Southerly WWTC Blower Serviceability Testing and Technology Selection for Energy Efficiency

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One Water Conference
Summary

• NEORSD Overview
• Project Background and Objectives
• Evaluation
• Design
• Performance and Feedback from Plant
NEORSD Southerly WWTC

- Two-stage advanced treatment facility
- Serves 500,000 residents of Cleveland, OH and Suburbs
- First Stage Aeration System (FSAS) reduce carbonaceous biological oxygen demand prior to Second State Aeration System (SSAS)
- Two stages operate in series during dry weather but after FSAS is capacity reached a portion of primary effluent directed to SSAS (capacity of 400 mgd)
Southerly WWTC Plant Upgrades

2012
ADF ~ 132 mgd
Peak ~ 175 mgd

2010 - 2015
Upgrade Primary Settling Unit Process

2016-2019
Upgrade Second Stage Lift Station

2012 - 2018
Upgrade and increase First Stage Activated Sludge System
Peak ~ 215 mgd process

2017 - 2021
Upgrade Second Stage Activated Sludge System
Overview and Objectives

• Four 4160V motor driven units installed in 1980s were oversized
• Units did not operate at best efficiency point
• At off-design flow rates, the risk of creating unusual aerodynamic flow patterns that can excite normal benign natural frequencies is increased
• Higher bearing loads which work against extended bearing life are encountered at low flows
• BC retained MSI for testing and analysis to help evaluate various options to “right size” the installation

Goal: Improve the mechanical reliability and efficiency of the unit process with improved automation and energy efficiency of the process air blowers.
Southerly WWTC Energy Demand

[Graph showing energy demand with labels for Plant Total, SSAS Blowers, and FSAS Blowers.]

- Plant Total: 32-67%
- SSAS Blowers: 10-22%

Dates from 8/29/2015 to 10/23/2015.
Annual Energy Costs

- Current 28,000 scfm: $450,000
- 20,000 scfm: $400,000
- Initial planned capability 12,500 scfm: $350,000
- Future 17,000 scfm: $300,000
Process Air Compressor Components

1. Compressor
2. 1250 HP Motor
3. Control Panel
4. Inlet Guide Vane Control
5. Discharge Diffuser Vane Actuator
6. Base Plate and Vibration Isolation
7. Power Termination Box
8. Vibration Monitoring

Flow
Turndown Limitations

- Disabled surge warnings and alarms
- Q<19,000 scfm resulted in T ~ 180° F discharge and alarm
- Manufacturer confirmed temp up to 220° F discharge was ok
Process Air Compressor Testing

Goals

1. Verify blower performance curves
2. Verify turndown capability
3. Check for vibration and resonant frequencies
   • Identify structural problems & weak points
   • Evaluate application of a VFD
Equipment Setup

1250 HP Motor

Gearbox/Blower
Equipment Setup

1. Tachometer
2. Torque gauge with telemetry
3. Shaft proximity sensors
Experimental Modal Analysis & Operating Deflection Shape

Compressor 4 Modal Data Points
(24 vibration locations/72 directions)
Compressor #4 Global ODS Vibration at 29.9 Hz (1x Input RPM) ISO View

- Junction box vertical support are flexing.
- Separation at the suction ducting vertical support
- Separation at the compressor gearbox connection to baseplate (both sides)
- Separation at baseplate connection (both sides)
Findings

- Field data compared well to the 1986 OEM HP vs. flowrate curve
- Rotordynamics lateral characteristics ok
- ~3% efficiency loss
- Unit #3 and #4 produced more flow than #1 and #2
- Mitigate soft foot issues
- Unit #3 Inlet Guide Vane indication and position not well matched

Discharge Diffuser Vanes must work in tandem with Inlet Guide Vanes to realize performance efficiency
Design Air Requirements – Modeled 10% Bins

Percent less than based on the midpoint of the bin. For the 0-10 percentile bin the values were based on the 5th (0.05) percentile.
## Operating Strategy Affects Demand

### FSAS Airflows Required at Standard Conditions, SCFM

<table>
<thead>
<tr>
<th>Tank Configuration</th>
<th>Design Minimum&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Current Annual Average</th>
<th>Current Maximum Month</th>
<th>Current Peak Hour</th>
<th>Future Annual Average</th>
<th>Future Maximum Month</th>
<th>Future Peak Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step Feed (2 Tanks)</td>
<td>6,500</td>
<td>11,200</td>
<td>22,900</td>
<td>27,500</td>
<td>13,200</td>
<td>28,300</td>
<td>33,800</td>
</tr>
<tr>
<td>Plug Flow (3 Tanks)</td>
<td>6,500</td>
<td>14,100</td>
<td>29,600</td>
<td>35,700</td>
<td>17,000</td>
<td>36,000</td>
<td>43,000</td>
</tr>
</tbody>
</table>

<sup>1</sup>Minimum airflows are based upon the 1) minimum process airflow requirements, 2) minimum aeration basin mixing and 3) minimum diffuser airflow

![Flow Quantity (MGD) vs Time](image)

- Designing for plug flow, peak hour future condition oversizes blower
- Oversizing increases surge potential
Alternative Layouts

- Alt 1 – Rehab existing ~ 11,000 to 28,000 scfm
- Alt 2 – Rehab existing, new impeller/motor ~16500 to 14500 scfm
- Alt 3 – New single stage ~ 6500 to 14500 scfm
- Alt 4 – New high-speed gearless turbo 6500 to 14500 scfm
- Alt 5 – Multistage
Existing Operating Envelope

- **Plug Flow Operation**
  - Current Annual Average
  - Future Annual Average
  - Current Maximum Month
  - Current Peak Hour
  - Future Maximum Month
  - Future Peak Hour
  - Blower Operating Range

- **Step Feed Operation**

- **Single Roots in Service**
  - Limited Turndown

- **Two Roots in Service**
  - 1 PAC in service
  - Excessive Capacity
  - 2 PACs in service
Modified Operating Range

- Plug Flow Operation
- Step Feed Operation
- One Single Stage Geared
- Two Single Stage Geared
- Three Single Stage Geared

Flow Rate (scfm)

- 1 PAC in service
- 2 PACs in service
- 3 PACs in service

- Current Annual Average
- Future Annual Average
- Current Maximum Month
- Current Peak Hour
- Future Maximum Month
- Future Peak Hour
- Blower Operating Range
# Preliminary Cost Analysis

## Alternative Costs ($)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Capital Cost</th>
<th>Annual O&amp;M Costs</th>
<th>Major Maintenance</th>
<th>Annual Energy 2017-2032</th>
<th>Annual Energy 2032-2047</th>
<th>30-Year NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Operation (Status Quo)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>520,000</td>
<td>744,000</td>
<td>-</td>
</tr>
<tr>
<td>1 – Rehabilitate Existing</td>
<td>3,709,000</td>
<td>37,000</td>
<td>390,000</td>
<td>292,000</td>
<td>508,000</td>
<td>17,210,000</td>
</tr>
<tr>
<td>2 – Rehabilitate Existing and Modify Impellers</td>
<td>4,259,000</td>
<td>37,000</td>
<td>390,000</td>
<td>310,000</td>
<td>548,000</td>
<td>18,630,000</td>
</tr>
<tr>
<td>3 – New Singe Stage</td>
<td>4,209,000</td>
<td>33,000</td>
<td>390,000</td>
<td>310,000</td>
<td>548,000</td>
<td>18,460,000</td>
</tr>
<tr>
<td>4 – New High Speed Direct Drive (air/magnetic bearing) 480V Turbo Blowers</td>
<td>4,674,000</td>
<td>29,000</td>
<td>600,000</td>
<td>275,000</td>
<td>536,000</td>
<td>18,310,000</td>
</tr>
</tbody>
</table>
Recommendation:

**Alternative 3 - New Single Stage**

- Ability to design for higher pressures (rise to surge reliability)
- Similar in energy savings
- Availability of high-speed turbo blower w/VFDs limited to 480V service, more susceptible to surge, corrosion or failure

- Least disruptive to 4160VAC electrical feed
- Time required for rehabilitation and “unforeseen” conditions
- Better comprehensive warranty than rehabilitation
Process Air Compressors

Located in
Compressor Building

MCC-CA1
MCC-CB1,CB2
MCC-CA2

Future

Process Air Compressors
New Process Air Compressors

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Building</td>
</tr>
<tr>
<td>Compressor Manufacturer</td>
<td>Siemens</td>
</tr>
<tr>
<td>Model Number</td>
<td>STC-GO (44SV-GL225)</td>
</tr>
<tr>
<td>Number of Compressors</td>
<td>Three</td>
</tr>
<tr>
<td>Capacity</td>
<td>14,500 scfm</td>
</tr>
<tr>
<td>Inlet Pressure</td>
<td>14.7 psia</td>
</tr>
<tr>
<td>Discharge Pressure</td>
<td>23.5 psia 9.2 psig</td>
</tr>
<tr>
<td>Motor Horsepower</td>
<td>900 Hp</td>
</tr>
<tr>
<td>Motor Speed</td>
<td>3,565 rpm</td>
</tr>
</tbody>
</table>
Process Air Compressors (Control Modes)

Local-Manual Mode

- Start/Stop
- Enter setpoint capacity (%)
- E-Stop

Remote-Manual Mode

- Start/Stop at OIT (Panelview) or SCADA (Wonderware) screens
- Enter setpoint capacity (%) OIT (Panelview) or SCADA (Wonderware) screens
  - PAC will adjust VDs to maintain this capacity.
- Stop at the vendor LCP
Performance / O&M Feedback

One unit in continuous operation since May 2018 ~ 70% to 100% capacity, most frequently ~ 12,500 scfm

Two parallel units as of early August

- Foundation footprint was critical to align discharge elbows
- Decision to incorporate a master PLC by vendor, or Owner area-wide PLC
- Selection of cooling system (air vs. water) was a key decision as well as the location of cooling unit
- Assignment of responsibility for motor starting profile is important
- Standard/alternative lubricants and responsibility to maintain
- Buy-in on automatic operation
Thank You

it’s about connecting

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# Blower Differentiating Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Direct Drive Turbo</th>
<th>Integrally Geared Turbo</th>
<th>Multi-stage centrifugal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Moderate</td>
<td>Highest</td>
<td>Low</td>
</tr>
<tr>
<td>Wire efficiency</td>
<td>~72%</td>
<td>~78%</td>
<td>~64%</td>
</tr>
<tr>
<td>Noise</td>
<td>Lowest (80 dBA)</td>
<td>Highest (94 dBA)</td>
<td>High</td>
</tr>
<tr>
<td>EI&amp;C Requirements</td>
<td>Highest</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Capacity, cfm</td>
<td>&lt; 15,000 (dual core)</td>
<td>&lt; 70,000</td>
<td>&lt; 50,000</td>
</tr>
<tr>
<td>Pressure, psig</td>
<td>&lt;15</td>
<td>&lt;30</td>
<td>&lt;25</td>
</tr>
<tr>
<td>RPM</td>
<td>&lt; 40,000</td>
<td>&lt; 25,000 (3,500 motor)</td>
<td>&lt; 3,500</td>
</tr>
<tr>
<td>Drive</td>
<td>Direct-inline</td>
<td>Planetary gear</td>
<td>Direct coupled</td>
</tr>
<tr>
<td>Bearings</td>
<td>Air Foil/magnetic</td>
<td>Oil lubricated journal</td>
<td>Roller bearing</td>
</tr>
<tr>
<td>Motor</td>
<td>Permanent magnet synchronous</td>
<td>Squirrel cage, induction, asynchronous</td>
<td></td>
</tr>
<tr>
<td>Cooling</td>
<td>Air or Water</td>
<td>Air or Water</td>
<td>Air</td>
</tr>
<tr>
<td>Capacity Control</td>
<td>VFD (up to 450 Hz)</td>
<td>Inlet guide and diffuser vanes</td>
<td>Inlet control valve</td>
</tr>
</tbody>
</table>