Water Hammer

Tackling Transient Events at San Jose Water Company

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What is Water Hammer?

Water hammer events (transient events) are disturbances in water flow from one steady-state condition to another.

What are Typical Causes of Water Hammer?

- Pump operations
- Valve operations
- Main breaks
- Rapid demand changes (hydrant flow)
Wave Propagation Animations

Pump Start Up

Pump Shut Off

Pressure Scale

Hi
Low
Hydraulic transient related concerns at SJWC:

- Infrastructure damage
- Property damage
- Regulatory compliance
- Public safety (pipe ruptures)
- Public health (negative pressures)
- Complaints
Transient Analysis – Goals and Approach

• SJWC Goals
  – Verify existence and extent of problem
  – Determine mitigation measures

• SJWC Approach
  – Obtain necessary knowledge and analysis tools
  – Conduct field tests
  – Analyze data
  – Select surge protection devices
Transient Analysis – Vickery Pump Station

Background

– History of problems and mitigation efforts
– New booster pumps installed with pump control valves
– Surge tanks installed
Field Testing

– Select strategic locations to install pressure loggers
  • Pump discharge
  • High pressure regions
  • Low pressure regions
  • Dead end mains

– Coordinate with Operations department
  • Pump operations
Transient Analysis – Vickery Pump Station

Pump Start Up – Pump Control Valve Setting

186 psi

116 psi

Time (s)

Pressure (psi)

1-Minute Opening

2-Minute Opening
Transient Analysis – Vickery Pump Station

Pump Shut Off – Pump Control Valve Setting

- 132 psi
- 11 psi
- 12 psi
- 10 s

1-Minute Closing
2-Minute Closing

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Pressure (psi)
Time (s)
Transient Analysis – Vickery Pump Station

Pump Start Up and Shut Down – Pump Discharge

Pressure (psi)

Time (s)

186 psi

116 psi

18 psi

132 psi

11 psi

No Surge Tank
Transient Analysis – Vickery Pump Station

Pump Shut Off With Surge Tank - Pump Discharge

Pressure (psi) vs. Time (s)

- 132 psi
- 11 psi
- 88 psi

11 psi

No Surge Tank
Surge Tank
Transient Analysis – Vickery Pump Station

Pump Start Up and Shut Down – Low Pressure Service

- 125 psi
- 73 psi
- 63 psi
- -14.7 psi

Pressure (psi) vs. Time (s) for No Surge Tank
Transient Analysis – Vickery Pump Station

Pump Shut Off With Surge Tank - Low Pressure Service

- 73 psi
- 14.7 psi
- 38 psi

Pressure (psi) vs. Time (s)
Transient Analysis – Vickery Pump Station

Pump Start Up and Shut Down – High Pressure Hydrant

Static Pressure ~ 171 psi

Run Pressure ~ 173 psi

197 psi

143 psi

No Surge Tank
Transient Analysis – Vickery Pump Station

Pump Start Up With Surge Tank – High Pressure Hydrant

- Pressure (psi)
  - 200
  - 195
  - 190
  - 185
  - 180
  - 175
  - 170

- Time (s)
  - 0
  - 5
  - 10
  - 15
  - 20
  - 25
  - 30
  - 35
  - 40

- Static Pressure 171 psi
- Record Start Trigger ~ 178 psi
- Record Stop Trigger ~ 173 psi
- 197 psi
- 188 psi

No Surge Tank
Surge Tank

Vickery Pump Station

Transient Analysis – Vickery Pump Station

Record Start Trigger ~ 178 psi
Record Stop Trigger ~ 173 psi
Static Pressure 171 psi
Transient Analysis – Vickery Pump Station

Pump Shut Off With Surge Tank – High Pressure Hydrant

With surge tank online, transient waves remained within recording triggers.

Static Pressure 171 psi

Upper Record Start Trigger ~ 178 psi

Lower Record Start Trigger ~ 161 psi

143 psi
Background

– History of problems
– Mitigation efforts
Field Testing
- Strategic locations to install pressure loggers
- Coordination with Operations department

Surge Modeling
- Calibration of existing system
- Future system (with surge protection device)
Transient Analysis – Pavilion Pump Station

- Reservoir
- Transmission Main Split
- Logger Pump Discharge
Transient Analysis – Pavilion Pump Station

Pump Start Up - Pump Discharge

- Reflection wave from transmission main split
- Reflection wave from reservoir

201 psi
198 psi
145 psi

Field
Model
Transient Analysis – Pavilion Pump Station

Pump Shut Off - Pump Discharge

Pressure (psi)

Time (s)

156 psi
186 psi
200 psi
196 psi
186 psi
70 psi
64 psi
Reflection wave from reservoir
Reflection wave from transmission main split

Field
Model
Initial Surge Tank Sizing:

\[ T_c = \frac{2L}{a} \]

\[ T_c = \frac{2 \times 4,080 \text{ ft}}{1,800 \text{ ft/s}} = 4.5 \text{ s} \]

Surge Tank Volume = \( T_c \times Q \)

\[ \text{Surge Tank Volume} = 4.5 \text{ s} \times 8.7 \text{ gal/s} = 40 \text{ gal} \]
Transient Analysis – Pavilion Pump Station

Pump Start Up - 50% Water / 50% Air

- 201 psi
- 200 psi
- 160 gal
- 145 psi
- 80 gal
- 40 gal
- 265 gal

Pressure (psi) vs. Time (s)
Transient Analysis – Pavilion Pump Station

Pump Start Up - 35% Water / 65% Air

Pressure (psi) vs Time (s)

- 201 psi
- 200 psi
- 195 psi
- 190 psi
- 185 psi
- 180 psi
- 175 psi
- 170 psi
- 165 psi
- 160 psi
- 155 psi
- 150 psi
- 145 psi

Time (s)

- 0 s
- 5 s
- 10 s
- 15 s
- 20 s
- 25 s
- 30 s
- 35 s

Legend:
- No Surge Tank
- Surge Tank (40 gal)
- Surge Tank (80 gal)
- Surge Tank (160 gal)
- Surge Tank (265 gal)
Transient Analysis – Pavilion Pump Station

Pump Trip - 2 Pumps 50% Water / 50% Air

- 236 psi
- 40 gal
- 80 gal
- 160 gal
- 265 gal
- 15 psi

Time (s)
Transient Analysis – Pavilion Pump Station

Pump Trip - 2 Pumps 35% Water / 65% Air

- 236 psi
- 80 gal
- 160 gal
- 265 gal
- 15 psi

Time (s) vs. Pressure (psi)

No Surge Tank
Surge Tank (80 gal)
Surge Tank (160 gal)
Surge Tank (265 gal)
Hydraulic transients are regularly occurring in water distribution systems

Transient waves can be far more extreme than anticipated

Transient waves propagate further than expected

Certain surge protection devices can be very effective, others not as effective

Surge protection devices can help mitigate potential public safety and public health concerns

Surge modeling is highly recommended for sizing surge protection devices

More transient analysis needs to be performed
Contact Information

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