AWEA Collection System Committee

Pump Station Design

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A cell phone has 18 times more bacteria than a public restroom.
Topics

• Wet Well Design
• Surge Analysis
Wet Wells

- Sources of Information
- Potential Issues
- Wet Well and Pump Suction Design
- Modeling
Sources of Design Information

• Hydraulic Institute (HI) standards and publications
• Sanks “Pumping Station Design”
• General industry standards, regulations and guidelines (AWWA, OSHA, NACE, NFPA, NEC, etc.)
• Journal articles, webinars, and conference presentations
• Manufacturer’s literature, including white papers
• Folks in this room
Potential Problems Associated with Improperly Designed or Constructed Intake or Wet Well
Pumps

- Reduced flow and head capacity
- Effects on power requirements
- Cavitation damage
- Vibration and noise
- Clogging of Pumps
Causes

- Submerged vortices
- Free-surface vortices
- Excessive pre-swirl (rotational velocity) of flow entering the pump
- Unbalanced flow entering pumps
- Entrained air or gas bubbles
- Solids and grit accumulation

Just a Minor Reduction in Pumping Capacity
Wastewater Wet Wells

- Deposition of Solids
- Corrosion
- Odors

The “Insert Designer’s Name” Grit Island
Causes

- Wet Well Layout results in areas of low velocity
  - Creates islands of solids that require ongoing maintenance
  - Deposited solids are re-suspended during higher flow
    - Pump wear
    - Plugging
- Influent drops from significant height or is introduced in a manner that causes turbulence
Intake and Wet Well Design – HI

- Flow Chart Addresses
  - Free surface or not
  - Clear Liquid or not
- For non-clear liquids 3 types of wet wells configurations are addressed
  - Rectangular
  - Circular
  - Trench
- When model test is required
  - Flow – 100,000 gpm
  - > 40,000 gpm/pump
Approach Flow Conditions (wet well or sump configuration)

From Hydraulic Institute, ANSI/HI-2012, Pump Intake Design
HI Recommended Intake Structure Layout

Figure 9.8.1 — Recommended intake structure layout

Figure 9.8.2 — Filler wall details for proper bay width
Formed Suction Intake

Figure 9.8.3 — Type 10 formed suction intake
Multiple Pump Wet Pit

Figure 9.8.4A — Wet pit duplex sump with pumps offset
Figure 9.8.4B — Wet pit duplex sump with pumps centerline
Figure 9.8.4C — Dry pit/wet pit duplex sump

\[ D_{s_{\text{min}}} = 2.5D_b + 2C_W + C_b \]

\[ D_{s_{\text{min}}} = 2D_b + 2C_W + C_b \]

\[ D_S \text{ by pit design} \]
HI Thoughts on a Rectangular Wet Well

“The geometry of a rectangular wet well is not particularly suited for use with solids bearing liquids but with special provisions for frequent cleaning such wet wells may be acceptable”

- Use of Mixer
- Return flow from pump back to wet well
- Just plan on cleaning it out all the time
Trench-type Wet Well

Figure 9.8.6 — Trench-type wet well
Open Bottom Can Intakes

Figure 9.8.10 — Open bottom can intakes (pumps less than 315 l/s [5000 gpm])
Closed Bottom Can Intake

Figure 9.8.11 — Closed bottom can
Remedial Measures
(Example shown for sub-surface vortices)
Remedial Measures
(Example shown for sub-surface vortices)
Sanks Pump Station Design Manual

• Includes a “Survey of Two Thousand Wastewater Pumping Stations”
  – Failure to follow HI standards
  – Compares dry and wet pit arrangements
  – Maintenance – ability to access wet wells and pull pumps
  – Base elbow tearing away from slab – loose bolts, improper embedment, etc.
  – Deep wet wells and submersible pump cables
  – Flow entrance conditions – water constantly falling on the pumps
Modeling

- Computational Fluid Dynamics (CFD)
- Physical Model
To Line or Not to Line

• Only get one opportunity to easily line a wet well
• Depending on the system the liner should provide a service life of 15 to 50 years
• Can reduce maintenance by reducing cleaning effort
When can you use Computational Fluid Dynamics (CFD)?

- Essentially any fluid flow conditions
- Closed conduit or open channel
- Subcritical or supercritical flow
- Steady-state or transient
- Newtonian or non-Newtonian fluids
- Laminar or turbulent flow
- Single or multi-phase (air-water, sediment-water)
- Complex combinations of above conditions
CFD results provide powerful visualization of flow characteristics

- 3D solutions (x, y, & z components) at each finite volume element
- Velocity and acceleration
- Pressure (or water surface elevation)
- Volume fraction of air
- Concentration of tracer
- Particle flow path
- Several other parameters including user defined parameters
Physical Modeling or CFD?

• Physical modeling is accepted by Hydraulic Institute where as CFD modeling is not

• CFD modeling is an order of magnitude less expensive

• CFD modeling can be performed with significantly less time

• CFD modeling allows for efficient evaluation of several alternatives
Summary

• CFD and physical modeling provide valuable and cost effective design guidance

• Building computer files is cheaper than plywood, nails, Plexiglas, and glue (i.e. CFD is cheaper than physical models)

• Plywood, nails, Plexiglas, and glue are cheaper than concrete, rebar, pipes, and pumps (i.e. a physical model is cheaper than the actual pump station)
Surge Analysis

Water hammer
(or Hydraulic Transients)
in Pump and Piping Systems
Surge Analysis

- Causes
- When to Perform an analysis
- Analysis Methods
- Mitigation Methods
Common Causes of Transients

- Uncontrolled Pump startup/shutdown (managed by design and operation procedures)
- Uncontrolled valve opening/closure (managed by design and operating procedures)
- Uncontrolled pump shutdown (power failure)
- Valve Malfunction or operator error
- Specialty valve operation (check, air release, pressure reducing, pressure relief)
- Pipe rupture
- Turbine load rejection
When to Perform a Surge Analysis

• You feel the hair stand up on the back of your neck?
• No Standards or Guidelines
• Flygt “Transient Analysis” Document
  • Pipeline Profile
  • Length – Greater Than 1000 ft
Analysis Methods

- Bentley Hammer
- AFT Impulse
- Numerous Vendor Packages
Mitigation Methods

The Oregonian, Thursday, December 6, 1984

Pipe’s gush kills 4 at Preston plant

RESSURE BLAST — Four workers were swept to their deaths Wednesday when pressure burst an intake flow pipe at power plant near Preston, Idaho. Water shot high into air, damaged front of plant.
Combination Air Valve

- Have a large orifice for air inflow but a small orifice for air outflow.
- This feature is extremely important to avoid transients caused by valve slam.
- But they are often in remote locations that do not allow easy/consistent maintenance.

RESULT — WATER HAMMER CONTROL

<table>
<thead>
<tr>
<th>PRESSURE RANGE</th>
<th>ORIFICE SELECTION CHART</th>
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<tr>
<td>0-150</td>
<td>0-300</td>
</tr>
<tr>
<td>3/32</td>
<td>1/16</td>
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<td>3/16</td>
<td>5/32</td>
</tr>
<tr>
<td>3/8</td>
<td>7/32</td>
</tr>
</tbody>
</table>

S-1500C
Surge chambers are closed tanks which contain pressurized air and water. Dual connections can be used to minimize their size.

Air compressor is used to control the water level. (Note: a bladder system can be used to eliminate the need for the compressor)

Figure 9. Surge Chamber Schematic

- Provide very good control but are much more expensive than air valves
Pump Motor Flywheels

- Pump motor flywheels provide a source of inertial energy to keep pumps spinning longer to reduce down surge pressures.
- May be less expensive than a surge chamber
- May be difficult to get reliable design from pump manufacturers which can increase pump operating risks.
Surge Anticipator Valves

- Valve opens when pressure falls below specified point
- Valve remains open for pre-set time
- Valve closes slowly to prevent high pressures resulting from rapid valve closure.
- If not set properly they can actually make the water hammer problem worse
- Require a discharge location
Surge Relief Valves

• Valve opens when pressure exceeds specified point
• Can be used to control positive pressures in the system
• Do little to control negative pressures and column separation
• Require a discharge location
Check Valves

- Limit reverse flow
- Standard swing check valves can generate transients due to slamming operation
- If system requires a surge chamber, must use quick closing, non-slam type check valve at pump discharge
  - Slanting disk buffered check valve
  - Nozzle check valve
Surge analysis cost is often very small compared to the risk of not evaluating and protecting the system.
Questions?