CONCEPT

# Water Hammer and Surge Analysis in Pipelines: Hydraulic Transients and Protection Design

9 – 13 November 2026
Amsterdam - Zuidas business district hotel

# Water Hammer and Surge Analysis in Pipelines: Hydraulic Transients and Protection Design

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## Introduction:

Water hammer and surge analysis decide whether a pumped pipeline survives its first pump trip or splits at a weld, collapses under vacuum or slams a check valve until the flanges leak. Many projects size pipe walls and pumps on steady-state hydraulics alone and meet transient pressures only after a failure. This Core Concept course trains engineers to predict hydraulic transients, run a surge study, compare peak and minimum pressures with pipe ratings and select protection devices. Participants produce a Surge Study and Protection Selection Report for a case pumped pipeline.

## Course Objectives:

- Establish the steady-state hydraulic gradient, pump operating point and minimum pressure margins of a pumped pipeline as the baseline for transient work
- Calculate pressure wave speed and Joukowsky surge for valve closure, pump trip and check valve slam events and judge when a full transient study is needed
- Build and run a transient model using method of characteristics software, with a scenario matrix covering normal, emergency and failure events
- Interpret maximum and minimum head envelopes against pipe pressure ratings, vacuum resistance and column separation risk
- Size and select surge vessels, air valves, surge relief valves, flywheels, slow-closing valves and non-slam check valves for a given duty
- Prepare a Surge Study and Protection Selection Report with operating limits and interlocks for a case pumped pipeline

## Target Audience:

- Pipeline engineers who design or operate crude, product and water transmission lines
- Water utility engineers responsible for pumping mains, booster stations and raw water transfer lines
- Process engineers who specify pumping systems, loading lines and emergency shutdown valves in plants and terminals
- Mechanical engineers who select pumps, valves and pressure protection for pumped systems
- Consultant and contractor engineers who prepare or review surge studies for new pipelines and upgrades

## Course Outline:

### Day 1: Steady-State Pipeline Hydraulics as the Surge Baseline

- Friction Factor, Reynolds Number and the Moody Diagram for Liquid Lines
- Minor Losses and Equivalent Length Across Valves, Meters and Fittings
- Pump Head-Flow Curve Versus System Curve for Single and Parallel Pumps
- Hydraulic Gradient Plotted Over the Pipeline Elevation Profile
- Critical High Points, Slack Flow and Minimum Pressure Margins

### Day 2: Transient Physics: Wave Speed, Joukowsky Surge and Characteristics

- Pressure Wave Speed From Fluid Bulk Modulus, Pipe Material and Wall Thickness
- Joukowsky Equation for Instantaneous Velocity Change and Its Limits
- Pipeline Period, Wave Reflection at Reservoirs and Dead Ends, Rapid Versus Slow Closure
- Method of Characteristics at Overview: Grid, Time Step and Boundary Conditions
- Vapour Cavity Formation, Column Separation and Rejoin Pressure Spikes

### Day 3: Transient Events and the Surge Modelling Workflow

- Valve Stroking Curves, Inherent Characteristics and Effective Closure Time
- Pump Trip Rundown, Rotating Inertia, Reverse Flow and Pump Start Transients
- Check Valve Slam: Dynamic Characteristics and Flow Deceleration Rate
- Oil Pipelines and Marine Loading Lines Versus Water Mains: ESD Valve Closure and Fluid Properties
- Transient Analysis Software Workflow: Data Gathering, Model Build, Scenario Matrix and Sensitivity Runs

### Day 4: Surge Protection Devices, Pressure Ratings and Operating Controls

- Maximum and Minimum Head Envelopes Against Pressure Rating, Vacuum Resistance and Cyclic Loading
- Surge Vessel Sizing: Gas Volume, Bladder or Compressor-Fed Types and Connection Losses
- Air Release, Air-Vacuum and Anti-Slam Air Valves at High Points
- Surge Relief Valves, One-Way Surge Tanks and Pump Flywheels
- Slow-Closing Valves, Non-Slam Check Valves and Interlocks for Pump Sequencing and Valve Stroke Limits

### Day 5: Surge Study Build and Protection Selection Report

- Failure Case Studies: Burst Mains, Vacuum Collapse and Loading Arm Damage
- Case Pipeline Model: Profile, Pumps, Valves and Unprotected Pump Trip Run
- Protection Options Comparison: Surge Vessel, Air Valve and Flywheel Scenario Runs
- Operating Limits Sheet: Valve Stroke Times, Start Sequence and Trip Interlocks
- Surge Study and Protection Selection Report Presentation and Peer Review

## Skills You Will Gain:

- Pipeline Hydraulic Gradient Analysis
- Wave Speed Calculation
- Transient Scenario Definition
- Surge Model Building
- Pressure Envelope Interpretation
- Surge Vessel Sizing
- Air Valve Placement
- Surge Protection Specification

## Why Attend This Course:

- Return with a Surge Study and Protection Selection Report built on a case pumped pipeline during hands-on modelling sessions
- Challenge surge study inputs and results from consultants and vendors, including wave speed, valve stroke curves and pump inertia
- Avoid bursts, vacuum collapse and check valve slam by fixing valve stroke times, start sequences and trip interlocks before commissioning
- Compare transient experience with engineers from water utilities, oil and product pipelines, marine terminals and process plants

## Conclusion:

A pumped pipeline is only safe when its transient pressures, not just its steady flows, stay inside what the pipe, valves and pumps can take. The week moves from steady-state hydraulics and pump curves, through wave speed, the Joukowsky equation, the method of characteristics and column separation, to valve, pump and check valve events and the modelling workflow. It then covers pressure envelopes and protection devices, before the final day turns this into a Surge Study and Protection Selection Report for a case pipeline.