Consolidated Edison Company of New York

Water Hammer Prevention:
Innovating with New Technologies

Presented by:

Dowlatram Somrah, ME, PE

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Agenda

- **Presenter Introductions**
- **Con Edison Steam System Overview**
- **Trap Operation**
- **Effects of External Water**
- **Flow of Condensate**
- **Physical Testing**
- **System Modeling**
  - Development and implementation of a pilot water hammer prevention model
- **Benefits of the Water Hammer Prevention Model**

Presenter Introductions

Dowlatram Somrah, ME, PE

- Section Manager – Steam Distribution Engineering
- Education
  - Cooper Union College – Undergraduate and Graduate Engineering Programs

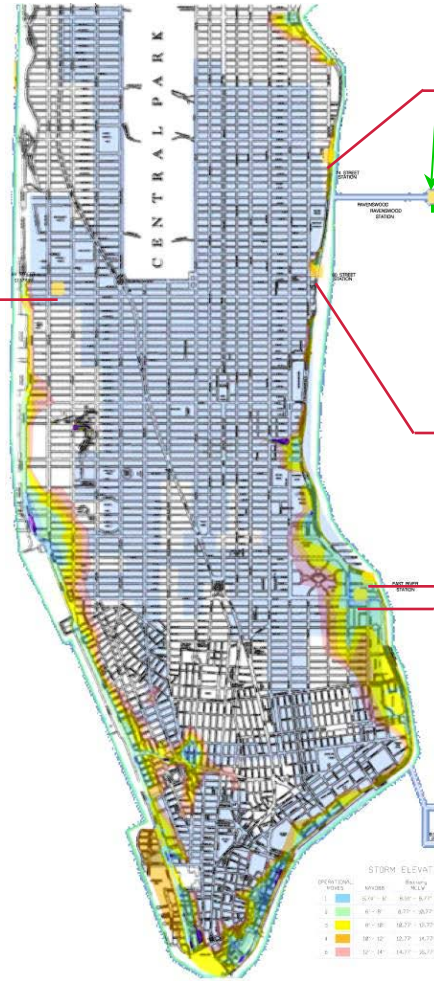
Frank A. Cuomo, PE, PMP

- Project Manager – Steam Distribution
- Education
  - Manhattan College School of Engineering
  - Baruch Zicklin Graduate School of Business

Con Edison Steam System Overview

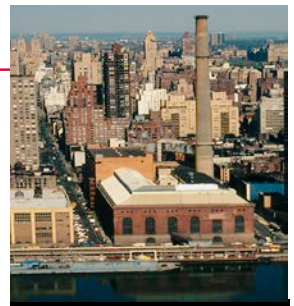
- **106 miles**
- **24.9 billion Lbs.**

59th Street Station

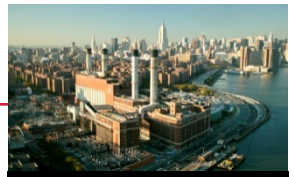


Via Tunnel

Ravenswood A House



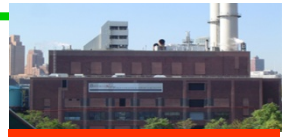
74th Street Station



East River Station

60th Street Station

Via Tunnel



B.N.Y.C.P. Plant

Manhattan

Brooklyn

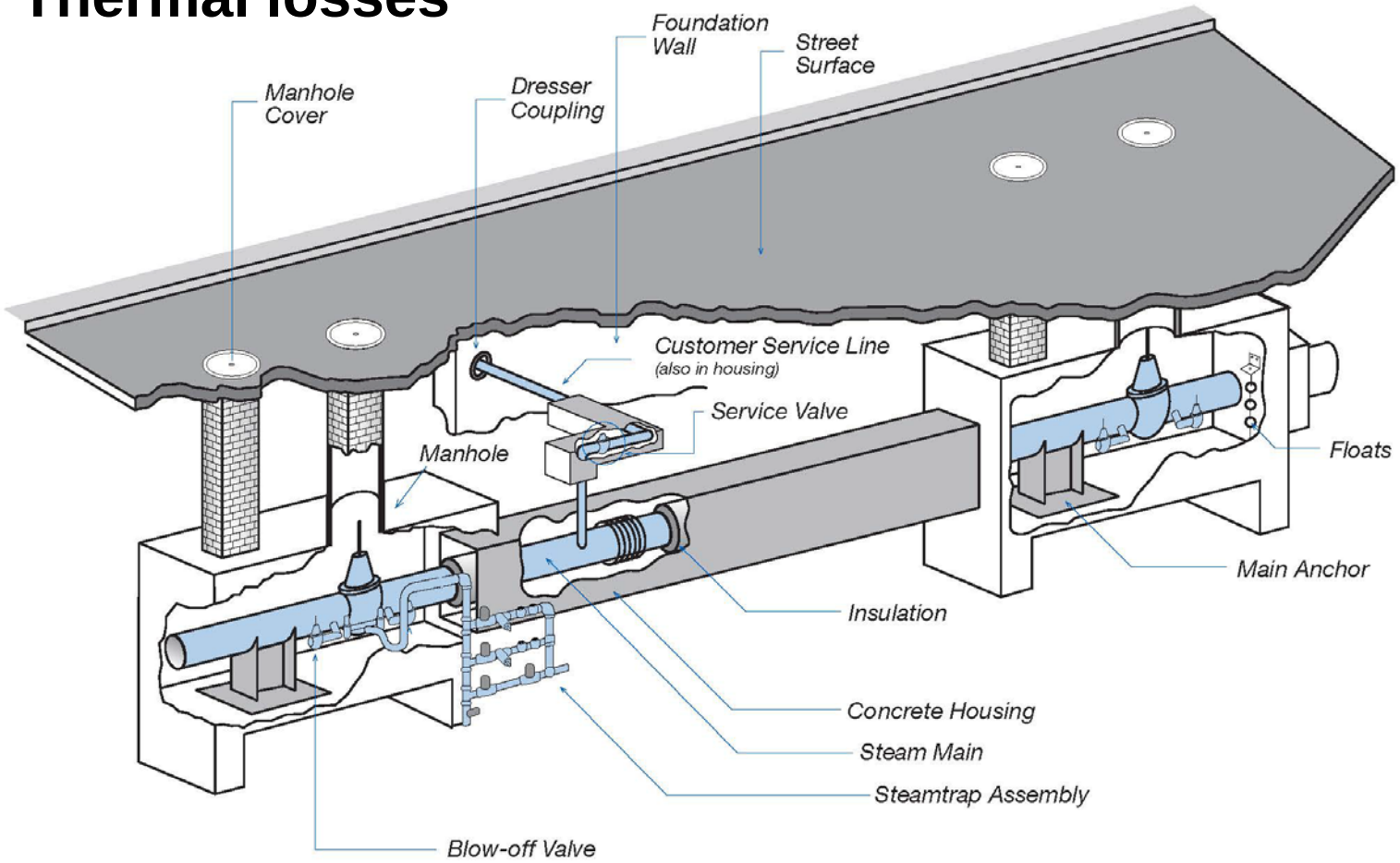
Queens

Con Edison Steam System Overview

- **Peak ~9,600 Mlb/hr**
  - **Commercial 48%**
  - **Residential 19%**
  - **Hospitals 9%**
  - **Hotels 6%**
  - **Museums 2%**
  - **Other 16%**

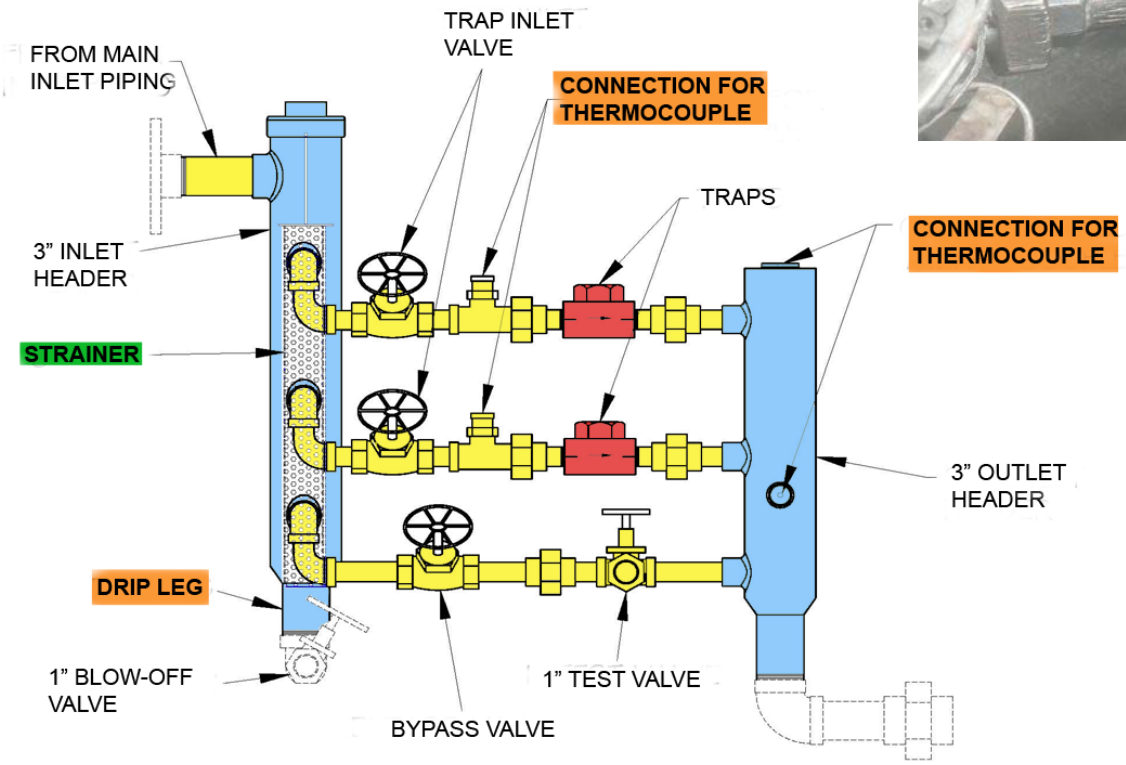
Con Edison Steam System Overview

- **106 miles**
- **Thermal losses**



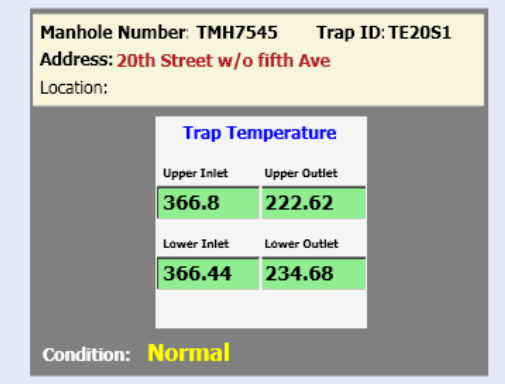
Trap Operation

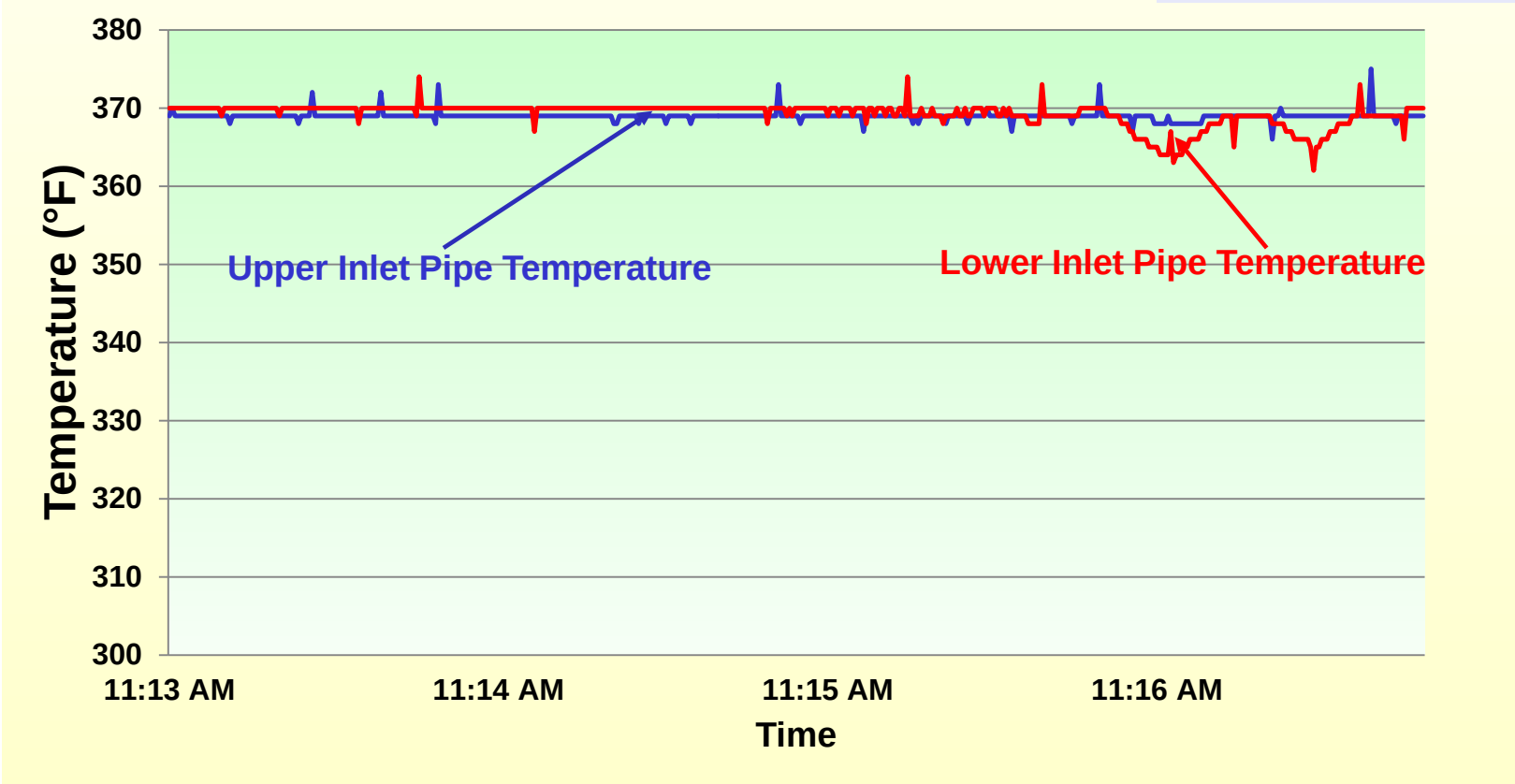
- **834 trap stations**
- **Monitor status**
- **Amount of condensate**



Trap Operation

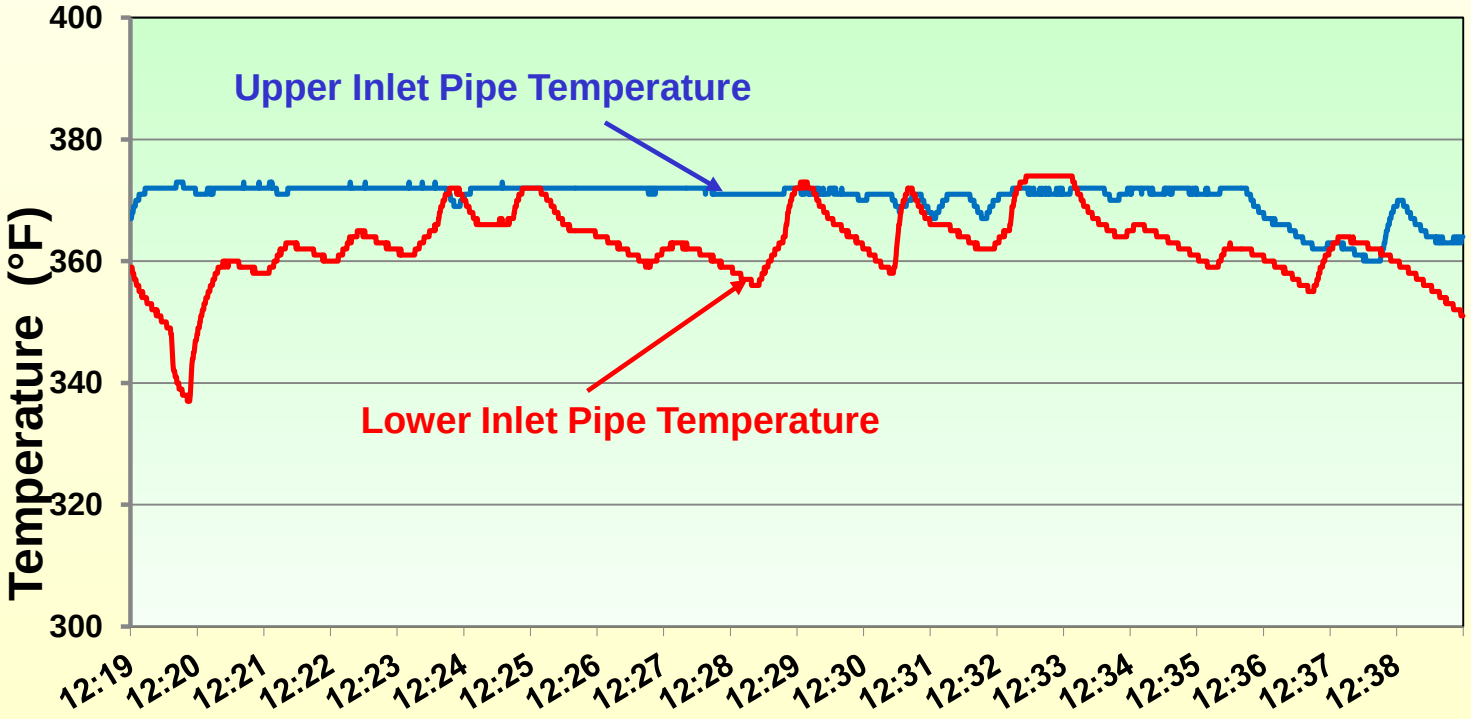
- **Upper and lower traps - normal**
- **Inlet temperatures within 5° F**





Trap Operation

- **Upper trap – normal; lower trap - overwhelmed**
- **Inlet temperatures vary by more than 20° F**



Effects of External Water

- **Wet insulation**
- **Partially or fully submerged steam mains**
- **Vapor condition**
- **Increased rate of condensate generation**

Vapor Condition - Moderate

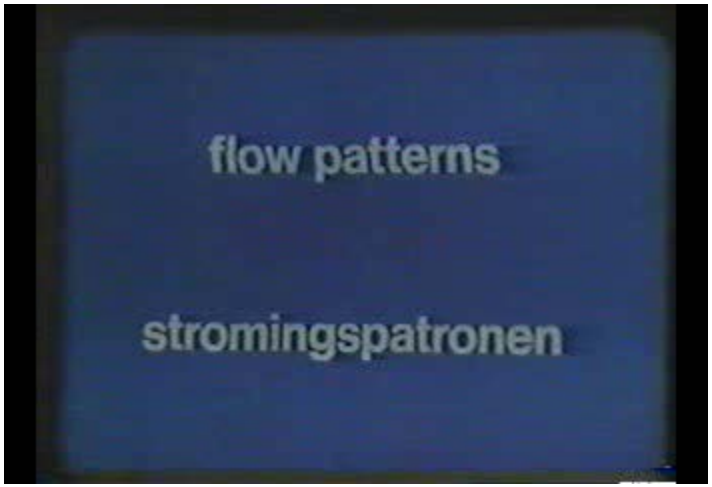
Flooded Manhole

Effects of External Water

- **Main submerged**
- **No vapor**
- **Main possibly filled with condensate**

Flow of Condensate

- **Video – flow of gas and liquid in clear PVC**



Flow of Condensate - Theory

- **Transition from stratified flow to annular flow described by Froude number (F_r)**
  - **Non-dimensional ratio of momentum and gravity**
  - **Pipe diameter dependent**

$$F_r = \frac{U_{sg}}{\sqrt{g \times D}} \times \frac{\rho_G}{\sqrt{\rho_L - \rho_G}}$$

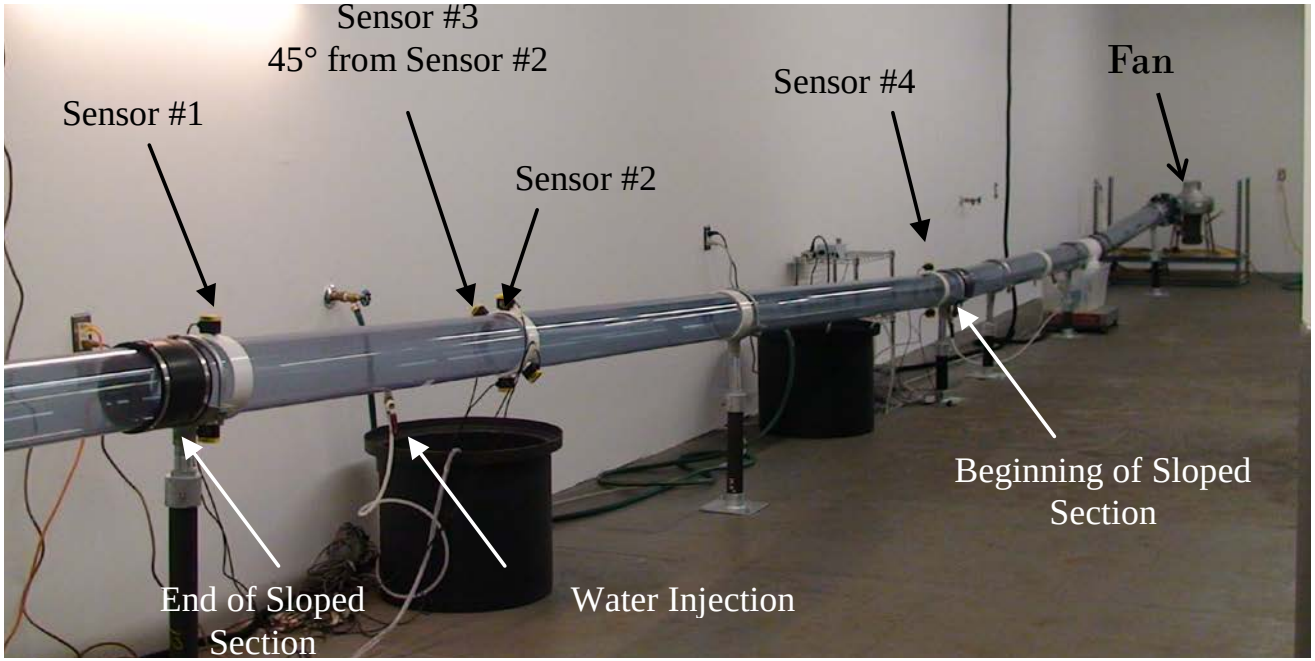
U_{sg} = velocity of steam
g = gravitational constant
D = internal pipe diameter
ρ_G = density of steam
ρ_L = density of condensate

Physical Testing

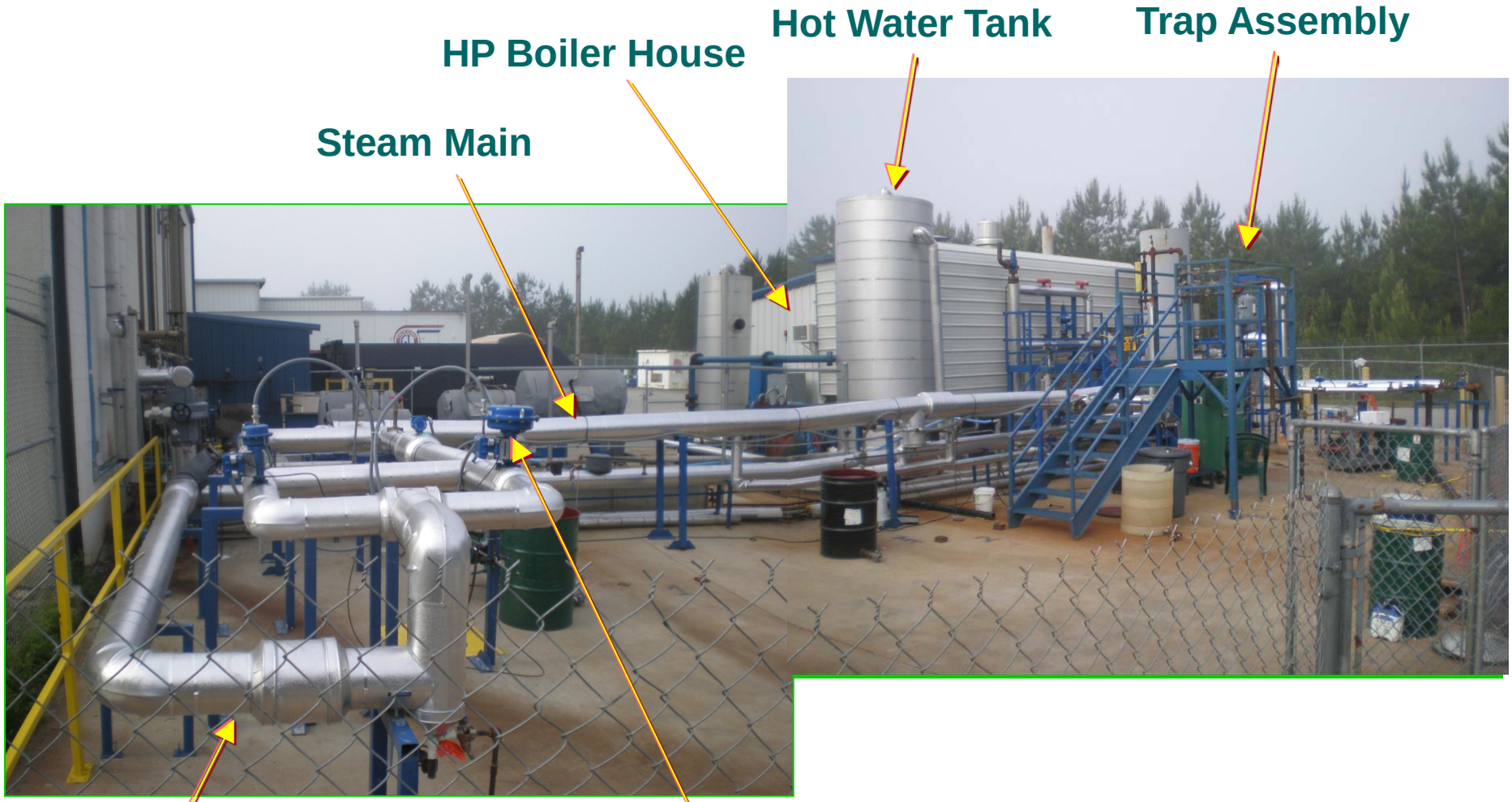
- **Geometrical configurations**
  - **Straight pipe – slopes from 1° to 5°**
  - **Pair of 22½° elbows**
  - **Pair of 45° elbows**
  - **Pair of 90° elbows with h/d = 2 to 12**
  - **Bends with shallow to steep angle changes**

Physical Testing – Air-Water

- **6” diameter clear PVC pipe**
- **1° through 5° slopes**
- **Varied water injection rate**
- **Varied air flow velocity**

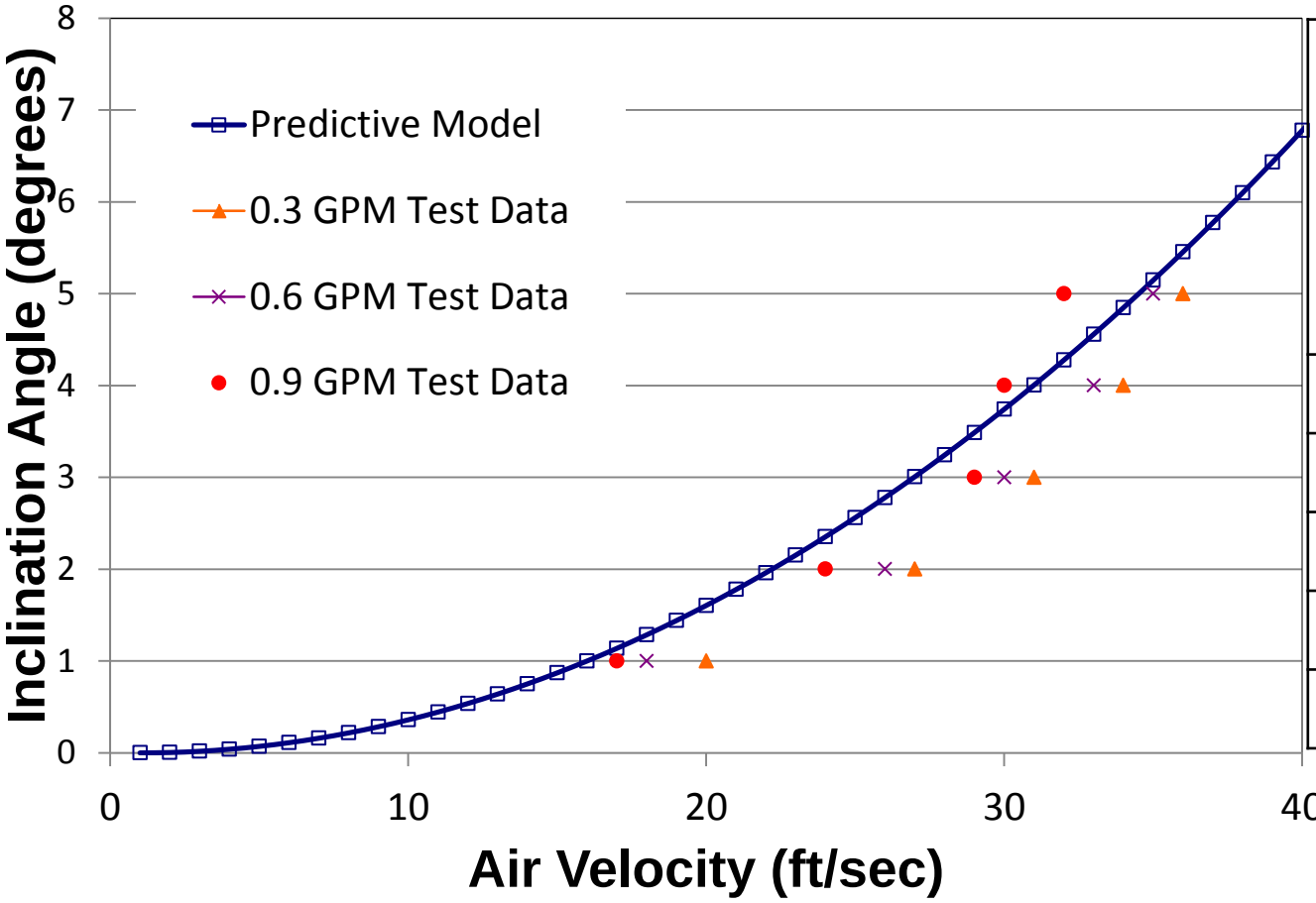


Physical Testing - Steam Validation



Physical Testing - Results

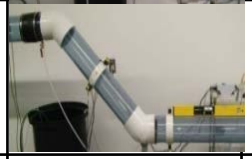
- **Air flow to push water up sloped pipe**



Pipe Slope	6" Pipe	
	Air Velocity (ft/sec)	Steam Velocity (ft/sec)
1°	20	8
2°	27	11
3°	31	13
4°	34	14
5°	36	15

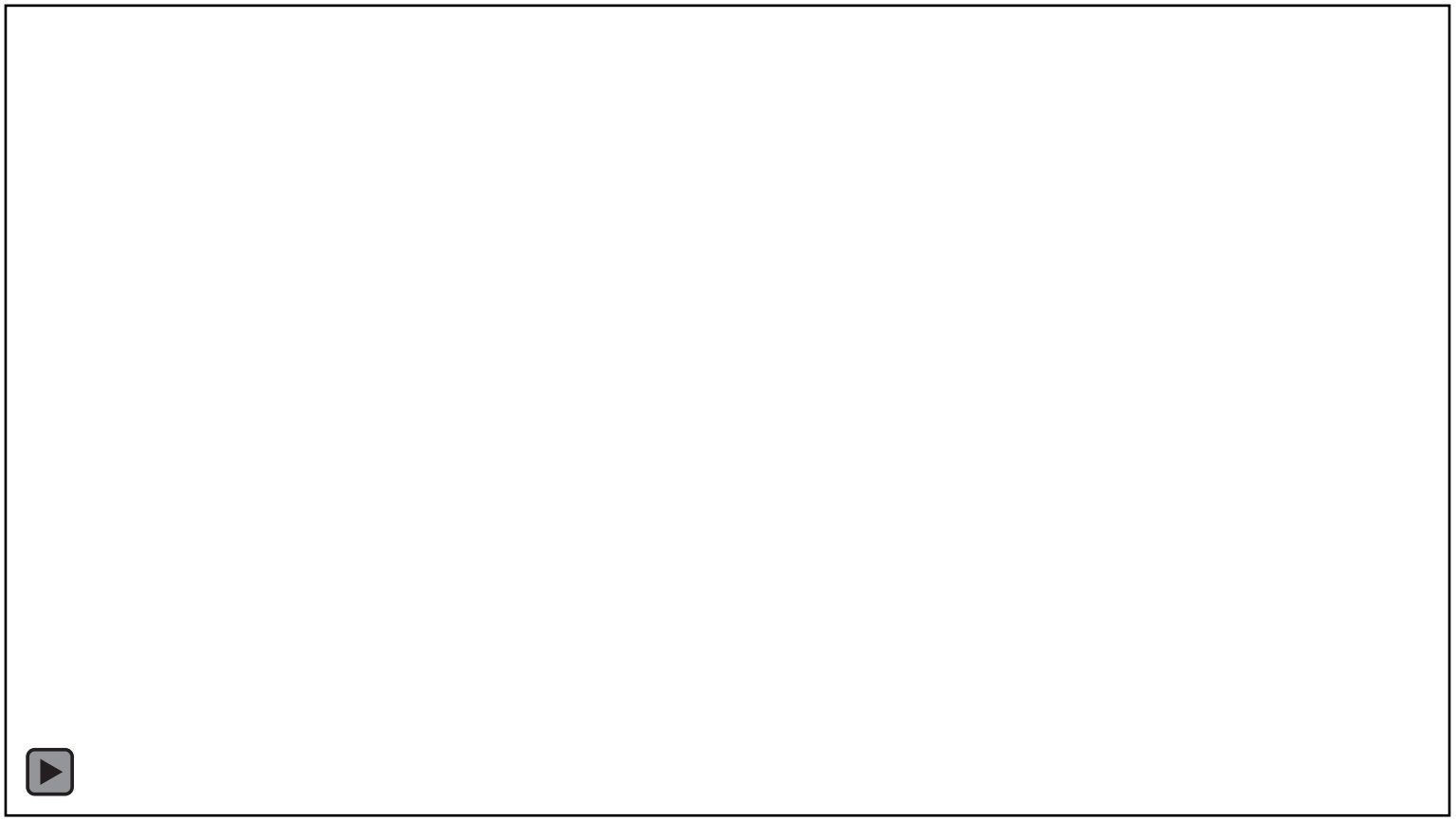
Physical Testing - Steam Application

- **Vertical offsets with standard elbows**

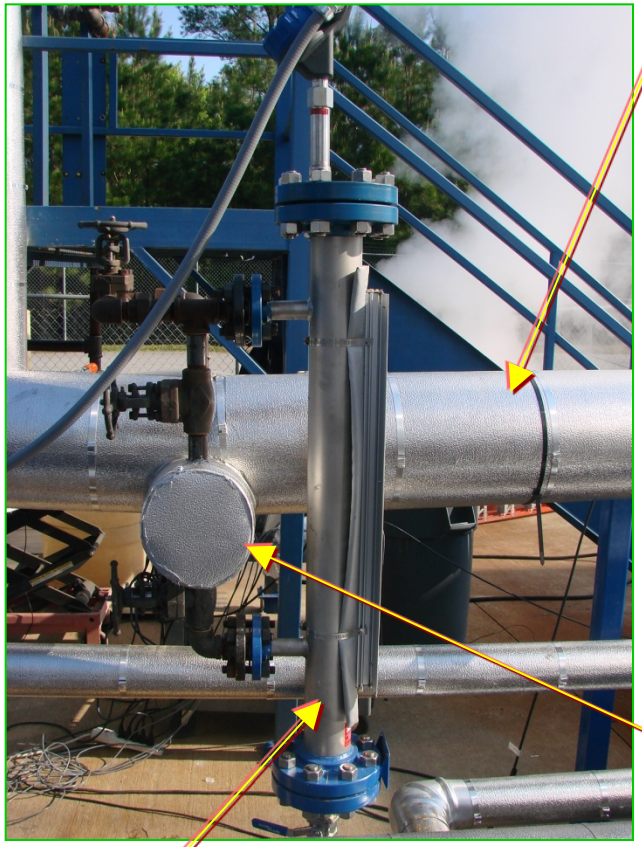
Geometrical Configuration	Picture	6" Pipe		16" Pipe	20" Pipe	24" Pipe
		Air Velocity (ft/sec)	Steam Velocity (ft/sec)	Steam Velocity (ft/sec)	Steam Velocity (ft/sec)	Steam Velocity (ft/sec)
22.5° Elbow		59	24	39	43	48
45° Elbow		63	26	41	46	51
90° - h/D = 12		58	24	38	43	47
h/D = 8		56	23	37	41	45
h/D = 4		58	24	38	43	47
h/D = 2		38	16	25	28	31

Physical Testing – Air-Water

- **Branch testing video - 6” diameter clear PVC pipes**



Physical Testing - Trap Station



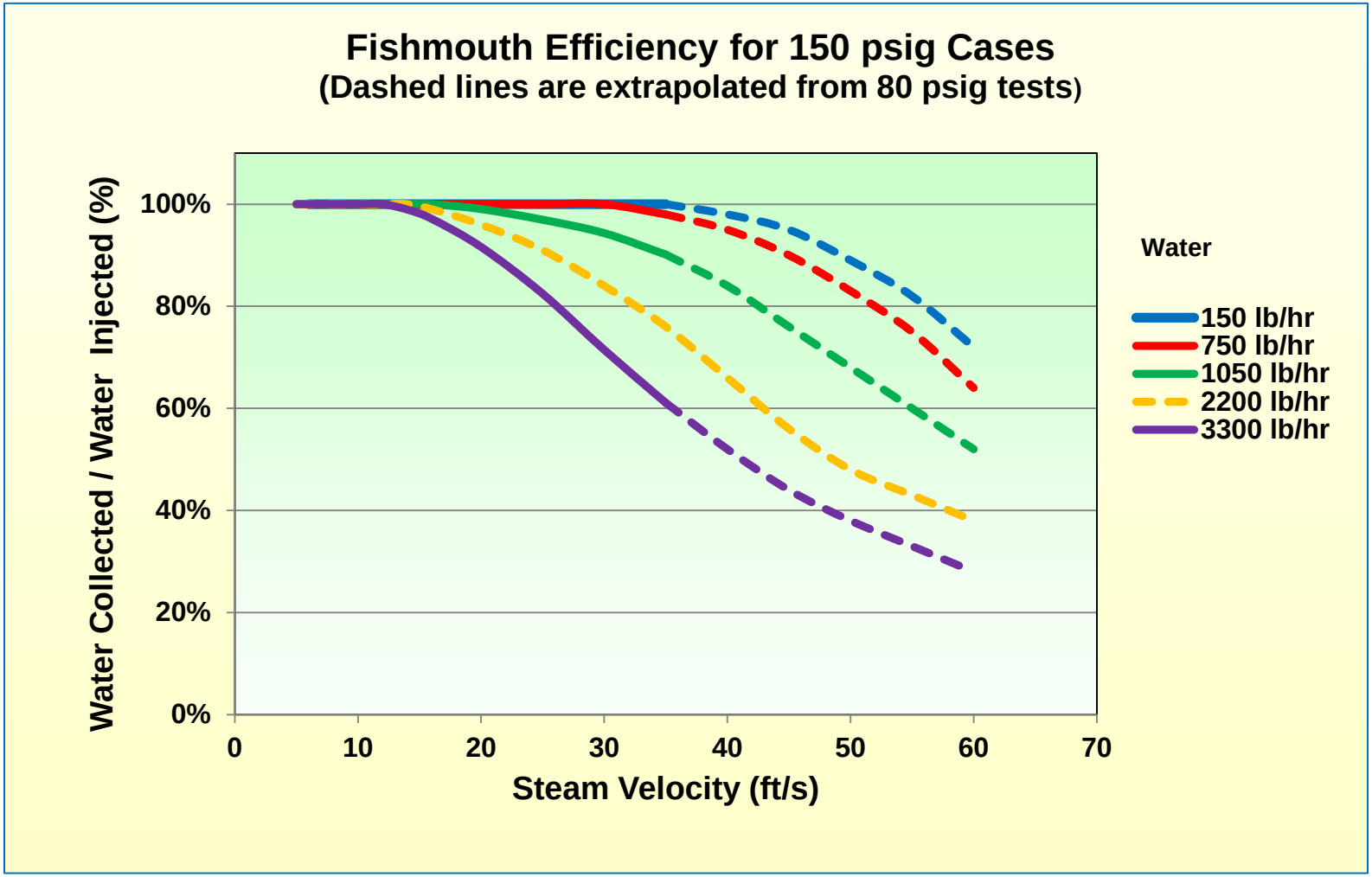
Steam Main

Standard Street Trap Assembly

Fish-mouth & Water Seal Connection

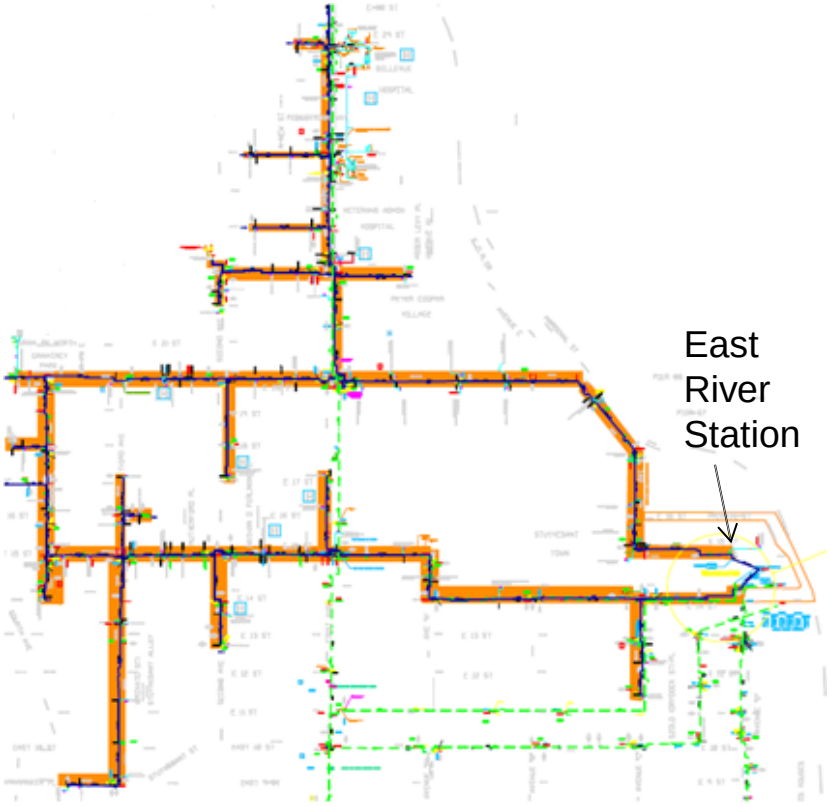
Level Transmitter

Physical Testing - Trap Station Test Results

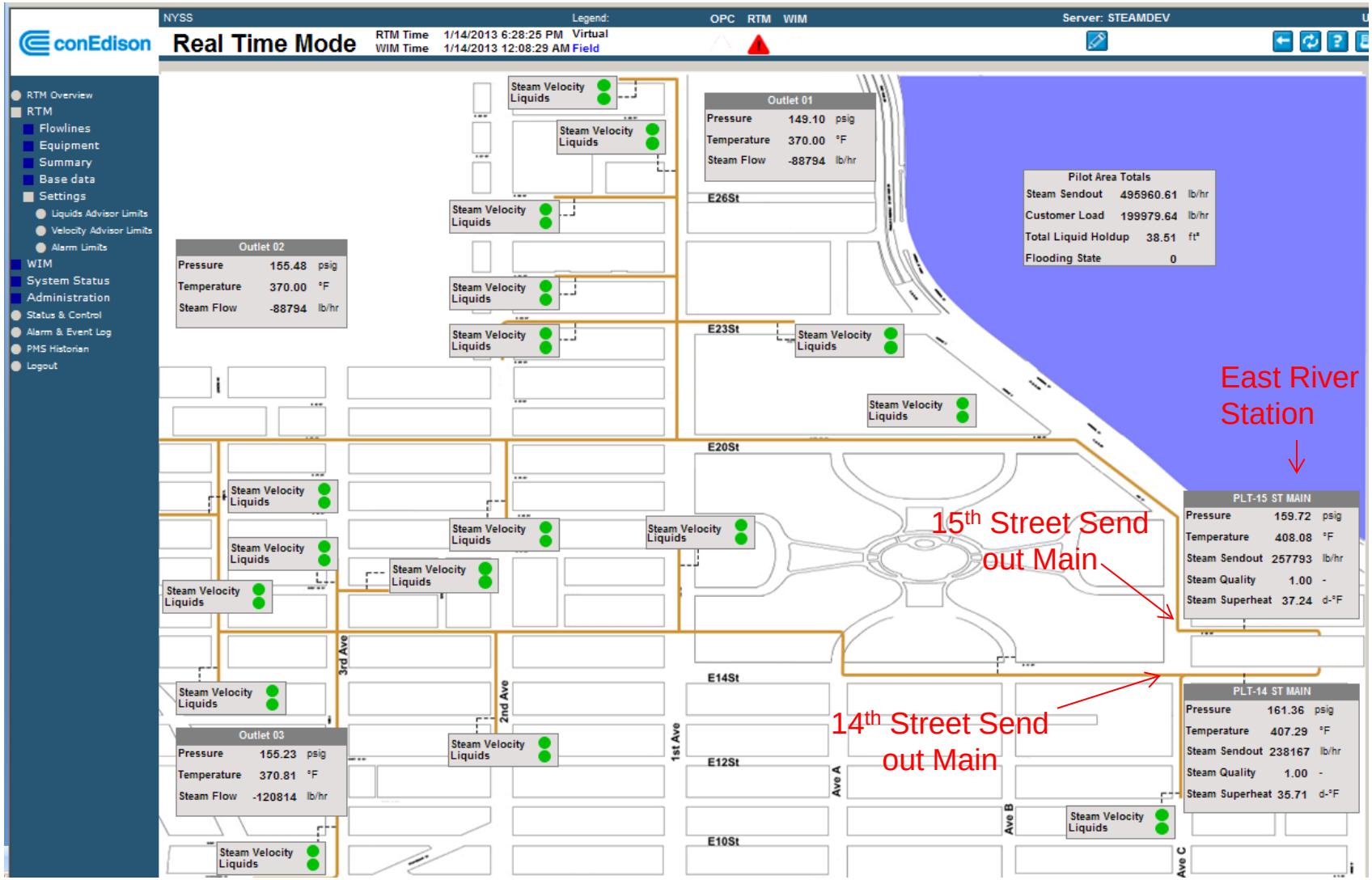


System Modeling

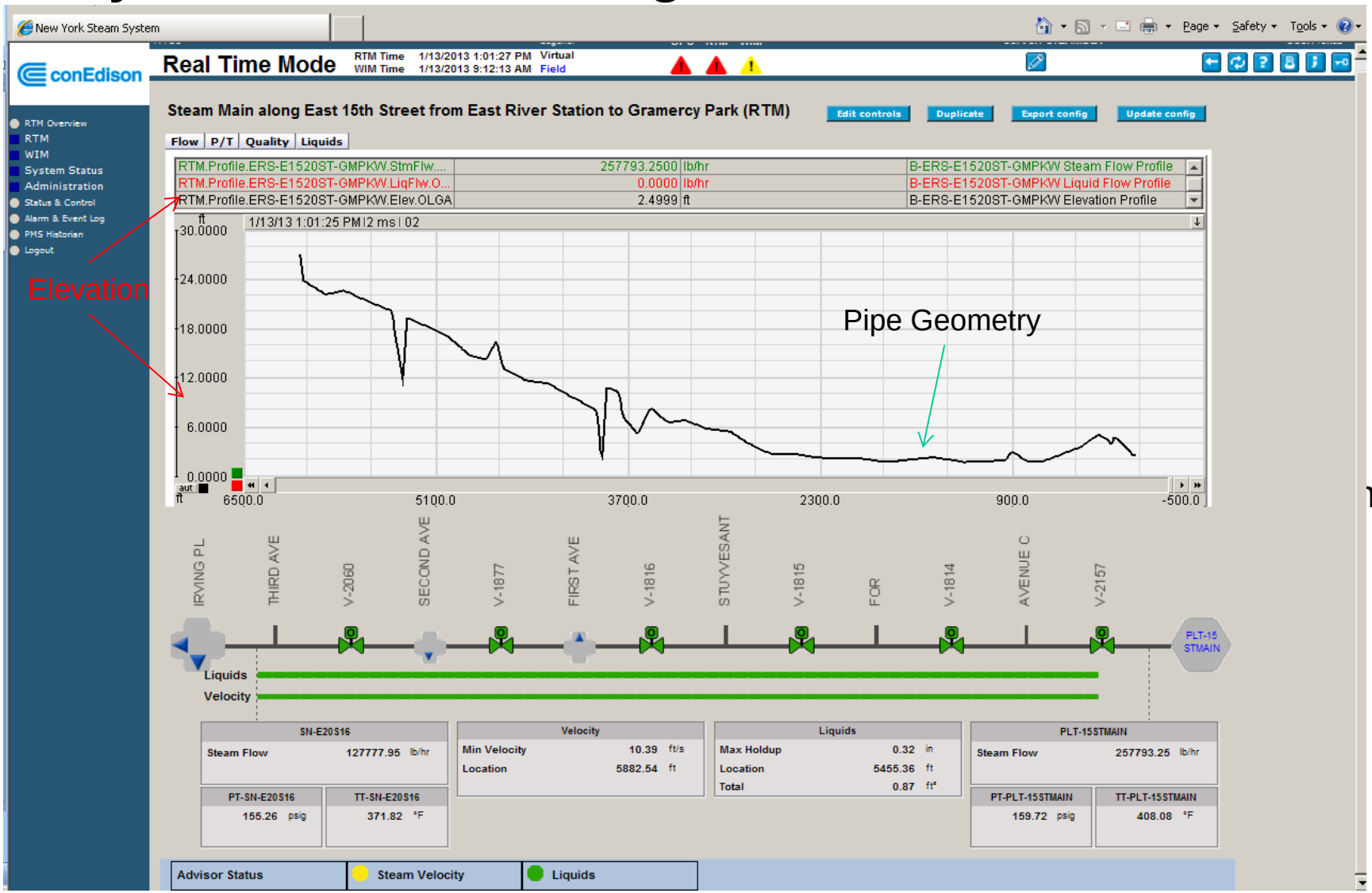
- Pilot Area
- 3.7 miles of distribution piping
  - Two send out mains
  - Utilize real time data and customer consumption at 5 – 7 minutes intervals
- Incorporate test results
- Calculated values
  - Pressure, temperature, velocity, condensate flow and build up, and discharge at traps
- Calibration
  - Field measured values



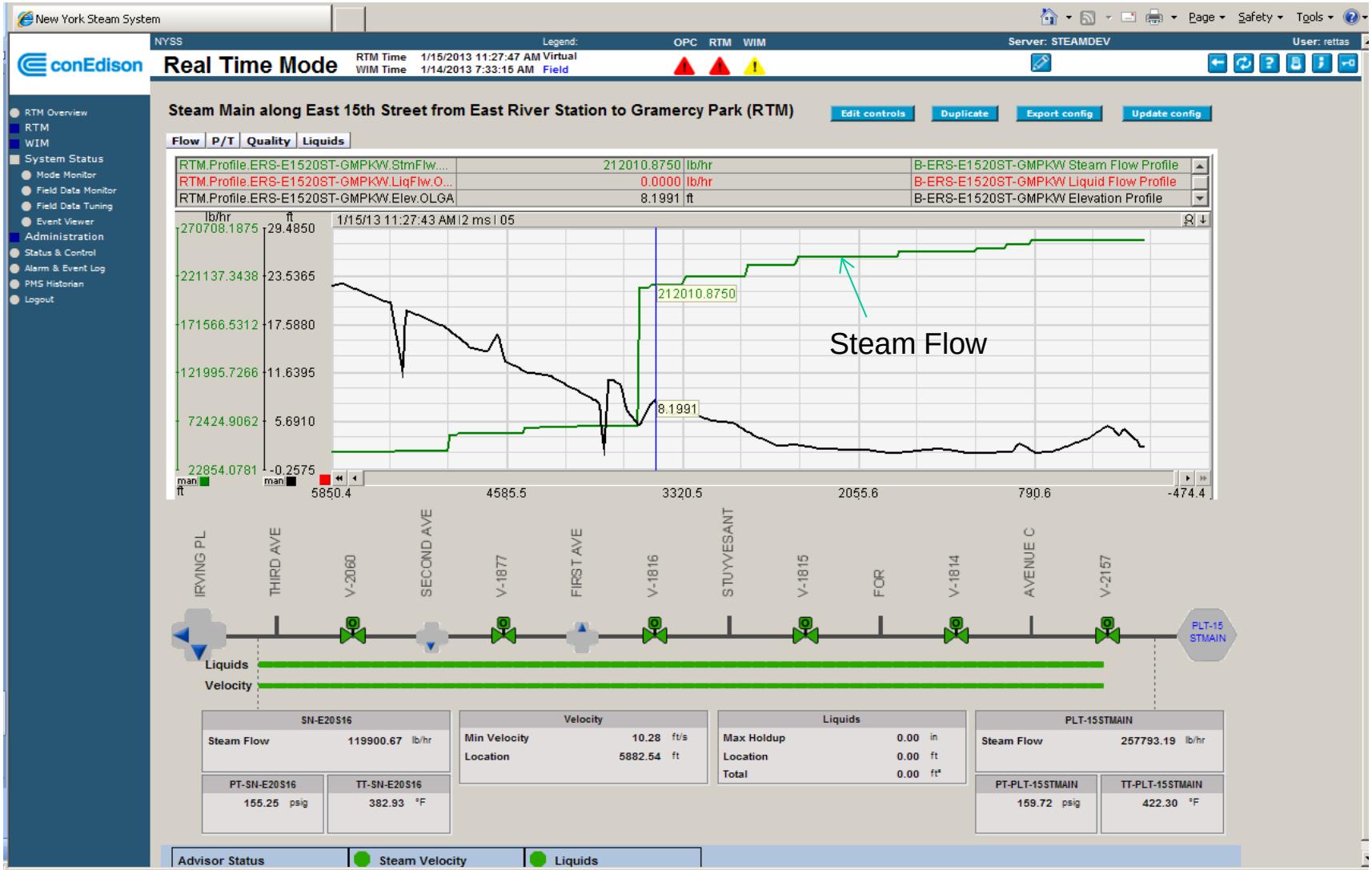
System Modeling - Pilot Overview



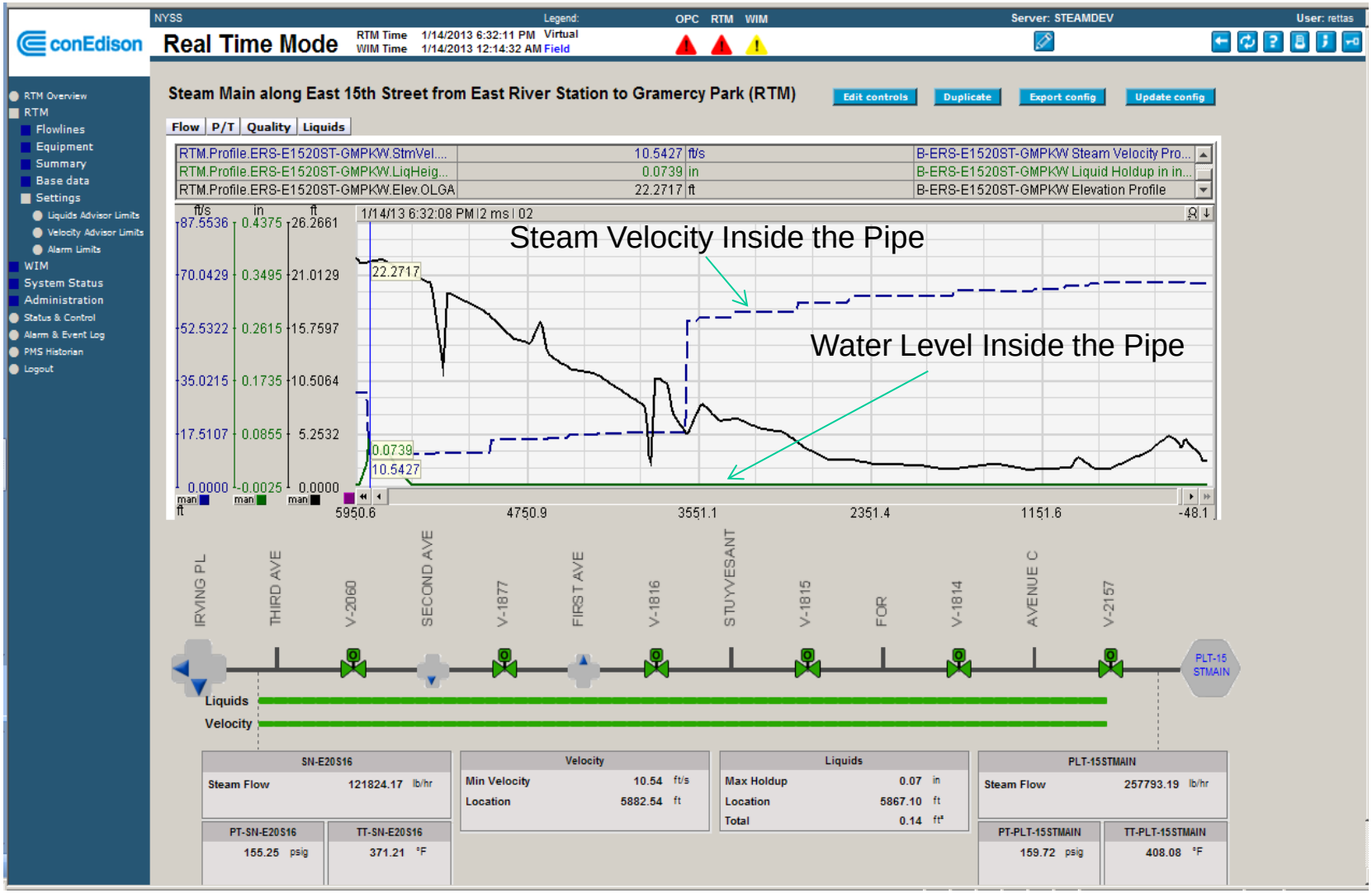
System Modeling - Simulation



System Modeling - Simulation

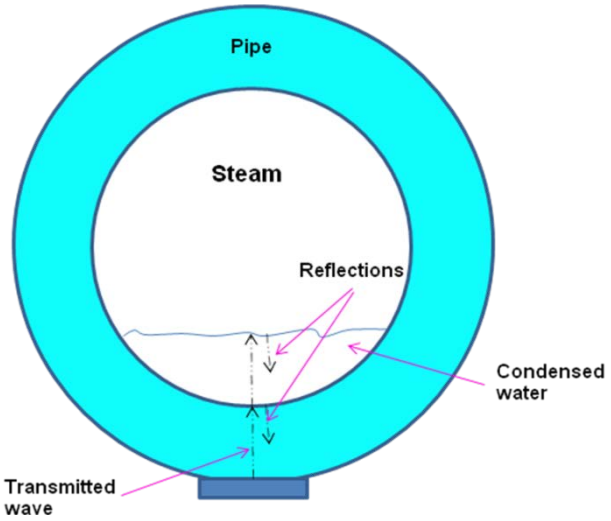


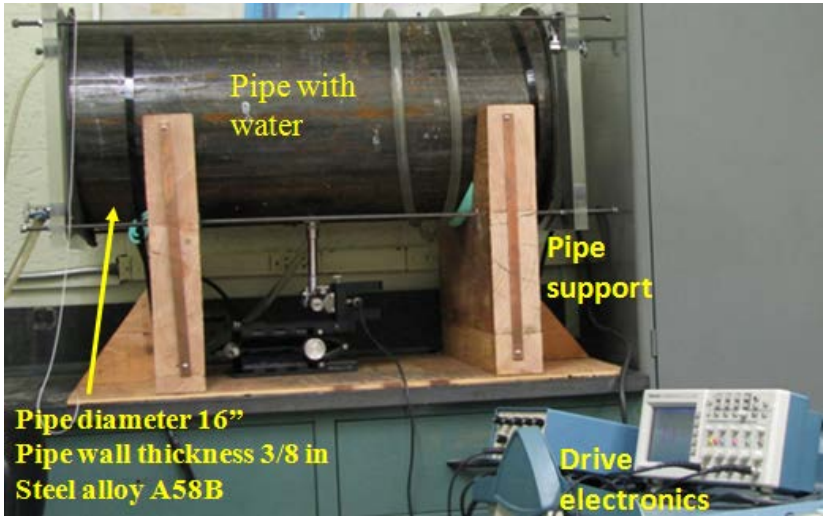
System Modeling - Simulation

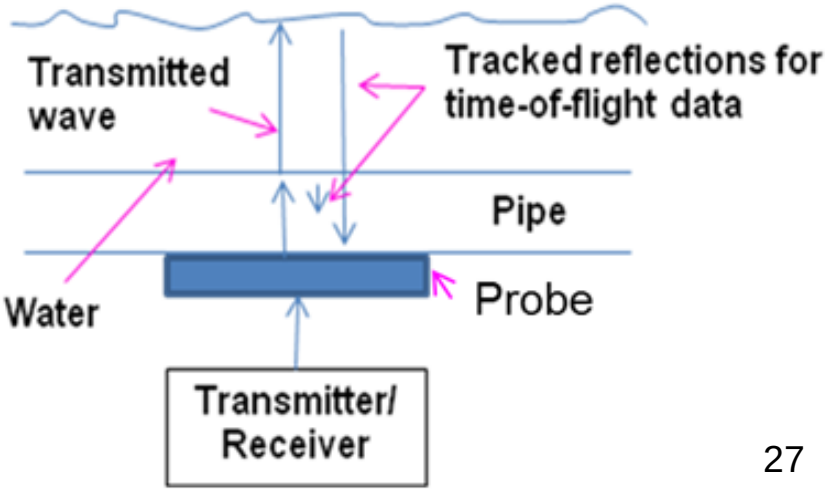


System Modeling – Monitoring Condensate Level

- **Pulse-echo measurement**
- **Condensate height**
  - **Reflected ultrasonic waves**
  - **Time of flight**
  - **Constant ultrasound velocity**

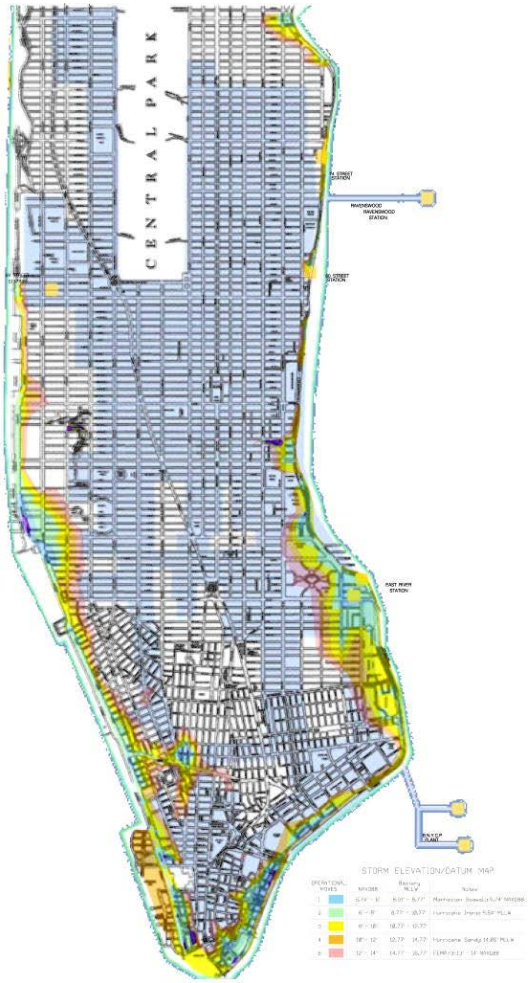






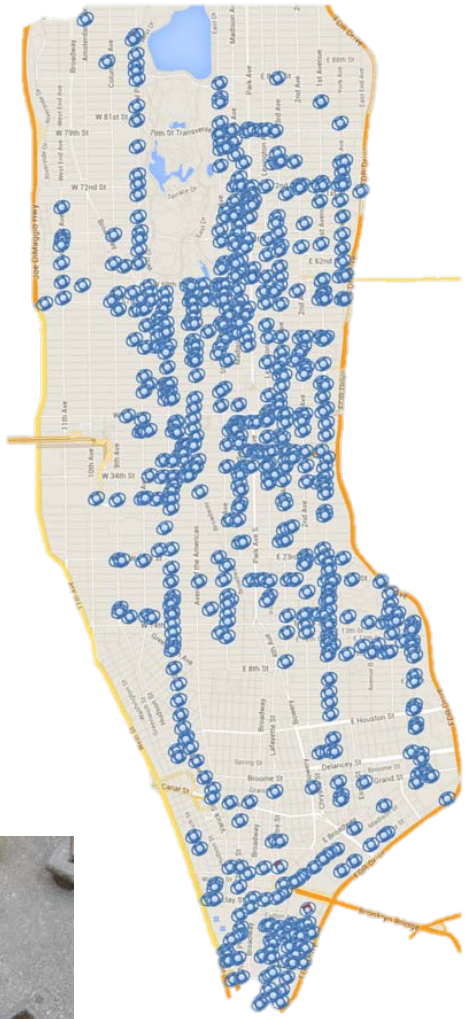
Benefits of Water Hammer Prevention Model

- **Conditional based simulation**
  - **Pipes segmented by flood zones**
  - **External water level monitoring**
  - **Integrated with remote monitoring**
  - **Different heat transfer coefficients**



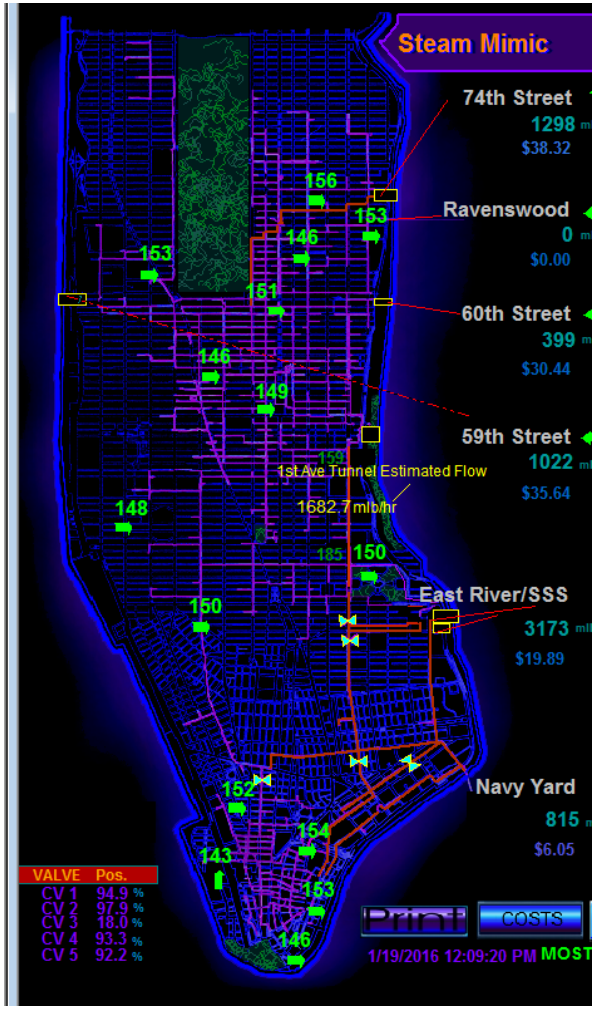
Benefits of Water Hammer Prevention Model

- **Real time calculated values system wide**
  - **Pressure**
  - **Temperature**
  - **Steam flow**
  - **Condensate build up**
- **Supplement field measured values**



Benefits of Water Hammer Prevention Model

- **Contingency analysis**
  - **Plan work outages**
  - **Improve system dispatch**
  - **Reduce low velocity in susceptible areas**
  - **Prevent high risk conditions**



Benefits of Water Hammer Prevention Model

- **Potential new alarms**
  - **Low velocity**
  - **Condensate build up**
- **Complement trap monitoring**
- **Improve confidence in alarms**
- **Improve response to mitigate high risk conditions**

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