PROVING THAT BLADDER SURGE TANKS CURED EXCESSIVE
SURGE CONDITIONS IN A 30” FORCE MAIN

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Background

The Sanitation District No. 1 of Northern Kentucky (SD1) provides wastewater collection and treatment for approximately 350,000 people in Campbell, Kenton, and Boone Counties. SD1’s system includes about 140 pump stations, 75 miles of force mains and about 1,500 feet of gravity sanitary sewers. The Lakeview Pump Station (PS) in Fort Wright, Kentucky, which was constructed in the mid 1970s, is a wet well-dry well PS with 8 centrifugal pumps (4 parallel sets of 2 pumps in series) with a combined pumping capacity of 21 MGD. The Lakeview force main (FM), which is primarily 30-inch-diameter prestressed concrete cylinder pipe (PCCP), is over 3 miles long. The system operates at pressures over 200 psi and was experiencing transient pressures (surge) up to 500 psi. Full vacuum conditions and subsequent vapor cavity collapse were also occurring in the higher portions of the FM (Figure 1) during surge events, which had routinely generated vibrations and noise at nearby homes resulting in customer complaints. In June 2009, a power outage at the PS created surge conditions that split a 14” gate valve in the PS (Figure 2), flooded the dry well and submerged the pumps and motors.

Evaluation of the Problem

To alleviate both the vapor cavity collapse and high-pressure surge conditions resulting from power outages and other emergency pump shutdowns as well as normal pump starts and stops, SD1 contracted with Hazen and Sawyer (H&S) to evaluate alternatives for a permanent solution. The evaluation included development and detailed calibration of a surge model using KYPipe’s PIPE2008 Surge software. A unique feature of the calibration was the use of transient pressure recorders capable of capturing dynamic pressure readings up to 1,000 Hz during surge
events that may only last for a few milliseconds (Figure 3). Pressure recorders were placed at the PS and on the problematic section of the FM to monitor normal pump operation and emergency pump shutdown scenarios (Figures 4 & 5). The calibration yielded a good understanding of the root causes of transients in the system, including vapor cavity collapse in the FM.

Once the model was developed and calibrated (Table 1), alternatives were evaluated to address transients at the PS and in the FM. These alternatives included installation of one or more bladder surge tanks at several locations in various combinations with pump control valves, fast-closing check valves, surge relief valve and/or combination air/vacuum valves.

**Implementation of the Solution**

Installation of two 7,500-gallon bladder surge tanks and four fast-closing check valves was selected as the most reliable, cost-effective solution to control surge conditions in the pump station and force main. Due to space constraints, the surge tanks were installed in a below-ground vault (Figure 6) outside of the pump station. Various instrumentation and controls were installed to monitor operation of the surge tanks, protect the tank components, and monitor surge pressures. These devices were used during and subsequent to startup to assess the effectiveness of the improvements and to more precisely calibrate the surge model. H&S coordinated with the contractor, surge tank manufacturer and SD1 to conduct several rounds of startup testing and performance monitoring, which were completed in January 2011.

The performance monitoring consisted of monitoring the flow rates from each pump set, water levels in the two bladder surge tanks, and transient pressures at multiple locations in the PS and on the FM. The data were analyzed and compared to pre-construction conditions and to the specified design criteria and performance conditions. Results showed successful control of pressures in the FM (Figure 7) and dramatic improvement in the PS (Figure 8). However, under pump trip conditions, check valve slam was resulting in pressure spikes in the PS that exceeded
the specified performance criteria. Thus, the project team coordinated with the manufacturers of the surge tanks and check valves to make modifications to the check valves that resulted in a significant reduction of these pressure spikes. Further operational adjustments brought the surge pressures within the specified limits—even under worst-case conditions (Figure 9).

The refined surge model that resulted from this effort has been used to evaluate alternatives for future PS and FM upgrades. The primary transient pressure monitor and other instrumentation at the PS will remain for long-term performance evaluation, and the data collected during the first year will be used as a baseline against which to evaluate future system performance. SD1 will continue to monitor operating data so that any problems can be promptly identified and addressed to ensure long-term reliability of the improvements.

Conclusion

This project demonstrates a successful approach to implementing and evaluating the effectiveness of surge improvements in an existing pumping system. It teaches important lessons on the implementation of surge improvements, including the value of performance monitoring and the importance of coordination among the owner, engineer, and equipment manufacturers throughout design and construction. This paper will discuss the following topics:

- Surge model calibration, including modeling challenges and limitations
- Design considerations for use of bladder surge tanks and check valves to control surge
- Performance monitoring procedures, results and subsequent equipment modifications
- Comparison of pre- and post-construction surge conditions
- Comparison of post-construction surge conditions to model-predicted surge conditions
- Evaluation of equipment performance vs. manufacturers’ literature & specified criteria
- Challenges and lessons learned from the project.

Through the successes and lessons learned from this project, participants will gain a better understanding of transient pressure concerns, surge attenuation, bladder surge tanks, and transient pressure monitoring.
Figure 1. Lakeview Force Main Profile

Figure 2. 14” Gate Valve at Lakeview Pump Station after June 2009 Surge Event

Figure 3. TP-1 Transient Pressure Monitor Data Recording Functionality (Courtesy of Pipetech International)

Figure 4. Pump Station Pressure Monitoring of 1 Pump Set Trip Prior to Construction
Figure 5. Force Main Pressure Monitoring of 1 Pump Set Trip Prior to Construction

![Graph showing pressure monitoring with peak FM pressure spike ~78 psi and minimum FM pressure as full vacuum.]

Table 1. Surge Model Calibration Results

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Pressure at PS</th>
<th>Pressure on FM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Field</td>
<td>Model</td>
</tr>
<tr>
<td>1 Pump Set Running Normal Shutdown</td>
<td>94-292</td>
<td>60-280</td>
</tr>
<tr>
<td>2 Pump Sets Running Normal 1 Set Shutdown</td>
<td>127-215</td>
<td>120-225</td>
</tr>
<tr>
<td>1 set Pump Trip</td>
<td>15-394</td>
<td>21-389</td>
</tr>
</tbody>
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Figure 6. Installation of Bladder Surge Tanks in Vault

![Image of bladder surge tanks installed in a vault.]

Copeland
Proving that Bladder Surge Tanks Cured Excessive Surge Conditions in a 30” Force Main
Page 5 of 6
Figure 7. Force Main Pressure Monitoring of 1 Pump Set Trip with Surge Tanks In Service

Figure 8. Pump Station Pressure Monitoring of 1 Pump Set Trip with Surge Tanks in Service

Figure 9. Pump Station Pressure Monitoring of 4 Pump Sets Trip with Surge Tanks in Service, After Additional Modifications