Field Testing of Pump Stations

As Presented to 2010 OWEA Annual Conference

Testing As Performed for Columbus, Ohio in 2008-2009
The Columbus Pump Stations

- 70 pumps in 24 stations
- Storm water and wastewater
- 5 to 500 horsepower
- 4 inch to 48 inch discharge
- All physical styles
- All stations are telemetered to a central SCADA system, but instrumentation is generally sparse
Small Packaged Station
Large Vertical Station
Large Axial Flow Submersible Station
Objectives

• Which pumps are wasting energy?
• Which pumps are a priority for repair/replacement?
• What is appropriate budget to sustain the pumps?
• What information is needed?
• What is the best way to obtain that info?
The nature of the problem...

• Some old, some new, some borrowed, some blue!
• Some pumps are used hourly
• Some pumps are not used every year
• All stations are unmanned and remote
• Observable performance opportunity is very limited
• Pumps valued at $5,000 to $360,000 each
What causes loss of performance?

- Age, years
- Run time, hours
- Rotational speed, rpm
- Wear due to abrasives, grit
- Corrosion due to electrolysis, salts
- Operating point off of best efficiency point
Performance Curve Example
Why is pump performance so important?

- “Off” performance causes premature seal and bearing failure thru increase vibration
- Pump repair/replacement requires equipment downtime, labor, and capital
- Pump performance affects power consumption
- Power consumption directly affects operating costs
Typical telemetered signals

- On/off
- Accumulated run time
- Wet well level
- Pump amps
- Station entry
- Loss of power
Instrumentation & SCADA limitations

- Reliability of primary sensors for flow, pressure, level, or power
- Data transients and anomalies
- Loss of calibration, both sudden and decay
- Loss of transmission signal
- Limitations in data storage and accessibility

Telemetering is a great tool, but in most cases the SCADA WORLD is not enough to determine individual pump performance in a reliable way.
The case for field testing ...

If you want to know how your pumps are performing (overall efficiency), hands-on field testing is the best way to find out.
Field testing – what is involved?

1. Collect & review existing records
2. Visit sites & gather more input information
3. Analyze station hydraulics
4. Develop test procedure; know expected values
5. Install test instruments
6. Perform field test
7. Analyze results
8. Draw conclusions
Test parameters

• Flow or volume and time
• Level
• Pressure / head
• Power
Portable Ultrasonic Flowmeter
Portable Ultrasonic Level Sensor
Polyphase Wattmeter
The Columbus experience

- Flow metering versus draw test
- Pressure gauges vs pressure transducers
- Level sensing vs stick measurement
- Ammeter vs polyphase watt metering
- Measuring power vs use of power bills
- Electronic data logging vs manual
Points to consider in field testing

- Ultrasonic flow meters – may be affected by throttling valve
- Force mains are dynamic – water surge pressure waves may be experienced
- Pressures may be positive or negative – sensors must be selected accordingly
- Voltages over 600 – requires special power metering equipment
Further points to consider

• Field testing is not as accurate or as repeatable as factory testing
• High usage stations may justify permanent power monitoring
• Station voltages above 1000 volts, may justify permanent power monitoring
**Typical output from field testing**

**PUMP TEST DATA FORM**

<table>
<thead>
<tr>
<th>STATION NO:</th>
<th>SA-13</th>
<th>PWR FACT:</th>
<th>DATE:</th>
<th>5/14/09</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCATION:</td>
<td>585 Sullivan Ave</td>
<td>VOLTAGE:</td>
<td>CREW:</td>
<td>AC, ML, JR</td>
</tr>
<tr>
<td>PUMP NO:</td>
<td>#4, Runs 1 &amp; 2</td>
<td>SPEED:</td>
<td>WEATHER:</td>
<td>Partly Cloudy, ~ 75°F</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(A) Time, hh:mm:ss</th>
<th>(B) Wet Well Level, ft</th>
<th>(C) Discharge Flow, gpm</th>
<th>(D) Metered Flow, gpm</th>
<th>(E) Discharge Pressure, psig</th>
<th>(F) Electrical Power, kwatts</th>
<th>(G) Electrical Current, amps</th>
<th>(H) Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 10:24:12</td>
<td>240.51</td>
<td>-</td>
<td>-</td>
<td>20.44</td>
<td>16.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(2) 1:20</td>
<td>243.69</td>
<td>13.579</td>
<td>-</td>
<td>19.95</td>
<td>209.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(3) 1:40</td>
<td>247.18</td>
<td>14.752</td>
<td>-</td>
<td>20.53</td>
<td>218.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(4) 1:50</td>
<td>250.39</td>
<td>14.233</td>
<td>-</td>
<td>20.78</td>
<td>215.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(5) 1:50</td>
<td>253.57</td>
<td>13.805</td>
<td>-</td>
<td>20.63</td>
<td>209.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(6) 2:00</td>
<td>256.63</td>
<td>13.284</td>
<td>-</td>
<td>22.18</td>
<td>216.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(7) 2:00</td>
<td>259.24</td>
<td>13.717</td>
<td>-</td>
<td>22.46</td>
<td>216.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(9) 10:55:24</td>
<td>239.49</td>
<td>-</td>
<td>-</td>
<td>19.02</td>
<td>212.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(10) 1:20</td>
<td>243.01</td>
<td>15.031</td>
<td>-</td>
<td>19.84</td>
<td>212.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(11) 1:40</td>
<td>246.19</td>
<td>13.757</td>
<td>-</td>
<td>20.03</td>
<td>216.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(12) 1:50</td>
<td>249.71</td>
<td>15.238</td>
<td>-</td>
<td>19.32</td>
<td>212.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(13) 1:50</td>
<td>252.77</td>
<td>13.284</td>
<td>-</td>
<td>21.08</td>
<td>215.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(14) 2:00</td>
<td>255.95</td>
<td>13.805</td>
<td>-</td>
<td>21.76</td>
<td>211.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(15) 2:00</td>
<td>258.11</td>
<td>14.560</td>
<td>-</td>
<td>21.94</td>
<td>213.9</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**NOTES:**
Head performance curve

SA-13, Pump 4, Test 05/14/2009

Rated Head ≈ 52 ft

Test Flow ≈ 12,500 gpm

Factory Flow at Rated Head ≈ 15,700 gpm
Power performance curve

SA-13, Pump 4, Test 05/14/2009

- Test Power at Factory Flow ≈ 214 kW
- Factory Power at Factory Flow ≈ 196 kW
- Factory Flow at Rated Head = 15,700 gpm

Factory Power Curve
△ Fully Open Test Point
- Theoretical Test Curve
Overall efficiency performance curve

SA-13, Pump 4, Test 05/14/2009

- Factory Efficiency
- Fully Open Test Point
- Theoretical Test Curve

Factory Efficiency at Factory Flow ≈ 79%

Test Efficiency at Factory Flow ≈ 53%

Factory Flow at Rated Head = 15,700 gpm
Annual Pumping Cost

For a given pump, must know ...

- Rate of flow, \( Q \)
- Head at \( Q \)
- Annual run time
- Overall efficiency at \( Q \)
- Unit cost of power
Concept of efficiency deficiency

- Efficiency of perfect machine
  - Versus
- Overall efficiency as field measured
  - Efficiency of variable frequency drive
  - Efficiency of motor
  - Efficiency of transmission shaft & couplings
  - Efficiency of pump
Prioritization among multiple pumps

- Highest water horsepower (flow X head)
- Most annual run time
- Greatest overall efficiency deficiency
  - Perfect machine – field measured efficiency
- Highest unit power cost

Together this allows calculation of highest Present Value of “wasted” power – a priority rating tool
<table>
<thead>
<tr>
<th>Station No. (1)</th>
<th>Pump No. (2)</th>
<th>Test Flow gpm (3)</th>
<th>Test Head feet (4)</th>
<th>Water Horse-power whp (5)</th>
<th>Annual Run Time hours (6)</th>
<th>Overall Efficiency % (7)</th>
<th>Unit Cost of Power $/kwh (8)</th>
<th>Present Value of Lost Power $</th>
<th>Current Priority % (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA-02</td>
<td>1</td>
<td>3,900</td>
<td>106</td>
<td>104</td>
<td>1,213</td>
<td>44</td>
<td>0.042</td>
<td>38,992</td>
<td>15.7</td>
</tr>
<tr>
<td>SA-02</td>
<td>3</td>
<td>4,100</td>
<td>115</td>
<td>119</td>
<td>490</td>
<td>58</td>
<td>0.105</td>
<td>25,553</td>
<td>10.3</td>
</tr>
<tr>
<td>SA-02</td>
<td>2</td>
<td>3,900</td>
<td>102</td>
<td>100</td>
<td>878</td>
<td>50</td>
<td>0.042</td>
<td>21,339</td>
<td>8.6</td>
</tr>
<tr>
<td>SA-13</td>
<td>1</td>
<td>660</td>
<td>72</td>
<td>12</td>
<td>3,034</td>
<td>47</td>
<td>0.074</td>
<td>17,501</td>
<td>7.0</td>
</tr>
<tr>
<td>SA-13</td>
<td>2</td>
<td>730</td>
<td>80</td>
<td>15</td>
<td>2,619</td>
<td>55</td>
<td>0.074</td>
<td>13,471</td>
<td>5.4</td>
</tr>
<tr>
<td>SA-05</td>
<td>2</td>
<td>2,650</td>
<td>24</td>
<td>16</td>
<td>2,988</td>
<td>48</td>
<td>0.042</td>
<td>12,578</td>
<td>5.1</td>
</tr>
<tr>
<td>SA-01</td>
<td>2</td>
<td>6,050</td>
<td>52</td>
<td>79</td>
<td>959</td>
<td>62</td>
<td>0.042</td>
<td>11,297</td>
<td>4.5</td>
</tr>
<tr>
<td>SA-05</td>
<td>3</td>
<td>2,500</td>
<td>18</td>
<td>11</td>
<td>2,273</td>
<td>38</td>
<td>0.042</td>
<td>10,196</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>68</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>248,365</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Lost Power is the difference between operating the actual pump and a perfect machine.

2. Present Value is based on interest rate (%) of: 5 and period (years): 10
• Loss of pump performance and increased power consumption frequently goes undetected
• Loss of pump performance wastes energy and literally sends money down the drain
• In general, permanent metering systems do not measure pump performance reliably
• Pump performance can be measured in the field with calibrated portable instruments
• Field-measured pump performance is a useful tool to prioritize repair/replacement projects