr>
<td>1200</td>
<td>2.40</td>
<td>4.80</td>
<td>9.60</td>
<td>19.20</td>
</tr>
<tr>
<td>1800</td>
<td>4.10</td>
<td>8.20</td>
<td>16.40</td>
<td>32.80</td>
</tr>
<tr>
<td>3600</td>
<td>10.20</td>
<td>20.40</td>
<td>40.80</td>
<td>81.60</td>
</tr>
<tr>
<td>7200</td>
<td>20.00</td>
<td>40.00</td>
<td>80.00</td>
<td>160.00</td>
</tr>
</tbody>
</table>

\[
\text{ARI} = \sqrt{\text{DFI}^2 + \text{B}^2}
\]

 Assigning Risk Indicator (ARI)

- \( \leq 2 = \text{Low Risk of Failure} \) (Normal)
- \( 2 > 3 = \text{Moderate Risk of Failure} \) (Next Planned Maintenance)
- \( 3 > 4 = \text{High Risk of Failure} \) (Repair in 30 Days)
- \( 4 > = \text{Very High Risk of Failure} \) (Repair Immediately)

\[ \text{ARI} = \sqrt{\text{DFI}^2 + B^2} \]

### Problem Detail Report - Reliability Services

**Predictive #17448**

Printed 12/23/2016 - 9:01 AM

<table>
<thead>
<tr>
<th>Problem:</th>
<th>Looseness/Impacting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority:</td>
<td>Trending Potential Problem</td>
</tr>
<tr>
<td>Technology:</td>
<td>Vibration</td>
</tr>
<tr>
<td>Santa Clara Valley Water District</td>
<td>Rinconada Plant</td>
</tr>
<tr>
<td>Plant Water Pump 3 RWTP (Plant Water Pump 3 RWTP)</td>
<td>Component: Pump</td>
</tr>
<tr>
<td>Fault Location:</td>
<td>Drive end Bearing</td>
</tr>
</tbody>
</table>

### Suggested Tasks

<table>
<thead>
<tr>
<th>#</th>
<th>Description</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Consider inspecting clearances at Pump case bearing location</td>
<td>Suggestion</td>
</tr>
<tr>
<td>20</td>
<td>Inspect all hold down bolts at the bearing and pump case</td>
<td>Next Scheduled Shutdown</td>
</tr>
</tbody>
</table>

### Notes

<table>
<thead>
<tr>
<th>Date</th>
<th>Initials</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/19/2016</td>
<td>WG</td>
<td>During our August survey, it was determined that this unit RPM has slowed down from our last collection. At this time we are seeing a looseness condition with impacting evident in the Pump bearings. When compared to the other Pumps, this unit has the highest amplitude of looseness in the spectrum. It could be a speed condition; however, we wouldn't want to dismiss it as such. I'd like to to continue to trend before recommending a replacement. See images below for details. Perform task when possible.</td>
</tr>
<tr>
<td>9/14/2016</td>
<td>WG</td>
<td>Pump 3 was out of service during our collection period. We will attempt to gather follow up data during our next survey.</td>
</tr>
<tr>
<td>12/22/2016</td>
<td>WL</td>
<td>We continue to see looseness and impacting in our data. Perform recommended task.</td>
</tr>
</tbody>
</table>
Looseness continues
Test

Condition Monitoring

<table>
<thead>
<tr>
<th>EQUIPMENT LOCATION</th>
<th>DESCRIPTION</th>
<th>DFI L1&lt;HI LIMIT</th>
<th>DFI L2= HI LIMIT</th>
<th>DFI L3= 1.5 X HI LIMIT</th>
<th>DFI L4 = 2.0 X HI LIMIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>RWTP</td>
<td>Plant Water pump #3</td>
<td>&lt;0.15</td>
<td>0.15</td>
<td>0.23</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Allowable pump vibration, pump types BB and OH

\[
ARI = \sqrt{DFI^2 + B^2}
\]
Test – OA Vibration Velocity

Condition Monitoring

Plant Water P3 - M2 - Horizontal - Vel Spec 180000 CPM “Case A”
2/7/2017 3:48:51 PM

DFI = 1
Test – Vibration Acceleration

**B = Stage 3**

Stage 3 = Damage is visible to the rollers - BSF appears in spectrum
Assigned Risk Indicator (ARI)

Assigning Risk Indicator (ARI)

- **≤2** = Low Risk of Failure (Normal)
- **2>3** = Moderate Risk of Failure (Next Planned Maintenance)
- **3>4** = High Risk of Failure (Repair in 30 Days)
- **4>** = Very High Risk of Failure (Repair Immediately)

\[ ARI = \sqrt{1^2 + 3^2} = 3.16 \]
Tests

Pump & Motor Rebuild Program – Condition Monitoring

Signs of potential damage in outer race.

Testing Procedure

- Longitudinal Scratching
- Radial Abrasions

Bearing Wear

Santa Clara Valley Water District
Standards - Summary

Condition Monitoring

- Acceptance Testing **Vibration Velocity**
  - EASA/NEMA MG-1 7
  - Hydraulic Institute ANSI/HI 9.6.4

- Risk Indicators for Predictive Maintenance
  - (Vibration **Velocity**) Acceptance Testing Limits → DFI
  - (Vibration **Acceleration**) → Bearing Wear ID Stage #

\[ ARI = \sqrt{DFI^2 + B^2} \]
FY17 Results

Pump & Motor Rebuild Program – Condition Monitoring

Predictive Maintenance Vibration Condition Ratings as of June 2017
(49 Units Surveyed)

- GOOD (Low Risk): 73%
- Fair (Moderate Risk): 6%
- Alarm 1 (High Risk): 8%
- Alarm 2 (Very High Risk): 12%

Machines Evaluated

Pump Monitoring Report (PG. 1)
Pump & Motor Rebuild Program

Pump and Motor Rebuild Stages

1. RISK INDICATORS

2. GENERAL SCOPE OF WORK (SOW)

3. REBUILD PROCESS & ROLES

4. TRAINING

5. RECORDS MANAGEMENT
## Scope of Work

### Pump & Motor Rebuild Program

### Template

- Common tasks for all rebuilds

### Section 001: Vertical Pump Rebuild

#### Part 1 - General
- 1.01 Standards and References
- 1.02 Related Sections
- 1.03 Submittals
- 1.04 Pump Repair Shop Qualifications
- 1.05 Quality Control
- 1.06 Warranty and Workmanship
- 1.07 Materials

#### Part 2 - General Work Requirements
- 2.01 Labor
- 2.02 Equipment and Field Performance Testing
- 2.03 Coatings and Linings
- 2.04 Letter of Clarification

#### Part 3 - Tasks
- 3.01 Task 1 - Truck Mounting and Transportation
- 3.02 Task 2 - Incoming Inspection and Testing
- 3.03 Task 3 - Pump Rebuild
- 3.04 Task 4 - Pump Coatings
- 3.05 Task 5 - Installation
- 3.06 Task 6 - Spare Parts for New Pumps
- 3.07 Task 7 - Start-Up
- 3.08 Task 8 - Pump Hydraulic Performance Field Test
- 3.09 Task 9 - Vibration Field Test
- 3.10 Task 10 - Supplemental Work
- 3.11 Scope of Work Phases

### Section 002: Vertical Motor Rebuild

### Section 003: Special Requirements and Equipment Description

#### Part 1 - General
- 1.01 Background and Location
- 1.02 Special Requirements
- 1.03 Pump Equipment Description

### Section 004: Pump Bid Items

#### Attachments
- Attachment 1 – Pump & Motor Installation Runout Checklist
- Attachment 2 – Pump and Motor Manufacturer Installation and Maintenance Manual
- Attachment XX – Competent Pump Repair Shop Pre-Qualification Questionnaire
- Attachment XX – Motor Repair Shop Qualifications and Quality Control
1.02 SPECIAL REQUIREMENTS

A. All project submittals shall be submitted to the following district project representative:

Kristopher Filice – Recycled Water Facility Supervisor
4100 Zanker Road, San Jose, CA
kfilice@valleywater.org
(408) 630-3527

B. Purchase documentation of replaced OEM parts and certificates for raw materials purchased for the manufacture of parts shall be provided to receive payment.

C. The pump coating and lining shall be replaced with Amerock 400, NSF 61 approved high solids epoxy. Surface preparation and application for coating and lining the pump shall be according to Amerock 400 product data application instructions.

D. District staff will provide a crane for motor removal.

Luz Penilla
Step 16. Name the person responsible for coordinating between Purchasing, the Contractor, maintenance, and district engineering staff.

Luz Penilla
Step 17. If the pump manufacturer expects a less expensive coating than the one listed in SECTION 001, add it here.

Luz Penilla
Step 18. List any special requirements to remove the pump. If not, the district will get charged extra after the project is awarded. We need to confirm if the crane and what support district will provide.
1.03 **PUMP EQUIPMENT DESCRIPTION**

A. The pump to be repaired is a XYZ Model ABC, one-stage bowl assembly vertical mixed flow pump.

B. The pump is driven by a 40 hp, 900 RPM, TEFC, 460 volt vertical hollow shaft inverter duty motor, premium efficiency, with thermostats and self-release couplings. The motor manufacturer is Emerson Electric and is a U.S. Electric model.

C. Design rated operating speed is 890 rpm.
Pump & Motor Rebuild Program

1. RISK INDICATORS

2. GENERAL SCOPE OF WORK (SOW)

3. REBUILD PROCESS & ROLES

4. TRAINING

5. RECORDS MANAGEMENT
 Roles & Responsibilities

- Maintenance & Operations (MAINT)
- Field Operations Administrator (FOA)
- Purchasing Dept (PURCH)
- Contractor (CONTR)
- Engineering (MECH & ELEC)
- Asset Management (AM)
Pump and Motor Rebuild - Stages

1. PROBLEM DETECTED
   * PROBLEM IS DETECTED BY MAINTENANCE OR CONDITION ASSESSMENT DATA COLLECTION SYSTEM
   * CREATE WO & REQUEST ENGINEERING SUPPORT FOR PRE-REBUILD TESTS AND INSPECTIONS

EST HRS
Stage 17: Rebuild, Shop Test & Report (CONTR)

Hold Points for District staff

Shaft Runout
Impeller Balancing
Electrical Testing

Submits final reports to FOA
Pump & Motor Rebuild Program

Pump and Motor Rebuild Stages

1. RISK INDICATORS

2. GENERAL SCOPE OF WORK (SOW)

3. REBUILD PROCESS & ROLES

4. TRAINING

5. RECORDS MANAGEMENT
Pump & Motor Rebuild Program

Pump and Motor Rebuild Stages

1. RISK INDICATORS
2. GENERAL SCOPE OF WORK (SOW)
3. REBUILD PROCESS & ROLES
4. TRAINING
5. RECORDS MANAGEMENT
1. Green Folder

2. White Folder

3. Naming convention of files:
   year-mm-dd_maximum 6 word descriptive name:
   e.g. 2016-03-17_RWTPBooster2VibrationReport
Final Thoughts

Pump and Motor Rebuild Stages

1. Risk Indicators
2. General Scope of Work (SOW)
3. Rebuild Process & Roles
4. Training
5. Records Management
Questions?

Pump and Motor Rebuild Stages