Waterhammer

Course Outline

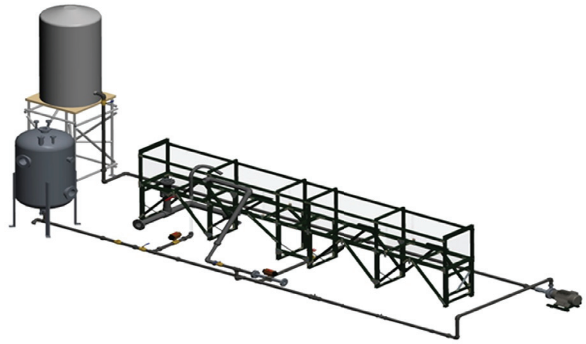
Waterhammer (also spelled water hammer) is a well-known pressure pulsation phenomenon experienced in many industries. It can be very destructive, and thus it is important to have a good understanding of the potential transients. This course will cover the fundamentals of the different types of waterhammer, the conditions that lead to highly energetic and dynamic transients, how to evaluate them, and, most importantly, how to design systems to reduce the likelihood of waterhammer.

The course will include live demonstrations, since each student should not only learn about waterhammer from a book, but also by witnessing it in real life. The demonstrations will provide the necessary understanding of the energy and dynamics of the transients.

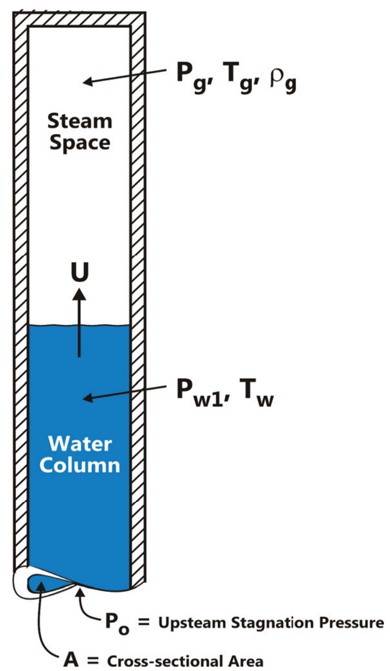
I. Waterhammer Fundamentals

1. What is a waterhammer
    a. Steam-water
        - Direct condensation
        - The breakdown of a protective thermal layer
        - Impact on a rigid wall (rapid valve closing, the water cannon, etc.)
        - Impact on another water column (column separation and rejoining)
    b. Noncondensable gases and water
        - Incompressible water column response
        - Compressible water column response
        - When to use each formulation
2. What causes damage
    a. The local pressure produced by a waterhammer event
    b. Force imbalance on the piping which overloads the supports
    c. Pressure wave reflections and amplifications
3. How can a waterhammer be prevented?
    a. Slower actuations of valves and pumps
    b. Acoustic dampers
    c. System configuration
    d. Procedural windows
    e. Venting/vacuum breakers

II. Conditions Which Set Up Waterhammer Events



1. Steam-water
   - a. Rapid actuations of valves and pumps
   - b. Steam contact with cold water
     - Steam generators
     - Heater drains
     - Initiating cold water flows
   - c. Leakage through valves
2. Noncondensable gas and water
   - a. Gas source
     - Air
       - Testing and maintenance
       - Use of compressed air during outages
     - Nitrogen
       - Leakage of N_2 saturated water through check valves, etc.
     - Hydrogen
       - Leakage of H_2 through closed valves
   - b. Accumulated gas volume in the injection systems (discharge/suction)
   - c. Pump testing using the mini-flow/recirculation line
   - d. Containment spray systems
   - e. Leakage through valves



III. Examples of Significant Waterhammer Events.

1. Steam-water
2. Noncondensable gases

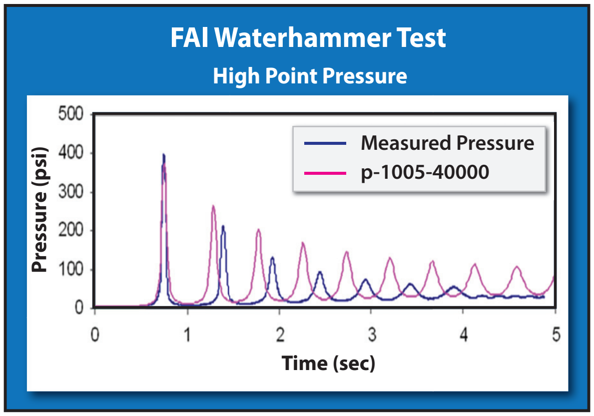
IV. Ways to Analyze Potential Waterhammer Events

1. Hand calculations for peak pressures
   - a. Steam and water
   - b. Noncondensable gas and water
2. Hand calculations for piping loads
   - a. Steam and water
   - b. Noncondensable gas and water
3. Method of characteristics
4. Epstein's analytical method
5. Computer codes

VI. Fundamental Considerations While Using Computer Codes for Waterhammer Analysis

(This module is intended to teach the attendee about the use of computer codes for waterhammer analysis. No specific code/program will be covered during the training, but only important aspects of waterhammer computer modeling.)

1. Relevant parameters for waterhammer analysis
   a. Important elements to consider
      - Piping network consideration
      - Mini-flow line/return path
      - Initial pressure
      - Gas accumulation locations
      - Initial Conditions
      - Time parameters/Courant limit
   b. Critical components.
      - Pressure boundaries
      - Pumps
      - Check Valves
      - Other Valves
      - Orifices
      - Gas Voids
      - Plotting frequencies
2. Sample problem
   a. Trips and Logic
   b. Initiation of the transient
      - Steady-state
      - Transient
   c. Pressure results
      - Pressure in the void
      - Pressure at relief valves
      - Suction piping vs. discharge piping pressures
   d. Flow results
      - Flow through pumps
      - Flow through mini-flow lines
      - Injection flow vs. dead-ended piping
   e. Force results
      - Segments to consider
      - Force on pipe segment equation
      - Comparison to pipe dead weight
   f. Numerical noise
   g. Determination of acceptance criteria
      - Relief valve/pressure results
      - Pipe dead weight/force results
      - Check valve slam/impact on pressure and force results



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