On Demand Pump Condition Assessment and Optimization
Typical Pump Life Cycle Cost

Energy (80%)

Capital/Maintenance/Other (20%)

Typical Pump Life Cycle Cost

Typical pump life-cycle cost profile (Courtesy of Hydraulic Institute and Pump Systems Matter)
Lowering Pump Life Cycle Costs

Typical pump life-cycle cost profile (Courtesy of Hydraulic Institute and Pump Systems Matter)
Affinity Laws for Pumps, Simplified

- Non compressible fluid (water)
- Centrifugal type pump
- Flow is proportional to speed of the pump
- Power is proportional to the \((\text{speed})^3\) of the pump
Affinity Laws for Pumps

Variable Speed vs. Throttled

> Energy saved with variable vs. fixed speed drives at 100% and 60% flow, according to the static head and pump sizing. The operating point is represented as the intersection of the pump curve with the system curve.
Affinity Laws for Pumps

Comparison of two efficiency scenarios at different flow rates: 8 to 9% more efficient with variable speed drives at 60% flow
What Would be the Best Method to Operate and Manage a Pump Station?

**Pump Condition Assessment**
- Measure pumps’ capacity and efficiency with automated pump tests
- Reduce operating costs
- Improve pump reliability

**Dynamic Pump Optimization**
- Continually adjust pump station to changing pump and system conditions to operate at peak efficiency
- Reduce operating costs
- Increase pump life
What Operators See – 5 Identical Pumps
The Reality – Pumps are Hardly Identical

Peak efficiency: 58% 87% 75% 70% 81%

Running this pump wastes 29% more energy per volume pumped... versus running this pump
Preferred Operating Range

System Curve | Tested Head | Tested Efficiency | Factory Head | Factory Efficiency

Pump Damage
Excessive Vibration
Recirculation
Cavitation

Preferred Operating Range
70% to 120% of BEP

Pump Damage
Cavitation
# Effect of Pump Impeller Wear

<table>
<thead>
<tr>
<th>System Curve</th>
<th>Tested Head</th>
<th>Tested Efficiency</th>
<th>Factory Head</th>
<th>Factory Efficiency</th>
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- >30% Reduced Capacity

- 1011 gpm
- 1502 gpm
- 59.5%
- 85.5%

Effect of Pump Impeller Wear

- >30% Reduced Efficiency

System Curve | Tested Head | Tested Efficiency | Factory Head | Factory Efficiency

Flow [gpm]

Head [ft]

85.5%

59.5%

1502 gpm

1011 gpm
Pump Condition Assessments

Annual Audits

- Expensive
- Not repeatable
- Often not actionable
- No financial impact analysis
- Not available ad hoc
On Demand Condition Assessment

Asset Management

• Perform regular automated pump tests

• Track pump operation in real time on pump curves

• Generate monthly operating reports

• Identify underperforming pumps for repair
Pump Health Index (PHI)

PHI represents current peak efficiency versus factory peak efficiency.

- **75 PHI = Severely Worn**
- **101 PHI = Factory Condition**

Schedule repairs for pumps with PHI < 85
PHI Pump Health Tracking

- Intelligently target pumps for repair
- Opens the door for advanced metrics and advanced optimization
- See pump operating points in real time on up-to-date pump curves
Prioritize Repairs with Financial Metrics

Input:
- Replacement Cost
- Cost of Electricity
- Expected Pump Life
- Interest Rate

Schedule repairs for pumps with PHI < 85
Prioritize Repairs with Financial Metrics

Monthly Summary Report

<table>
<thead>
<tr>
<th>Monthly Summary</th>
<th>Aqua Water Supply Corp.</th>
<th>September, 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Volume</td>
<td>245.9</td>
<td>86%</td>
</tr>
<tr>
<td>Optimizer worked (%)</td>
<td>203,120</td>
<td>10.7%</td>
</tr>
<tr>
<td>Energy Saved (kWh)</td>
<td>24,377</td>
<td>Savings</td>
</tr>
<tr>
<td>Energy Saved (%)</td>
<td>314,683 kWh</td>
<td>$2,437.68</td>
</tr>
</tbody>
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Energy Saved - Year in Review

| Energy Saved Dollars ($) | $31,468.29 |

Past 12 Months

Pump Repair Recommendations:

Top Recommended Repairs:

- **Pump1**
  - TU/S Pump Station
  - ROI: 233.7%
  - Present Value: $47,737
  - Payback Period: 2.9 years

- **Pump3**
  - TU Pump Station
  - ROI: 112.9%
  - Present Value: $28,214
  - Payback Period: 5.6 years
What Would be the Best Method to Operate and Manage a Pump Station?

Pump Condition Assessment

- Measure pumps’ capacity and efficiency with automated pump tests
- Reduce operating costs
- Improve pump reliability

Dynamic Pump Optimization

- Continually adjust pump station to changing pump and system conditions to operate at peak efficiency
- Reduce operating costs
- Increase pump life
Pump Station Energy Consumption

- VFD Losses
- Motor Losses
- Pump Losses
- Friction Losses
- Useful Work
Specific Energy

Specific Energy = \frac{\text{Energy In (kWh)}}{\text{Volume Out (MG of water pumped)}}
Specific Energy vs. Flow

- 40 Hz
- 47 Hz
- 60 Hz

Specific Energy (kWh/MG) vs. Flow (GPM)
Dynamic Pump Optimization

Pump Station with 5 Pumps: Possible Operating Ranges

Flow (gpm) vs. Specific Energy (kWh/MG)

Best Solution | Best Pump Ranges | Outside Preferred Operating Range | Possible Pump Operation
Dynamic Pump Optimization
Pump Station with 5 Pumps: Best Pump Ranges

Best Solution | Best Pump Ranges | Outside Preferred Operating Range | Possible Pump Operation
Dynamic Pump Optimization

Pump Station with 5 Pumps: Best Pump Ranges

- Specific Energy (kWh/MG)
- Flow (gpm)

Best Solution | Best Pump Ranges | Outside Preferred Operating Range | Possible Pump Operation

Lower Pumping Cost
Dynamic Pump Optimization
Pump Station with 5 Pumps: Best Solution

Best Solution | Best Pump Ranges | Outside Preferred Operating Range | Possible Pump Operation
Continuous Optimization

Dynamic Pump Optimization

- Continually operate at peak energy efficiency
- Operate within each pump’s Preferred Operating Range
- Reduce leaks with Digital Transient Control
- Peak demand and time-of-day energy management
Typical Project Requirements

• System
  o Centrifugal Pumps

• Control Hardware
  o VFD Pump Motor Controllers (optimal)
  o PLC Pump Controller (existing or new)
  o Pump Assessment and Optimizing Panel

• Instrumentation
  o Suction Pressure or Wetwell Level
  o Discharge Pressure
  o Flow
  o Power per Pump
Typical Physical Installation

- Install Pump Assessment and Optimization Panel
- Install conduit connections from panel to PLC cabinet (120 VAC power and communications cable)
- Mount external cellular antenna (if necessary)
- Configure PLC to receive panel pump operation and speed recommendations
- Configure PLC to allow panel to read required PLC registers
- Configure HMI to enable operators to toggle optimization mode and display Specific Energy data
Case Study – Camp Swift High Service Pump Station

• 4 “Identical” Pumps – 200 HP
• Dramatically improved impeller life
• Energy Savings – 18%
Case Study – S8 Water Well

- 250 HP Well Pump
- Energy Savings – 30%
SH195 Pump Station

- 5 “identical” pumps – 1150 HP
- Discovered lead pump was significantly worn
- Energy Savings – 25%
Quiz

• PHI stands for Pump ________?

• True or False: in a reduced flow situation, best pump efficiency can be achieved through throttling.