UrbanUtilities

Analysis of pressure transients in pipeline systems

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1 Purpose

Pressure transients can cause pipeline pressures to exceed design limits, impacting system integrity, safety, and reliable operation. Excessive transients can shorten the life of piping and equipment, increase the risk of failures, and lead to more customer complaints.

This document outlines the requirements and preferred practices for conducting pressure transient analysis in pressure pipeline systems. The objective is to identify and mitigate risks associated with pressure transients to ensure system integrity and operational safety.

2 Scope

This document outlines the minimum requirements for hydraulic transient analysis and the associated reporting to be undertaken during the planning and design of new assets, upgrades to existing assets, and investigations into the performance and operational issues of existing infrastructure.

It applies specifically to the pressure transient analysis of pipelines, pumps, valves, and pressure vessels within Urban Utilities' drinking water, recycled water, and wastewater pressure pipeline systems.

The pressure transient design elements addressed in this document include:

- Assessment of maximum positive pressures
- Assessment of minimum negative (vacuum) pressures
- Assessment of fatigue loading

3 Definitions and acronyms

In this document, the following definitions apply

Table 3.1 Definitions

Item	Definition/Description
Allowable Operating Pressure	The internal pressure, excluding surge, that a component can safely withstand in service
Competent engineer	A suitably qualified and experienced engineer who is able to apply knowledge and skills to achieve the intended engineering task.
Maximum Allowable Operating Pressure	The maximum internal pressure, including surge, that a component can safely withstand in service

Item	Definition/Description
Normal operating conditions	Conditions consistent with the design intent for daily operation of the system.
Abnormal operating conditions	Conditions outside the design intent and daily operation of the system consistent with uncontrolled or irregular operation.
Frequent transient events	Regularly occurring events that cause cyclical pressure transients (e.g. normal pump stop/start cycles in a pumping station)
Infrequent transient events	Infrequently occurring events that cause pressure transients (e.g. power failure)
Surge or transient pressure	Synonymous terms referring to pressure changes within pipelines, typically resulting from sudden changes in flow velocity. These terms are used interchangeably.

Table 3.2 Abbreviations

Abbreviation	Definition/Description
AOP	Allowable Operating Pressure
MAOP	Maximum Allowable Operating Pressure
DP	Design Pressure
RPEQ	Registered Professional Engineer Queensland
SEQ Code	The South East Queensland Water Supply and Sewerage Design and Construction Code
WSAA	Water Services Association of Australia

4 Requirements for Hydraulic Transient Analysis

4.1 Assessment of proposed works

The designer must assess the transient pressure implications associated with any proposed works on new or existing pressurised pipeline systems, including any interrelated pumping systems.

It is not intended to mandate a comprehensive transient analysis for every pressure system. However, unless specifically excluded or otherwise directed by Urban Utilities, whenever work is performed on a pressure pipeline system (including new systems, refurbishments,

augmentations, or changes to critical/significant components), a qualitative assessment must be carried out to determine:

a) Whether a transient analysis is warranted, and
b) The appropriate level of transient analysis required.

For simple, low-head, low-velocity pipelines with minimal likelihood and consequence of failure, a basic first-order calculation may demonstrate that pressure transients are negligible, making a detailed transient analysis unnecessary.

Conversely, pipeline systems with higher flow rates, velocities, complexity, or with greater consequence and/or likelihood of failure will likely require a comprehensive transient analysis and mitigation strategy.

If it is determined that a transient analysis is not warranted, this decision must be documented in the Design Report.

When transient analysis is assessed as not required the hydraulic design report must, as a minimum, include:

a) A description of the project background and scope relevant to transient pressure considerations.
b) Justification for the decision not to undertake a transient analysis.
c) A list of all assumptions and qualifications made during the assessment.
d) Documentation of potential risks associated with transient pressures.
e) Demonstration, through engineering judgement, risk analysis, interpretation, and/or first-order calculations, that omitting transient analysis will not expose Urban Utilities to unacceptable risks.
f) Recommendations for design or operational controls to manage residual risks.

Where a transient analysis is deemed necessary, it must be performed by competent engineering personnel and according to this document, with the aim of identifying and mitigating risks related to transient pressure effects.

Transient analysis should be identified in the planning phase. Transient analysis should be performed during the initial design stage in conjunction with system design activities and system operation, and predictable emergency operation should be evaluated during designs.

4.2 Pressure Transient Analysis Flowchart

The Figure 4.1 shows a general flow chart for pressure transient analysis. The analysis is intended to identify and address consequences of pressure transients in normal and abnormal operating conditions, including maximum pressure, sub atmospheric conditions, cyclic loading and fatigue, then the applicable surge protection to mitigate these.

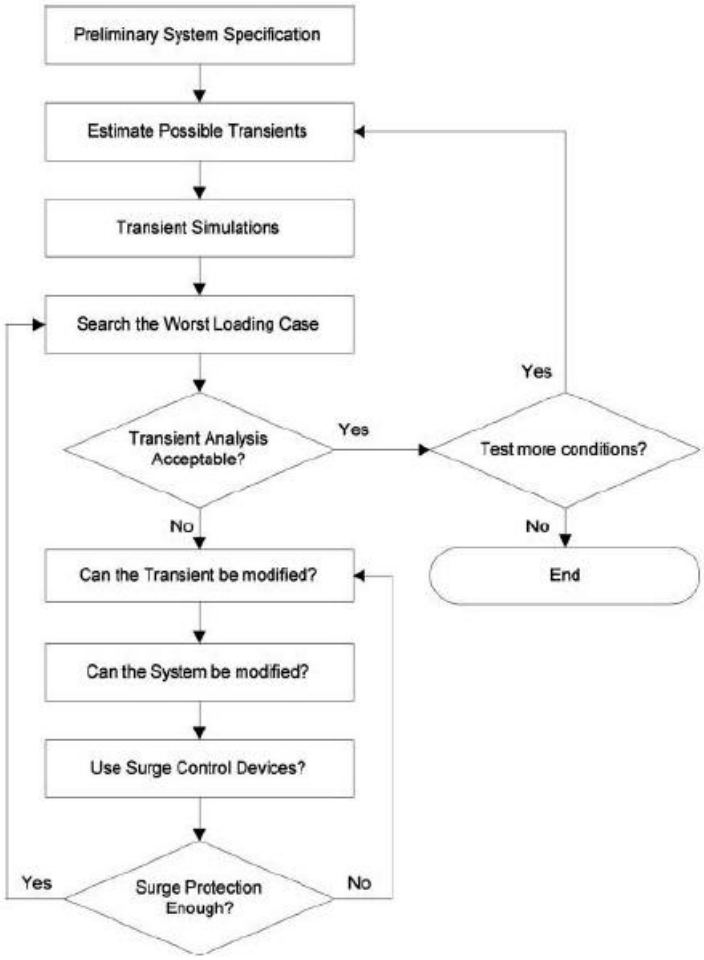

Figure 4.1 Pressure Transient Analysis Flowchart

4.3 Transient Scenarios to Analyse

A clear understanding of how the system operates is essential for setting up the transient model. Before analysing transients, the design engineer must identify both normal and abnormal operating conditions and the potential causes of harmful hydraulic transients. This must be done in consultation with the Urban Utilities Integrated Planning Group modelling team and Operation and Maintenance teams.

Modelling scenarios must meet minimum requirements and also consider preferred requirements outlined below where applicable. During the investigation phase, the design engineer should identify all potential situations that could cause unacceptable transient pressures.

4.3.1 Minimum Requirements

The analysis shall, at a minimum, include the following transient scenarios where applicable:

a) Pump startup and shutdown events,
b) Multi pump operation and controlled pump transition events.
c) Pump station and individual pump uncontrolled (trip) scenarios, (e.g. power failure, emergency shutdown),
d) System behaviour maximum and minimum system curve
e) Rapid valve operations, including closure/opening of isolation valves, check valves and air valve slam events.
f) Hydrant / air valve operation
g) Sudden pipe flow increases (e.g. pipe rupture or sudden changes in system demand).
h) Critical location – component failure and malfunction scenarios (e.g. blocked air valves, surge device failures)
i) Reservoir valve operation at Max, Min water level

4.3.2 Preferred Additional Scenarios

Where relevant to the system, the analysis should also consider:

a) Cascading pump station trips (e.g. trip of a pump station due to power failure causes trip of a downstream pump station, or two pump stations trip due to a power supply zone failure).
b) Simultaneous pump trips within a pump station
c) Valve operations in a system cause a simultaneous pump trip.
d) Air ingress into, and expulsion from, the system.
e) Transient effects induced by control system logic, such as variable frequency drive (VFD) ramping and control valve hunting.

4.4 Pressure Criteria for Design

This section provides guidance on pressure-related aspects of transient analysis for pipeline design. It does not cover structural design, which must be addressed separately, using results from the transient analysis as input.

Transient pressures must not exceed the maximum allowable operating pressure (MAOP) of the pipe, as specified in the relevant product standard/nominated by the manufacturer, or defined by the Pipe Nominal Pressure Rating (PN) whichever is lower.

The MAOP is to be calculated based on the lowest MAOP among all system components, with appropriate allowance for derating factors such as corrosion (internal & external), internal wear, cyclic fatigue or temperature effects. Design factors must be applied in accordance with the relevant industry standards, such as those produced by the Plastics Industry Pipe Association of Australia (PIPA), etc.

For plastic pipes, the Design Pressure must account for all frequent and infrequent transient events, ensuring the pipeline remains within safe operating limits under all expected conditions.

Surge protection devices (air chambers, surge tanks, pressure relief valves, etc) may be required to ensure transient pressures / cyclic pressure ranges remain within allowable limits.

4.4.1 Maximum & Minimum Transient Pressures

Criteria for evaluation of transient pressures identified in the analysis are outlined in Table 4.1:

Table 4.1 – Transient Pressure Criteria

Condition	Normal Operation		Abnormal Operation	
	Water	Sewer Pressure Mains	Water	Sewer Pressure Mains
Maximum Transient Pressure Metal Pipes (frequent transient)	< DP	< DP	< DP	< DP
Maximum Transient Pressure Metal Pipes (infrequent transient)	< MAOP	< MAOP	< MAOP	< MAOP
Maximum Transient Pressure Plastic Pipes (frequent and infrequent transient)	< MAOP	< MAOP	< MAOP	< MAOP
Minimum Pressure (gauge)	50 kPA	50 kPA	20 kPA	-80 kPA (subject to assessment on case-by-case basis)

While Table 4.1 sets transient pressure limits, there may be situations—such as innovative designs, high costs, safety concerns, or unique site conditions— where compliance isn't practical. In those cases, the design engineer should provide an alternative solution suitable for the project's needs while justifying any deviation from the transient pressure criteria, and

related risks & opportunities in accordance with the Urban Utilities Deviation from Technical Standards Procedure (PRO752).

4.4.2 Minimum Transient Pressure

Negative pressures below certain limits can cause pipe deformation, joint failure, or ingress of contaminants through leaks. It is desirable to have positive pressure in the system under all operating scenarios.

Drinking or recycled water supply system must not be subjected to sub-atmospheric pressures except in rare and fully justified cases, due to the risk of contamination.

In wastewater systems occasional negative pressures within the limits specified in Table 4.1 may be acceptable, provided the pipeline system is specifically engineered to withstand such conditions. Refer also to the requirements in the SEQ Sewage Pumping Station Code.

4.4.3 Fatigue Assessment

Plastic pipes subjected to cyclical loading are susceptible to fatigue failure. Therefore, in addition to a transient analysis of pressure, a fatigue analysis must be undertaken for plastic pipe systems. This analysis ensures that the typical system operating pressures, cyclic pressure ranges and/or transient pressures do not lead to premature pipe failure.

Where plastic pipes are included in the system (e.g., PVC, GRP, PE), the transient analysis report must contain a dedicated fatigue analysis section. Design engineers must apply an appropriate fatigue de-rating factor when specifying plastic pipes to account for long-term cyclic loading effects.

WSA03 Clause 3.6.3, fatigue analysis is not required for metallic pipes and fittings.

4.4.4 Pressure limits in Existing Pipelines

Reduced pressure limits apply when introducing new pressure transients into existing pipelines. For sensitive systems, such as aging pipe networks with brittle materials (e.g., asbestos cement (AC) pipes), or areas with high rates of pipe breaks or leakage, pressure limits should be determined in consultation with both the Urban Utilities Planning, Engineering and Operation & Maintenance teams.

4.5 Modelling Package

The designer must consult with Urban Utilities to determine whether an existing pressure transient model is available.

Unless otherwise agreed with Urban Utilities, models must be provided in Bentley HAMMER 2024 or higher format or an equivalent format compatible with HAMMER, ensuring the model can be saved and reused by Urban Utilities in the future.

In scenarios where traditional water hammer software is not suitable, specialist applications such as computational fluid dynamics (CFD) simulation tools with appropriate capabilities may be used, subject to acceptance by Urban Utilities.

4.6 Water CAD/GEM Hydraulic Model Data

When the modelling task involves an existing network or an upgrade to it, Urban Utilities' water service networks are supported by WaterCAD/GEM hydraulic models. These models can be used as a foundation for transient analysis by exporting the network data to create a base model.

However, since the existing hydraulic models are designed for steady-state conditions, it is essential to thoroughly review all surge protection devices and hydraulic parameters within the network to ensure accurate transient analysis.

4.7 Longitudinal Sectional Drawing

The surveyed longitudinal sectional drawing of the rising main should be used for detailed analysis. A good transient model should have all high and low point nodes along the pipe's longitudinal profile, as captured in the survey, to ensure accurate calculations at critical locations. Additionally, all dead ends—such as those involving check valves—should be carefully assessed as part of the transient analysis, as they can significantly influence pressure transients.

4.8 Existing Pipe Network Analysis

All surge suppression systems and devices and surge control components should be identified and assessed to ensure they are in good condition and properly maintained. In addition, the pressure management system and any high-speed pressure loggers used to track system performance and detect potential issues should be reviewed.

4.9 Pipe Route

At the planning stage, digital elevation map data should be used to assist with pipe route selection. The goal is to identify the optimal route and site locations that minimize transient impacts on the pipeline. Alternative routing options and other relevant factors, such as pipe length, construction feasibility, and installation constraints, should also be evaluated. Initial transient analyses should be conducted for each proposed route to support informed decision-making.

4.10 Surge Control

Surge control measures are necessary when transient analysis identifies pressure or performance conditions that could compromise system integrity or reliability, including:

- Maximum pressure exceeds the pipe rating.
- Minimum pressure reaches vapor pressure or falls below pipe material limits.
- Incorrectly size air valves can lead to valve slam, valve chatter, excessive noise and reverberation.
- Existing surge control systems fail to function as required.
- Interaction between surge protection devices causes pressure instability or oscillation.
- Transient forces exceed the structural capacity of pipeline supports or anchors.

4.11 Surge Control Strategy

Surge Control Strategy

- Identify the impact of both positive and negative pressure transients in the absence of surge control devices.
- Evaluate a range of available surge control options before selecting the preferred strategy.
- A combination of surge control devices is often the most effective approach to mitigate pressure transient risk.

4.12 Model Results

The transient analysis model should be run for each defined scenario. Solutions must be developed to address all potential transient conditions identified across these scenarios.

4.12.1 Transient Analysis – Without Surge Protection

The following results should be generated and reviewed:

- Pipe Elevation vs. Pipe Length
- Hydraulic Grade Line (HGL) vs. Pipe Length
- Maximum Head vs. Pipe Length
- Minimum Head vs. Pipe Length
- Head/Pressure vs. Time

4.12.2 Transient Analysis –With Surge Protection

The following results should also be assessed to evaluate the effectiveness of surge protection:

- Pipe Elevation vs. Pipe Length
- HGL vs. Pipe Length
- Maximum Head vs. Pipe Length
- Minimum Head vs. Pipe Length
- Head/Pressure vs Time

5 Documentation and Reporting of Transient Analysis

The transient analysis report is expected to include the following as relevant:

1. **Executive Summary**

    - Executive summary highlighting key findings and associated risks.

2. Project Context

- Brief description of the broader project context.
- Overview of proposed infrastructure and its operating modes.
- Identification of interfaces with existing systems.
- Consideration of potential future system expansions or modifications.

3. Hydraulic Modelling

- Summary of the transient model used, including software version and any known limitations.
- All input data and modelling assumptions, with references to supporting documentation (included in appendices).
- Evaluation of how key parameter variations influence results (sensitivity analysis).
- Discussion of operational modes and rationale for selected modelling scenarios.
- Definition of steady-state hydraulic grade line (HGL), addressing maximum and minimum system curves.

4. Compliance and Standards

- Reference to Urban Utilities' specific requirements and design standards.
- Justification for any deviations from standards, including documented acceptance prior to final submission.

5. System Assessment and Risk Analysis

- Assessment of both unprotected and protected system configurations.
- Presentation of maximum and minimum system pressures, clearly indicating net positive and negative pressures.
- Assessment of component failure and malfunction scenarios (e.g., blocked air valves, surge device failures).
- Commentary on infrequent versus frequent operations, and their implications on system design and performance.

6. Mitigation and Control Strategies

- Evaluation of a range of mitigation strategies, not limited to the preferred solution.
- Explanation of why alternative mitigation options were rejected.
- Modelling and presentation of control strategies (e.g., max/min settings)

7. Results and Recommendations

- Discussion of results, including outcomes from any sensitivity testing.
- Conclusions from the study
- Recommendations, including:

- Mitigation solutions to address identified risks and transient pressures.
- Sizing requirements and selection criteria for all recommended equipment and components (e.g., surge vessels, air valves, control valves).

8. Supporting Documentation

- Provide all relevant supporting material appended to the Design Report, including, but not limited to

  - soft copy model files,
  - data sheets, calculations,
  - drawings relevant to the transient analysis and any other technical documentation.

6 Quality Assurance

A peer review of the hydraulic transient model shall be conducted by a competent engineer to ensure accuracy and compliance with relevant standards.

The hydraulic pressure transient report submitted to Urban Utilities must be endorsed by the RPEQ.

Where feasible, field validation should be performed using pressure transient loggers or pilot testing to verify model predictions against actual system behaviour.

7 Referenced Related Documents

7.1 Relevant Codes and Standards

The following codes, industry standards are be used in conjunction with this document where applicable for the application:

- SEQ Water Supply Code;
- SEQ Sewage Pumping Station Code (eg Cl 10.4);
- WSA 01 Polyethylene Pipeline Code of Australia;
- WSA 03 Water Supply Code of Australia (eg Cl 3.6 “Design for Dynamic Stresses”);
- WSA 04 Sewage Pumping Station Code of Australia
- AS 4087 - Metallic Flanges for Waterworks Purposes
- AS/NZS 4130 – Polyethylene pipes (PE) for pressure applications
- Plastics Industry Pipe Association of Australia references, including but not limited to:
  - PIPA POP010A: *Polyethylene-Pressure-Pipes-Design-for-Dynamic-Stresses*
  - PIPA POP010B: *Fusion-Fittings-for-Use-with-Polyethylene-Pressure-Pipes-Design-for-Dynamic-Stresses*
  - PIPA POP101: *PVC-Pressure-Pipes-Design-for-Dynamic-Stresses*
- PRO752, Urban Utilities, Deviation from Technical Standards Procedure

- TMS1727, Urban Utilities, Trunk Water Main Design and Construction Code: Addendum to SEQ Service Providers Edition of the WSAA Water Supply Code