Commissioning of Pump Systems at East Bay Municipal Utility District

March 20, 2019

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Agenda

- Introduction to EBMUD
  - What is covered in the presentation, who are the presenters
  - Water Supply and Distribution
  - Who we are
  - Structure of Engineering Department

- Background & Goals for Commissioning Program
  - Historic approach
  - New Commissioning Services Group (CSG)
Agenda, cont.

- Commissioning Case Studies:
  - Chemical Feed Pump System
  - Vertical Turbine Pumps

- Closeout Documentation
  - O&M manuals, SOPs, PM forms, training files, As-Builts, PLC HMI and program files

- Lessons Learned and Commissioning Goals
Water Supply & Service Area

EBMUD WATER SUPPLY

1.4 million Water Customers
685,000 Wastewater Customers
Major Infrastructure Assets (water)

Raw Water System
- 7 reservoirs
- Aqueducts

Treatment System
- 3 inline WTPs
- 3 conventional WTPs

Distribution System
- 4,200 miles of pipeline
- 122 pressure zones
- 164 reservoirs
- 135 pumping plants
- 100 regulators/RCS
Who We Are

BOARD OF DIRECTORS

OFFICE OF THE GENERAL MANAGER

INTERGOVERNMENTAL AFFAIRS
PUBLIC AFFAIRS

GENERAL MANAGER
Alexander R. Coate

Office of the District Secretary
Assistant to the General Manager

OFFICE OF GENERAL COUNSEL

WATER & NATURAL RESOURCES DEPARTMENT

NATURAL RESOURCES DEPARTMENT

WATER RESOURCES PLANNING DIVISION
WATER SUPPLY IMPROVEMENTS DIVISION
BAY DELTA CONSENSUS TEAM

EAST BAY WATERSHED & RECREATION DIVISION
FISH & WILDLIFE DIVISION

REGULATORY COMPLIANCE OFFICE
WATER QUALITY OFFICE
ASSET MANAGEMENT

MAINTENANCE & CONSTRUCTION DEPARTMENT
WATER OPERATIONS DEPARTMENT
WATER TREATMENT & DISTRIBUTION DIVISION
WATER DISTRICT PLANNING DIVISION
WATER SUPPLY DIVISION

ENGINEERING & CONSTRUCTION DEPARTMENT

WASTEWATER DEPARTMENT

DESIGN DIVISION

FINANCE DEPARTMENT

IT APPLICATIONS DIVISION

ACCOUNTING DIVISION
TREATMENT DIVISION
TREASURY OFFICE

IT OPERATIONS DIVISION

RISK MANAGEMENT OFFICE
IT SECURITY DIVISION

LABORATORY SERVICES DIVISION

INTERNAL AUDIT OFFICE

PURCHASING DIVISION

BUDGET OFFICE

INFORMATION SYSTEMS DEPARTMENT

CUSTOMER & COMM. SERVICES DEPARTMENT

ACCOUNTING DIVISION

CONTACT CENTER FIELD SERVICES DIVISION

IT OPERATIONS DIVISION

CUSTOMER SERVICES SUPPORT DIVISION

EMPLOYEE RELATIONS DIVISION

IT SECURITY DIVISION

EMPLOYEE & ORGANIZATION DEVELOPMENT DIVISION

RECRUITMENT/CLASSIFICATION DIVISION

NEW BUSINESS OFFICE

OFFICE OF DIVERSITY & INCLUSION

WATER CONSERVATION DIVISION
Who We Are

- Design and construction of new or rehab infrastructure projects

Develop pump specifications and test procedures/forms

Inspect pump installation and enforce design intent
• Developed holistic field testing in early 2000s
  • Functional Test: all equipment and devices
  • Performance Test: selected equipment
  • Control Systems Functional Test: EBMUD staff only
  • Startup Test: All systems operated by EBMUD, contractor on standby

• Witness approach (functional & performance tests): Contractor run, District witnessed to avoid any disputed results

• Design Engineers conducted the testing
Commissioning Services Group

Dedicated Commissioning Services Group (CSG)
Created in 2017

- Provide technical expertise and leadership for all commissioning related work to improve overall safety, quality and reliability upon handover to the client (O&M)

- Enhance overall coordination and communication between Design, O&M and Construction

- Promote continuous design improvements by sharing lessons learned
CSG - How We Work

Design
Construct
Commission
Operate

Planning
Testing
Start-up
Overview of Commissioning Services Group Roles & Responsibilities

**Design**
- Establish Startup Goals & Review P&IDs 10%-50% stage
- Review Documents
  - Specs
  - DWGs
  - Work Restrictions
  - Process Strategy
  - Commissioning Plan
- Assign Startup Team Roles
  - Design Eng.
  - Startup Eng.
  - CM/CI
  - Client (OMD)
- Prepare Commissioning Memo to Construction

**Construction**
- Write/Update Commissioning Plan & startup schedule
- Conduct Commissioning Kickoff Meeting
- Verify that test pre-requisites are met

**Operation**
- Conduct Startup Test perf. by OMD staff
- Coordinate (Operational) Startup Test
- Support/Conduct Control System Functional Testing
- Witness Performance Testing
- Approve Test Reports
- Support Troubleshooting as needed
- Support Commissioning close-out Documentation
- Prepare through with O&M and Construction

**Support**
- Conduct Lessons Learned Mtg. with Construction & Design
- Prepare Commissioning
  - RFS
- Conduct Walk-through with O&M and Construction
- Support
  - PM document transfer
  - As-built checks
  - O&M manuals

**Coordination**
- With Construction and Client
- Perform process Training and coordinate vendor training

**Witness Equipment Functional Testing**
- electrical
- mechanical
- instrumentation

**Witness**
- Performance Testing
- Support
- Conduct Walk-through with O&M and Construction

**Submit**
- daily
- commissioning
- punch list to CM
- Prepare
  - Commissioning close-out Documentation

**Attend**
- Factory Test/Inspections

**Review**
- Commissioning Submittals & RFIs
- Submit Daily Startup Reports on EADOC

**Submit**
- commissioning punch list to CM

**NTP**
- Verify that test pre-requisites are met

**RFS**
Chemical Feed Pump System
Vertical Turbine System
- Electrical
- Mechanical
Hydrogen Peroxide (HP) Chemical Feed Pump System
What is Hydrogen Peroxide?

- Disinfectant, bleaching agent
- Boiling point: 226°F, freezing point: -33°F
- Clear, soluble in water.
- Pungent odor
- Unstable and breaks down:
  \[ 2 \text{H}_2\text{O}_2 \rightarrow 2 \text{H}_2\text{O} + \text{O}_2 + \text{heat} \]
- Need degassing valves at various points in piping
What is HP used for at EBMUD?

- Remove excess ozone residual in drinking water treated with ozone
  \[ H_2O_2 + 2 O_3 \rightarrow 2 OH \cdot + O_2 \]
- Hydroxyl radicals (OH●) react with taste & odor causing compounds (i.e., MIB & Geosmin) in drinking water
- HP is dosed based on ozone dosage
- Calculated mass ratio is 2.8:1 of \( O_3 \) to \( H_2O_2 \)
- In practice, 3.5:1 to 5:1 is used
What does the HP system consist of?

Storage Tank

- High Temperature Can Indicate Decomposition in Progress
- Rapid Change in Tank Level Can Indicate Leak
- Motorized Outlet Valve Closes Upon Leak Detection
- Manual Drain Valve
What does the HP system consist of?

Containment Sump & Sump Pump

- 6,000+ gallon Containment Volume above Sump
- 135 gallons

Manual Operation Only
What does the HP system consist of?

Submersible Sump Pump

- BJM Pumps, TIGF 32-9NL
- Pump Capacity: 46 GPM, 27 ft. head
- Vertical or horizontal discharge
- On/off mechanical switch for level control
- Pump material: Chemical resistant NORYL resin
What does the HP system consist of?

Metering Pumps

Standby Pump Can Serve Any Ozone Contactor

Remaining 4 Metering Pumps Are Dedicated to Specific Contactors
What does the HP system consist of?
What does the HP system consist of?

Hydraulic Diaphragm Metering Pump Skid

- Pulsafeeder, Pulsapro PP680
- Pump Capacity: 4 GPH, 100 psi.
- Type: Positive displacement
- Protection against overpressurization
- Points from pump skid to PLC:
  - Leak detection
  - High pressure
- Flow control:
  - Manual: stroke length
  - Automatic: VFD
What does the HP system consist of?

Metering Pump Suction Piping Arrangement

- Metering Pump & Motor
- Calibration Column
- Leak Detection Sensor
- Pump Stroke
- From Storage Tank
What does the HP system consist of?

Metering Pump Discharge Piping Arrangement

- Pulsation Dampener
- Back Pressure Valve
- Pressure Gauge
- Pressure Switch
- Pressure Relief Valve
- To Flow Meter
What does the HP system consist of?

Piping Arrangement & Instrumentation

- Coriolis Flow Meter
- Discharge Degassing Vent
- Dilution Water Flow Indicator
- Dilution Water Solenoid Valve
- To Contactor
What does the HP system consist of?

What Happens Inside a Contactor Basin

- Hydrogen Peroxide Diffuser
- Ozone Diffusers
- Diluted Hydrogen Peroxide
What does the HP system consist of?

Control Panel & HMI
How does the HP system work?

- **Control modes**
  - Dosage mode
  - Ratio mode
  - In both modes, flow meter provides feedback signal to control metering pump speed

- **Key interlocks**
  - Pump: various alarms
  - Tank: leak detection alarm
  - Pump operation interlocked with contactor status
  - Dilution water valve operation interlocked with metering pump and contactor status.
How does the HP system work?

Metering Pump Control HMI Screen

- **Pump 201/Contactor 2 Dosage Setpoint**: 1.000 mg/liter
- **Ozone:HP Ratio SP**: 5.00
- **Mode**: Dosage
- **Flow Setpoint for P201/Contactor 2**: 0.000 gph
- **Contactor 2 Status**: Offline
- **Remote**: Ready, In Service
- **Speed SP**: 50.0%
HP System Startup Sequencing

1. MCC Modifications Complete & Tested
2. HP System Installed
3. Fill Tank with Water

- Instrumentation Calibration, Troubleshooting, Loop Testing
- Metering Pump Startup, Troubleshooting
- Establish Communication between Local Control Panel & DCS
- Functional Testing (from Local Control Panel)
- Functional Testing (remotely from DCS)
- Drain Water from Tank, Fill with HP
- Purge Air, Prime System with HP
- Operate System with HP

With Water

With Chemical
Instrumentation Startup Steps

- Field calibration
- Verify and document field device setpoints
- Point-to-point control loop checks
- Local and remote operation of valves
- Verify flow meter accuracy
**FIELD FUNCTIONAL TEST DATA FORM**

**EBMUD Project Title:** Sobrante & USL Ozone – 2117  
**Test Date(s):** 10/31/2018  
**Section No.:** 43 33 20.01  
**P&ID No.:** 503.00-J-064.01 to 05

### II. Field Functional Test

#### 1. Calibration/Loop/Electrical

1.1 Verify all instruments in the package system have been properly calibrated and the Field Calibration Tags have been completed and installed on each instrument.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Setting</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. PRV-266</td>
<td>50 psig</td>
<td>Recirculating pressure</td>
</tr>
<tr>
<td>b. PI-267</td>
<td>50 psig</td>
<td>No tag</td>
</tr>
<tr>
<td>c. PI-268</td>
<td>100 psig</td>
<td>No tag</td>
</tr>
<tr>
<td>d. PSH-267</td>
<td>75 psi</td>
<td>Pressure switch was adjusted toward the right by Flolanite</td>
</tr>
<tr>
<td>e. FI-264</td>
<td>5 gpm</td>
<td>Service Water Flow Indicator</td>
</tr>
<tr>
<td>f. FIT-264</td>
<td>5 gph</td>
<td>No flow indicator installed. Device installed is a backflow preventer</td>
</tr>
<tr>
<td>g. PCV-264</td>
<td>35 psi</td>
<td>Back pressure valve</td>
</tr>
</tbody>
</table>

#### 2. Installation Check

2.1 Correct equipment tags have been installed (tags shall match P&IDs).

- **Pass Fail NA**
  - [ ] Pass
  - [ ] Fail

2.2 All fields on Asset List Spreadsheet completed for device. (Contractor shall show inspector at the time of the test that the asset list is complete and accurate for this system).

- [ ] Pass
- [ ] Fail

#### 3. Operations Check

3.1 Verify motor rotation

- [ ] Pass
- [ ] Fail

*Stroke is noisy when not fully closed.*
Pump Startup and Functional Test Steps

- Purge all air out of piping
- Bump pump motor to verify correct rotation
- Verify pump performance with calibration column draw-down tests
- Compare calibration column results to flow meter readings
- Test alarms & control interlocks
  - Pump alarms: fail to run, VFD fail, high pressure, leak detection
  - Pump cannot operate when respective contactor is offline
  - Dilution water valve operation dependent on metering pump & contactor status.
Pump Test Form

FIELD FUNCTIONAL TEST DATA FORM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>1%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Testing Time</td>
<td>Secs</td>
<td>401</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Actual Testing Time</td>
<td>Secs</td>
<td>401</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Calibration Column (4000mL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starting Volume</td>
<td>mL</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Ending Volume</td>
<td>mL</td>
<td>232</td>
<td>156</td>
<td>116</td>
<td>128</td>
<td>80</td>
</tr>
<tr>
<td>Test Volume</td>
<td>mL</td>
<td>26</td>
<td>9.4</td>
<td>134</td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>Flow Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flowmeter</td>
<td></td>
<td>6.29gph</td>
<td>1.49gph</td>
<td>2.12gph</td>
<td>0.69gph</td>
<td></td>
</tr>
<tr>
<td>Calculated Flow Rate</td>
<td></td>
<td>6.29gph</td>
<td>1.49gph</td>
<td>2.12gph</td>
<td>0.69gph</td>
<td></td>
</tr>
<tr>
<td>Flow Rate Difference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical Data</td>
<td></td>
<td>AB/AC/BC</td>
<td>AB/AC/BC</td>
<td>AB/AC/BC</td>
<td>AB/AC/BC</td>
<td></td>
</tr>
<tr>
<td>Volts (Phase to phase)</td>
<td>Volts</td>
<td>141/141/149</td>
<td>253/254/255</td>
<td>367/367/368</td>
<td>483/480/482</td>
<td></td>
</tr>
<tr>
<td>Amps (Phase to phase)</td>
<td>Amps</td>
<td>0.15/0.14/0.75</td>
<td>0.76/0.74/0.76</td>
<td>0.53/0.53/0.51</td>
<td>0.76/0.74/0.75</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>Hertz</td>
<td>15</td>
<td>30</td>
<td>45</td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

Calculations:

This pump was found to be under-performing during initial startup. In addition, due to deformed diaphragm and air bubbles trapped in PRV found in PMP 401, all other pumps were re-checked. Drawdown calibration for this pump was repeated on 11/15/2018. Comparison to flowmeter readings was performed on 11/28/2018 and 2/6/2019. See data on next page.
### FIELD FUNCTIONAL TEST DATA FORM

**EBMUD Project Title:** Sobrante & USL Ozone – 2117  
**Equipment Name:** Liquid Chemical Diaphragm Metering Pump  
**Tag No.:** 2B8-AP-PMP-401  
**Test(s) Date(s):** 11/15/2018  
**Section No.:** 43 33 20.01  
**P&ID No.:** 503.00-J-064.01 to 05

#### 3.4 Data Chart

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>1%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Testing time</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated Testing Time</td>
<td>Seconds</td>
<td>60sec</td>
<td>60sec</td>
<td>60sec</td>
<td>60sec</td>
<td></td>
</tr>
<tr>
<td>Actual Testing Time</td>
<td>Seconds</td>
<td>60sec</td>
<td>60sec</td>
<td>60sec</td>
<td>84sec</td>
<td></td>
</tr>
<tr>
<td><strong>Calibration Column (4000mL)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starting Volume</td>
<td>mL</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Ending Volume</td>
<td>mL</td>
<td>182</td>
<td>114</td>
<td>44</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Test Volume</td>
<td>mL</td>
<td>68</td>
<td>130</td>
<td>206</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td><strong>Flow Rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flowmeter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculated Flow Rate</td>
<td>gph</td>
<td>1.95gph</td>
<td>3.07gph</td>
<td>4.22gph</td>
<td>6.54gph</td>
<td></td>
</tr>
<tr>
<td>Flow Rate Difference</td>
<td>gph</td>
<td>+0.89gph</td>
<td>+0.93gph</td>
<td>+0.95gph</td>
<td>+0.95gph</td>
<td>+0.99gph</td>
</tr>
<tr>
<td><strong>Electrical Data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volts (Phase to phase)</td>
<td>Volts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amps (Phase to phase)</td>
<td>Amps</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>Hertz</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Calculations:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Flowmeter Readings:**

- 11/18/2018 PMP-401-01 FIT-414: 0.79gph, 1.9gph, 3.24gph, 4.305gph
- 2/6/2019 PMP-401-01 FIT-414: New FIT, replaced on 12/12/2018  
  - Flow Meter SN#44863825  
  - Transmitter SN#44863825  
  - 1.06gph, 3.15gph, 3.22gph, 4.35gph
Issues Found & Resolution

Piping installation error: pumps pumping to incorrect contactor, incorrectly dosing contactors
Re-programmed control system, rather than re-pipe system
Issues Found & Resolution

- Lack of air relief valves in suction piping - prevented proper pump priming during startup
- Missing degassing valve in suction piping - pressurized piping when system is offline

P&ID Note:

NOTES
1. NOT ALL PRESSURE RELIEF AND DEGASSING VALVES ARE SHOWN. PROVIDE DEGASSING VALVES AT ALL HIGH POINTS IN PIPING AND PRESSURE RELIEF VALVES IN ANY SEGMENT OF PIPING ISOLATED BETWEEN VALVES.
Design clarification issued to add air relief valve and degas vents
Mal-functioned flow meters

- Reading flow when there is no flow
- Incorrect/inaccurate dosage of hydrogen peroxide
- Flow meters are very sensitive to movement/touch
- Flow meter issue or installation issue?
- Replaced two flow meters, performed field validation tests
Control system programming corrections

- Erroneously latching alarms
- Leak detection alarm
- Incorrect mapping of points between contactors
- Metering pump PID control loop tuning
Lessons Learned from HP System Commissioning

- Seek input from O&M staff during Design Phase
- Drawings to clearly show all pressure relief and degassing valves in piping
- Closely inspect of piping installation against conformance drawings
- Ensure Contractor is flushing pipes prior to all testing (chemical and water service), with substantial tracking and recording.
- Request factory rep troubleshoot at first occurrence of flow meter malfunction
- Perform control system functional testing with PLC programmer
- Coordination, coordination, coordination!
QUESTIONS
Commissioning Case Studies

- Chemical Feed Pump System
- Vertical Turbine Pumps
  - Electrical
  - Mechanical
Electrical System Commissioning

- Design Review
- Submittal Review
- Factory Tests
- Installation
- Equipment Integration
- Field Startup and Commissioning
- Final Reports and As-Built Drawings
Design Review

- Design based on current codes, standards and regulations
  - NFPA70 (NEC)
  - ANSI
  - IEEE
  - NEMA

- Design for safety (NFPA 70E)
  - Circuit breaker remote racking mechanism
  - Remote open/close operation
  - Equipment status monitoring (hardwired and network communication)

- Design for equipment maintainability and accessibility (NFPA 70B)
Submittal Review

- Critical step to ensure that equipment to be provided:
  - Meets the design specification
  - Physical Size
  - Functionality
  - Compatibility with equipment from different vendors to ensure successful overall system integration

- Submittal reviews performed by design engineer and commissioning engineer

- Prevents costly changes and schedule delays during Construction Phase
Factory Acceptance Test

- Final step to ensure equipment to be provided meets design specifications
- Capture and implement design changes made between Design Phase and Construction Phase
- Prevents costly field changes and schedule delays after equipment is delivered
Factory Acceptance Test

Portable generator section inaccessible prior to field modification

Before Modification

After Modification
Equipment Installation

- Visual inspection of equipment installation
- Verify installation meets manufacturers recommendation and current codes and regulations
- Verify equipment clearance/accessibility for maintenance
Incoming utility power switchgear for pumping plant

- All power and control wires terminated and matching design drawings
- NETA Phase 1 testing completed
- Circuit breaker Trip Units programmed based on the Coordination Study
- Arc Flash sticker installed
Remote breaker operation panel

Incorrect Mimic Bus

Correct Mimic Bus

Mimic Bus corrected to match the actual installation
Remote racking mechanism

- Verify the source for control power (120Vac) to operate all the accessory devices
- Verify operation of all the accessories
- Verify clearances for front and back access
Equipment Installation

Circuit breaker removal lift truck and ramp

- Test physical fit of the accessory
- Any special ramp requirements
Motor Control Center for Pumping Plant

- Verify shipping splits between sections
- Main bus connections, Neutral bus, Ground bus
- Control wiring between sections

Neutral Bus *not* connected between sections
Field Startup and Commissioning

- Final visual inspection & walk-through with O&M and construction team before energizing the equipment

- Energization
  - Phase rotation checks with Utility and Generator power
  - Bump motors to check rotation
Field Startup and Commissioning

PLC Control Panel for Pumping Plant

- PLC control program uploaded
- Point-to-point control loop checks of field devices
- Functional testing
  - Alarms
  - Interlocks
  - Control sequences
Field Startup and Commissioning

PLC Control Panel HMI for Pumping Plant

- Perform testing of all field devices from the end device to the HMI
- Ideally initiate the actual condition for status, alarm, fault or analog signal at the end device
- Some failure modes need special setup to verify the operation of the system
Field Startup and Commissioning

PLC Control Panel HMI for Pumping Plant

- Controls Engineering group developed HMI screens to aid during commissioning
- Verify device status directly on the HMI screen
Field Startup and Commissioning

Motor Starter

Vertical Turbine Pump Motor
Field Startup and Commissioning

Motor Starter

- Program Trip Units based on Coordination Study
- Install Arc Flash stickers
- Program settings for Motor Soft starter
  - Motor FLA
  - Start/Stop ramp times
- Verify actual readings (amperage) with the readings on the Softstarter display
Field Startup and Commissioning

Vertical Turbine Pump

- Motor winding heaters
  - Storage concerns during construction and during commissioning (condensation buildup)

- Thermal switches interlocks to motor starter
Field Startup and Commissioning

Motor-Actuated Valve

- Local/Remote Operation
  - Programming changes

- Verification of limit switch feedbacks
  - Adjustments/programming changes
Field Startup and Commissioning

Pressure Transmitter

- Initial checks of analog loops
  - from the device to HMI
  - using the vendor simulator

- Final verification of analog
  - values with the system running

- Pressure Indicating Transmitter
- Flow Indicating Transmitter
- Temperature Indicating Transmitter
Documentation & Field Changes

- Red-lined/ yellow marked drawings based on changes and testing during commissioning
- Coordinate with design engineer on design changes identified during functional testing
- Design, Commissioning and Controls Engineers to review final as-builts
Documentation & Field Changes

- Completed test forms for individual devices
- Completed test forms for complete system integration
- Final documentation to O&M groups
QUESTIONS
Commissioning Case Studies

- Chemical Feed Pump System
  - Vertical Turbine Pumps
    - Electrical
    - Mechanical
Vertical Turbine Pumps

Vertical Turbine Pump Commissioning

- Submittals
- Barrel Installation
- Factory Tests
- Field Tests
SUBMITTALS

Rotodynamic Design Analysis

- Natural Frequency: no critical or resonant frequencies within ±20% of operating speed
- Deflections – manufacturer’s recommendations
FACTORY PERFORMANCE TEST

- Certified Pump Curve
- Noise Tests
- Vibration Test: Acceptance Criteria (ISO 10816-7)

ISO 10816-7, Annex A, Category I:
- <268 HP on-site test (rigid foundation):
  0.10 IPS-rms.
- <268 HP factory test (flexible foundation):
  0.13 IPS-rms.
- >268 HP on-site test (rigid foundation):
  0.13 IPS-rms.
- >268 HP factory test (flexible foundation):
  0.17 IPS-rms.
Vertical Turbine Pumps
FACTORY PERFORMANCE TEST

Pump Performance Curve

- Pump and bowl (dashed) performance. Bowl adjusted for construction and viscosity.
- Pump further adjusted for friction and power losses of lineshaft and thrust bearings. Pump is not adjusted for any static lift.
- The duty point represents the head at the discharge nozzle centerline.

**Primary Design Point**
- 980 gpm at 370 ft pump head
- 83% minimum pump efficiency
- Performance Guaranteed to HL 14.6 Grade 1U

**Secondary Design Point**
- 1000 gpm at 360 ft pump head
  (For Reference Only)

- Power
- Efficiency
- NPSHr
- Flow - USgpm
- Head - ft
- Power - hp
- NPSHr - ft

6.53 in
## FACTORY PERFORMANCE TEST

HI 14.6-2016: Acceptance Criteria

<table>
<thead>
<tr>
<th>Test parameter</th>
<th>Guarantee requirement</th>
<th>Standard deviation (Δ)</th>
<th>Grade 1</th>
<th>Grade 2</th>
<th>Grade 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Δt_Q (%)</td>
<td>10%</td>
<td>16%</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Δt_H (%)</td>
<td>6%</td>
<td>10%</td>
<td>14%</td>
</tr>
<tr>
<td>Rate of flow</td>
<td>Mandatory</td>
<td>t_Q (%)</td>
<td>± 5%</td>
<td>± 8%</td>
<td>± 9%</td>
</tr>
<tr>
<td>Total head</td>
<td>Mandatory</td>
<td>t_H (%)</td>
<td>± 3%</td>
<td>± 5%</td>
<td>± 7%</td>
</tr>
<tr>
<td>Power</td>
<td>Optional (either/or)</td>
<td>t_P (%)</td>
<td>+ 4%</td>
<td>+ 8%</td>
<td>+ 9%</td>
</tr>
<tr>
<td>Efficiency</td>
<td></td>
<td>t_η (%)</td>
<td>− 3%</td>
<td>− 5%</td>
<td>− 7%</td>
</tr>
</tbody>
</table>

### Table 14.6.3.4 — Pump test acceptance grades and corresponding tolerance band

<table>
<thead>
<tr>
<th>Test parameter</th>
<th>Guarantee requirement</th>
<th>Symbol</th>
<th>1B</th>
<th>1E</th>
<th>1U</th>
<th>2B</th>
<th>2U</th>
<th>3B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of flow</td>
<td>Mandatory</td>
<td>t_Q</td>
<td>± 5</td>
<td>± 5</td>
<td>0%</td>
<td>± 8</td>
<td>0%</td>
<td>± 9</td>
</tr>
<tr>
<td>Total head</td>
<td>Mandatory</td>
<td>t_H</td>
<td>± 3</td>
<td>± 3</td>
<td>0%</td>
<td>± 5</td>
<td>0%</td>
<td>± 7</td>
</tr>
<tr>
<td>Power</td>
<td>Optional (either/or)</td>
<td>t_P</td>
<td>+ 4</td>
<td>+ 4</td>
<td>+ 10</td>
<td>+ 8</td>
<td>+ 16</td>
<td>+ 9</td>
</tr>
<tr>
<td>Efficiency</td>
<td></td>
<td>t_η</td>
<td>− 3</td>
<td>− 0</td>
<td>− 0</td>
<td>− 5</td>
<td>− 5</td>
<td>− 7</td>
</tr>
</tbody>
</table>

\( a \) Efficiency is a calculated value that is dependent on pump power input, and therefore, either minimum efficiency or maximum pump power input at the guarantee point can be specified, but not both.

**NOTE:** All tolerances are percentages of values guaranteed.
# FACTORY TOLERANCE

<table>
<thead>
<tr>
<th>Description</th>
<th>Requirement</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CL150 – Std. Drawing 324-EA CL300 – Std. Drawing 325-EA</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0.01 in variation in circumferential and radial seating surface flatness per ASME PCC-1-2013</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.001 inch + 0.001 inch per foot diameter pump head base (i.e. the requirement for a 4ft diameter plate would be 0.004&quot;)</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>125-250 microinch roughness</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>+0.001 inch/-0.000 inch</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Total tolerance stackup shall be 0.0001 inch/inch coupling face diameter, or 0.0005 inch maximum, whichever is greater</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0.002 inch</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE 1:** Barrel Top Plate and Sole Plate Flatness has additional tolerance in Field Installation Vertical Turbine Pump Tolerance Inspection Data Form

Contractor Signature: ___________________________ Date: __________

EBMUD Witness Signature: ___________________________ Date: __________
BARREL PLACEMENT

• True vertical: ±3/64” per foot of barrel length
• Fill barrel with water prior to placing concrete to reduce buoyancy
• Block and anchor in place
**Vertical Turbine Pumps**

### FIELD TOLERANCE

<table>
<thead>
<tr>
<th>Description</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>H Barrel Top Plate (or Sole Plate) Level and Flat</td>
<td>0.002 inch per linear foot diameter level &amp; 0.01 in variation in circumferential and radial seating surface flatness per ASME PCC-1-2013</td>
</tr>
<tr>
<td>I Barrel Vertical</td>
<td>Suction bell shall be centered within 3% of suction bell diameter</td>
</tr>
<tr>
<td>J Barrel Top Plate Roughness</td>
<td>125-250 microinch roughness (spiral or concentric)</td>
</tr>
<tr>
<td>K Motor Shaft to Motor Mounting Face Perpendicular</td>
<td>0.001 inch</td>
</tr>
<tr>
<td>L Uncoupled Motor Shaft total indicated runout (TIR)</td>
<td>0.001 inch</td>
</tr>
<tr>
<td>M Impeller Lift</td>
<td>Per Manufacturer</td>
</tr>
<tr>
<td>N Coupled pump with motor, pump shaft TIR just above the seal</td>
<td>0.002 inch</td>
</tr>
</tbody>
</table>

Contractor Signature: __________________________ Date: ______________

EBMUD Witness Signature: __________________________ Date: ______________
BARREL PLACEMENT
BARREL FLAT AND PARALLEL
BARREL FLAT AND PARALLEL
Vertical Turbine Pumps

Alignment using jacking screws
Vertical Turbine Pumps
Motor shaft run-out test
Couple motor and pump shaft and repeat run-out test
FIELD FUNCTIONAL TEST

- Installation check and certification
- Calibration check of all related instruments and Loop Checks to MCC and PLC
- Insulation resistance, rotation check
- 1 hour Run Test:
  - Recirc water or pump to distribution
  - monitor amps/volts and discharge water temperature
  - Motor Test: full load amps check
## Instrument Calibration Sheet

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>MANUFACTURER</th>
<th>PROJECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME: DIFFERENTIAL PRESS TRANS</td>
<td>MODEL: 3051CD3A02A1M5BADOH2L4</td>
<td>NAME: EBMUD – ORINDA WTP</td>
</tr>
<tr>
<td>SERIAL NUMBER: 2093975</td>
<td>RELIABILITY &amp; MAINTENANCE</td>
<td></td>
</tr>
</tbody>
</table>

### Functions

<table>
<thead>
<tr>
<th>Range</th>
<th>Value</th>
<th>Units</th>
<th>Computing Function? Y/N</th>
<th>Control? Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incite</td>
<td>CHART</td>
<td>Describe</td>
<td></td>
<td>Action? Direct / Reverse</td>
</tr>
<tr>
<td>Record</td>
<td>SCALE</td>
<td></td>
<td></td>
<td>Modes? P/I/D</td>
</tr>
<tr>
<td>Trans.</td>
<td>INPUT</td>
<td></td>
<td></td>
<td>SWITCH? Y/N</td>
</tr>
<tr>
<td>Convert</td>
<td>OUTPUT</td>
<td>4-20</td>
<td>ma</td>
<td>Unit Range: -5 TO 20 PSIG</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Differential? Fixed / Adjustable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reset? Automatic / Manual</td>
</tr>
</tbody>
</table>

### Analog Calibrations

<table>
<thead>
<tr>
<th>Required</th>
<th>As Calibrated</th>
<th>Discrete Calibrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>Scale / Indicated</td>
<td>Output</td>
</tr>
<tr>
<td>0%</td>
<td>-5</td>
<td>4.00 MA</td>
</tr>
<tr>
<td>10%</td>
<td>-2.5</td>
<td>5.60 MA</td>
</tr>
<tr>
<td>50%</td>
<td>7.5</td>
<td>12.00 MA</td>
</tr>
<tr>
<td>75%</td>
<td>17.5</td>
<td>16.00 MA</td>
</tr>
<tr>
<td>100%</td>
<td>20</td>
<td>20.00 MA</td>
</tr>
</tbody>
</table>

CONTROL MODE SETTING: P: 1; D: 9

### Notes

- Component Calibrated and Ready for Start-up.
- Scale changed to elevation per request of EBMUD 5/18/2017
- Service: Effluent #1A
- Tag No.: 233-FWS-PIT-601A
# Vertical Turbine Pumps

## Loop Testing

### 233 Washwater Pump Units 4 and 5 CP

#### Washwater Unit #4

**TEST PHASE:** Operational Readiness Test (ORT)

<table>
<thead>
<tr>
<th>Drawings</th>
<th>TB</th>
<th>TB</th>
<th>Address</th>
<th>Tag</th>
<th>Point Description</th>
<th>Off</th>
<th>On</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>2873-5004-2</td>
<td>TB2(+01)</td>
<td>TB2(-01)</td>
<td>TDUI/O CH-01</td>
<td>326-WWS-NL-704</td>
<td>Washwater Unit #4 Motor Status</td>
<td>N/A</td>
<td>Running</td>
<td></td>
</tr>
<tr>
<td>2873-5004-2</td>
<td>TB2(+02)</td>
<td>TB2(-02)</td>
<td>TDUI/O CH-02</td>
<td>326-WWS-NA-704</td>
<td>Washwater Unit #4 Fault</td>
<td>N/A</td>
<td>Fault</td>
<td></td>
</tr>
<tr>
<td>2873-5004-2</td>
<td>TB2(+06)</td>
<td>TB2(-06)</td>
<td>TDUI/O CH-06</td>
<td>326-WWS-NA-704</td>
<td>Washwater Unit #4 Discharge Temp</td>
<td>Alarm</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>2873-5004-2</td>
<td>TB2(+03)</td>
<td>TB2(-03)</td>
<td>TDUI/O CH-03</td>
<td>326-WWS-ZSL-704</td>
<td>Washwater Unit #4 FCV 704 Position</td>
<td>N/A</td>
<td>0% Open</td>
<td></td>
</tr>
<tr>
<td>2873-5004-2</td>
<td>TB2(+04)</td>
<td>TB2(-04)</td>
<td>TDUI/O CH-04</td>
<td>326-WWS-ZSM-704</td>
<td>Washwater Unit #4 FCV 704 Position</td>
<td>N/A</td>
<td>5% Open</td>
<td></td>
</tr>
<tr>
<td>2873-5004-2</td>
<td>TB2(+05)</td>
<td>TB2(-05)</td>
<td>TDUI/O CH-05</td>
<td>326-WWS-ZSH-704</td>
<td>Washwater Unit #4 FCV 704 Position</td>
<td>N/A</td>
<td>100% Open</td>
<td></td>
</tr>
</tbody>
</table>

#### Analog Input Checklist

<table>
<thead>
<tr>
<th>Drawings</th>
<th>TB</th>
<th>TB</th>
<th>Address</th>
<th>Tag</th>
<th>Point Description</th>
<th>Range</th>
<th>Eng Units</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Digital Output Checklist

<table>
<thead>
<tr>
<th>Drawings</th>
<th>TB</th>
<th>TB</th>
<th>Address</th>
<th>Tag</th>
<th>Point Description</th>
<th>Off</th>
<th>On</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>2873-5004-5</td>
<td>CR1-11</td>
<td>CR1-14</td>
<td>TDUI/O CH-24</td>
<td>326-WWS-HS-704</td>
<td>Washwater Unit #4 Motor Command</td>
<td>Stop</td>
<td>Start</td>
<td></td>
</tr>
<tr>
<td>2873-5004-5</td>
<td>CR2-11</td>
<td>CR2-14</td>
<td>TDUI/O CH-25</td>
<td>326-WWS-HS-704</td>
<td>WW Unit #4 FCV 704 Command</td>
<td>Close</td>
<td>Open</td>
<td></td>
</tr>
</tbody>
</table>

#### Analog Output Checklist

<table>
<thead>
<tr>
<th>Drawings</th>
<th>TB</th>
<th>TB</th>
<th>Address</th>
<th>Tag</th>
<th>Point Description</th>
<th>Range</th>
<th>Eng Units</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Loop Status Checklist

**Item To Be Confirmed**

- Component installation is complete.
- All electrical terminations and/or pneumatic tubing connections are complete.
- Component calibration and/or adjustment is complete.
- Loop is operational.

**TESTED BY:**

**WITNESSED BY:**

**Date:** 01/01/2017

**Date:** 01/01/17
Vertical Turbine Pumps
Installation Check

FIELD FUNCTIONAL TEST

• Installation check and certification
Vertical Turbine Pumps
Field Functional Test

FIELD FUNCTIONAL TEST DATA FORM

<table>
<thead>
<tr>
<th>EBMUD Project Title:</th>
<th>Orinda WTP Filters, Hypo, and Electrical Imps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Name:</td>
<td>Vertical Turbine Pumps</td>
</tr>
<tr>
<td>Tag No.:</td>
<td>326 - WTP - ZMP - 705</td>
</tr>
<tr>
<td>Test Date(s):</td>
<td>6 - 1 - 17</td>
</tr>
<tr>
<td>Section No.:</td>
<td>33 12 23.10</td>
</tr>
<tr>
<td>P&amp;ID No.:</td>
<td>51D. 00 - J - 037.1</td>
</tr>
</tbody>
</table>

I. Pretest Documentation/Setup

<table>
<thead>
<tr>
<th>Documents:</th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
<th>Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Interconnection &amp; Loop diagrams provided.</td>
<td>☑</td>
<td>☑</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>b) Technical Submittal complete (contractor show EDOCs record).</td>
<td>☑</td>
<td>☑</td>
<td>☐</td>
<td>SBM 3.3</td>
</tr>
<tr>
<td>c) Spare Parts provided.</td>
<td>☑</td>
<td>☑</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>d) Final O&amp;Ms provided (contractor show final O&amp;Ms).</td>
<td>☑</td>
<td>☑</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>e) Final O&amp;Ms provided (contractor show final O&amp;Ms).</td>
<td>☑</td>
<td>☑</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>f) All fields on Asset List Spreadsheet completed for device (Contractor shall show inspector at the time of the test that the asset list is complete and accurate for this system)</td>
<td>☑</td>
<td>☑</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>g) Field Test Setup (Identify any test instrument, special setups like tanks, hoses, etc):</td>
<td>Amp meter, volt meter, torque wrench, infrared thermometer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h) Discharge flow control valve (FCV) functional test completed (FCV Tag# 705 - D)</td>
<td>☑</td>
<td>☑</td>
<td>☐</td>
<td></td>
</tr>
</tbody>
</table>

II. Field Functional Test

<table>
<thead>
<tr>
<th>1. Calibration/Loop/Electrical</th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
<th>Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Instrument commissioning complete.</td>
<td>☑</td>
<td>☑</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>1.2 Loop Checks complete.</td>
<td>☑</td>
<td>☑</td>
<td>☐</td>
<td></td>
</tr>
</tbody>
</table>
## Vertical Turbine Pumps

### Field Functional Test

<table>
<thead>
<tr>
<th>Field Functional Test Data Form</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EBMUD Project Title:</strong></td>
</tr>
<tr>
<td><strong>Equipment Name:</strong></td>
</tr>
<tr>
<td><strong>Tag No.:</strong></td>
</tr>
</tbody>
</table>

1. **Electrical commissioning complete (NETA testing, ref Section 26 08 00).**
   - Pass Fail

2. **Installation Check** (manufacturer's representative shall coordinate these checks and then certify the pump systems are ready for operation)
   - 2.1 Correct equipment tags have been installed (tags shall match P&IDs)
   - 2.2 Verify Field Calibration Tag for discharge temperature switch (TSH-__) or transmitter (TT-__) has been properly filled out and installed
   - 2.3 Complete installation checks for pump and motor listed in the manufacturer's O&M manual.
   - 2.4 Verify equipment nameplate data matches the O&M manual.
   - 2.5 Inspect anchorage, mechanical and accessible electrical bolted connections with a torque wrench. Values shall be in compliance with manufacturer's written recommendations.
   - 2.7 Verify correct lubrication has been installed. Check bearing sumps for oil leaks.
   - 2.8 Sign and date the Manufacturer's Certificate of Proper Installation. No running tests can proceed prior to receipt of this document.

3. **Operations Check** (Will be completed as part of the Control Systems Functional test)
   - Pass Fail

4. **Controls Check** (Will be completed as part of the Control Systems Functional test)
   - Pass Fail

5. **Alarms Check** (Will be completed as part of the Control Systems Functional test)
   - Pass Fail

89
**Vertical Turbine Pumps**

**Field Functional Test**

---

### FIELD FUNCTIONAL TEST DATA FORM

**EBMUD Project Title:** Orinda WTP Filters, Hypo, and Electrical Imps

**Equipment Name:** Vertical Turbine Pumps

**Tag No.:** [326-WW5-9TP-75]  

**Test Date(s):** 6-1-17

**Section No.:** 33 12 23.10  

**P&ID No.:** 512.20 - J - 027.1

---

#### 6. Run Check

6.1 Run the pump near the design point for a minimum of 1 hour. Adjust the discharge control valve as necessary to achieve the design conditions (4,100 gpm @ 85 ft). It might be necessary to recirculate the water using the plant surge/relief valve; adjust as necessary.

6.2 Record amps and volts at each lead every 15 minutes during the run test.

6.3 Monitor the discharge water temperature throughout the run test and record the value every 15 minutes (may use an infrared thermometer measured at the pump discharge piping). STOP THE TEST if the water temperature reaches 85 °F.

---

**Pass Fail NA**

<table>
<thead>
<tr>
<th>Time</th>
<th>Volts</th>
<th>Amps</th>
<th>Temp (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td>491</td>
<td>14.7</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>492</td>
<td>13.5</td>
<td>49.4</td>
</tr>
<tr>
<td></td>
<td>492</td>
<td>14.6</td>
<td>51.3</td>
</tr>
</tbody>
</table>

**Comments:** 49.2 14.6

---

Pumps shall operate smoothly and at a consistent sound level without unusual noises throughout the test. The manufacturer’s field representative shall account for any unusual vibration and/or noise (including potential bearing noise), and shall stop the test and investigate any abnormalities. If the run test is stopped for any reason, it shall be started again until the pump operates without incident for the full time specified.

---

#### 7. Other Tests and Checks

7.1 District Engineers might monitor vibration, sound, and/or displacement at any time and at any location during the functional test.

7.2 At the conclusion of the functional test, the Contractor shall follow the manufacturer’s instruction for long-term storage. (This might include dewatering the pump suction/discharge lines and the barrel.)
FIELD PERFORMANCE TEST

- Pump Curve (within 3% of head and efficiency at design point)
- Vibration Test: running and natural frequencies (no natural frequencies within 15% of operating speeds)
- Pump Deflections: ≤ manufacturer’s requirements
- Sound Test (≤3 dBA above spec)
# Vertical Turbine Pumps

## Vertical Turbine Pump Performance Test Data Form

<table>
<thead>
<tr>
<th>Spec</th>
<th>Section</th>
<th>Tag</th>
<th>Pump S/N</th>
<th>P&amp;ID Drawing</th>
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<th>Nominal Test RPM</th>
<th>Measured Pump Design Condition</th>
<th>gpm @ ft.</th>
<th>Pump Design Shutoff</th>
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<th>Unit No</th>
<th>Static Discharge at Start</th>
<th>Motor S/N</th>
<th>Resonant Frequency</th>
<th>Measured Static Suction at Start</th>
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<td>Static Suction at End</td>
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<td>Motor Minimum Efficiency</td>
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<td>Background Sound dBA</td>
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<td>Motor Nominal Efficiency</td>
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<th>Sound Level dBA measured @</th>
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<td>Flow</td>
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<th>Discharge Pressure (PSIG)</th>
<th>Suction Pressure (PSIG)</th>
<th>Electrical Power (kW or hp)</th>
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<th>Pump Efficiency (%)</th>
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| Calculate Overall Efficiency at Design Condition: | % |
| Calculate Pump Efficiency at Design Condition: | % |
Vertical Turbine Pumps

VIBRATION/DEFLECTION

- Transducers on XYZ axis at upper and lower motor bearings
- Dial indicator at top of pump head

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Vertical Turbine Pumps
NATURAL FREQUENCY TESTING

Figure 9. Transfer function from Shasta PMP-001 modal survey
QUESTIONS
Closeout Documentation

- Commissioning system binders for O&M staff
  - Test results
  - Interconnect drawings
  - Control sequences
  - Field red-lines
Closeout Documentation

Example signed test form

```
FIELD FUNCTIONAL TEST DATA FORM

EBMUD Project Title: 2117 USL Ozone (Raw Water System)  
Test Date(s): 7/26/2018 - 8/3/2018

Equipment Name: Open Loop Cooling Water Pumps (District-Installed)  
Tag No.: PMP-510; PMP-520; PMP-530  
Section No.: 01 75 17, 46 05 10, 46 05 94
P&ID No.: 505.00-J-048.01; 048.02

6. Run Check
6.1 Operate the system for 1 hour in Auto. System operated as expected, without unexpected noise, or vibration.
   Pass Fail NA   Comments: Vibration testing not yet completed by Central Machine Shop

III. Participants/Witness
Test conducted:
By (signature): [Signature]   Date: 1-24-19
Title: Supervisor   Company Name: OURA

EBMUD Witness:
By (signature): [Signature]   Date: 7/26/18
Title: Senior Civil Eng.   Company Name: EBMUD
```
Closeout Documentation

Example P&ID red-line
Closeout Documentation

Example red-lined interconnect drawings
Lessons Learned
Roles and Responsibilities

- Who is the lead: CSG? CM? Contractor? O&M? Designer or Consultant?
  - Decide who leads what efforts
  - **Single-point authority** for directing each commissioning test program

- Commissioning coordination memo to Construction and client clearly defines roles, responsibilities, and limitations
Lessons Learned
Design Phase

- Design Contract Documents need to include:
  - well spelled-out process control strategies
  - developed programming and HMI/SCADA screens
  - Specify system integrator

- Perform a commissioning review to address:
  - Testing features built into the design – i.e., priming & flushing connections, pump recirc loops, measurement points
  - How to bring a system on-line?
  - How do you get electric power? What workarounds are necessary?
Lessons Learned
Construction Phase

- District CSG to promote understanding of commissioning process and workflow
  - Hold commissioning meetings with Construction team and Contractor (kick off, later – weekly)
  - Explain Commissioning sequencing and importance of Functional/Performance tests, Control System Functional Test, Startup Test
  - Enforce inclusion of commissioning related tasks in Construction Schedule and development of a separate, detailed commissioning schedule
  - Share commissioning daily reports with O&M staff
Lessons Learned
Construction Phase

- District Construction Team to:
  - Lead inspection of mechanical and electrical equipment by EBMUD construction inspectors during installation and prior to startup
  - Enforce hold points
    - test submittals, labelling, as-builts, O&Ms, PMs etc. prior to functional testing
    - Time assigned to testing should **not** be considered “float” and should not be taken or negotiated to meet deadlines
- District Training Coordinator:
  - Vendor Training: review training agenda and schedule just in time to have meaningful field training next to classroom training
Applying Lessons Learned

- Commissioning & Start-up Coordinator Central Point of Contact (one internal and one external personnel) for all commissioning-related work.

- CSG staff is preparing and sharing commissioning plans, test procedures and test forms proactively, vs. reactively marking up insufficient Contractor test submittals.

- Initiate and conduct courtesy walk-through inspections with maintenance and operations staff prior to major startup milestones (i.e. Energize MCC, pump system startup).

- During Startup Phase, conduct short, informal morning coordination meetings with Contractor foreman, resident engineer, construction inspector and relevant O&M staff.
Applying Lessons Learned

1. Issuing internal memo that outlines:
   - Major commissioning tasks
     - Spec sections related to tasks
   - Roles and Responsibilities
     - Internal groups responsible for tasks
   - Commissioning Flow Chart Guideline

2. Commissioning Kick Off Meeting
   - Share information with Contractor as guideline for scheduling
   - requested Contractor build in subtasks into 3-week look ahead
# Applying Lessons Learned

## Commissioning Tasks & Responsibilities

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<th>Subtask / Pre-requisite</th>
<th>Design Team</th>
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# Applying Lessons Learned – Contractor Comm. Schedule

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Commissioning
Short/Long Term Goals

- Train EBMUD construction inspectors in inspection of electrical and controls equipment

- Implement lessons learned from previous CSG projects in master specs for new in-house and Consultant-led Design projects

- Incorporate commissioning plans and commissioning sequencing flow charts into Design contract documents