Government of South Australia

SA Water

Engineering Services

Technical Standard
TS 147

Surge Mitigating Infrastructure

Revision: 2.0
Date: 07 April 2016

Copyright

Application & Interpretation of this Document

It is the responsibility of the users of this Standard to ensure that the application of information is appropriate and that any designs based on this Standard are fit for SA Water's purposes and comply with all relevant Australian Standards, Acts and regulations.

Users of this Standard accept sole responsibility for interpretation and use of the information contained in this Standard. Users should independently verify the accuracy, fitness for purpose and application of information contained in this Standard.

Only the current revision of this Standard should be used which is available for download from the SA Water website.

Significant/Major Changes Incorporated in This Edition

Nil.

This standard is technically equivalent to TS 147 dated 7 November 2014.

Document Controls

Revision History

Revision	Date	Author	Comments
1	7th November 2014	M Stephens	Issued for Use
2.0	27 January 2016	M Stephens	

Template: Technical Standard Version 4.00, 02/11/2015

Approvers

Role	Signature and Date
Responsible Discipline Lead Mark Stephens	7/04/2016 X Signer's Name Signed by: ST002516
Manager Engineering Technical Services Murat Aksoy	7/04/2016 X Signer's Name Signed by: AK003305
Senior Manager Engineering Services Richard Gray	7/04/2016 X pp Robert Alaia Signer's Name Signed by: AL003250

Reviewers

Role	Name	Revision	Review Date

Contents

List of figures

List of tables

1 Introduction

SA Water is responsible for operation and maintenance of an extensive amount of engineering infrastructure.

This standard has been developed to assist in the design, maintenance, construction, and management of this infrastructure.

1.1 Purpose

The purpose of this standard is to detail minimum requirements for surge infrastructure to ensure that assets subject to hydraulic surges are designed, constructed and maintained to ensure they operate safely and maintain their design asset life.

1.2 Glossary

The following glossary items are used in this document:

Term	Description
DPL	Design Pressure Limit
SA Water	South Australian Water Corporation
TG	SA Water Technical Guideline
TS	SA Water Technical Standard

1.3 References

1.3.1 Australian and International

The following table identifies Australian and International standards and other similar documents referenced in this document:

Number	Title
AS 1210	Pressure vessels
AS/NZS 3709 (ISO 1940-1:2003)	Vibration and shock - balance quality of rotating rigid bodies Note: ISO standard to be used
AS 4024.1601	Safety of machinery - Design of controls, interlocks and guarding - Guards - General requirements for the design and construction of fixed and movable guards
AS 4024.1602	Safety of machinery - Interlocking devices associated with guards - Principles for design and selection
AS 4024.1603	Safety of machinery - Design of controls, interlocks and guards - Prevention of unexpected start-up
AS 4024.1604	Safety of machinery - Design of controls, interlocks and guarding - Emergency stop - Principles for design

1.3.2 SA Water Documents

The following table identifies the SA Water standards and other similar documents referenced in this document:

Number	Title
TS 144	Design and specification of valves other than globe control valves including check (non-return) air and isolation valves
TS 146b	Requirements for Pump Specification, Procurement and Testing and Preparation of Pump Datasheets
TS 146c	Commissioning and Monitoring Mechanical Equipment
TS 148	Design, specification and monitoring requirements for HVAC and other ventilation systems

1.4 Definitions

The following definitions are applicable to this document:

Term	Description
SA Water's Representative	The SA Water representative with delegated authority under a Contract or engagement, including (as applicable): • Superintendent's Representative (e.g. AS 4300 & AS 2124 etc.) • SA Water Project Manager • SA Water nominated contact person
Responsible Discipline Lead	The engineering discipline expert responsible for TS 147 defined on page 3 (via SA Water's Representative)
Design	The specification of the configuration, selection and sizing of equipment to achieve required hydraulic and operational outcomes.

2 Scope

This standard applies to the design, specification and operation of all pump, turbine and valve elements in systems.

3 Introduction

Surge can be induced in water and wastewater systems under a variety of conditions including (but not limited to):

Uncontrolled operation of equipment:

- Loss of power or control (automatic or manual) to pumps, turbines or valves,
- Mechanical failure of pumps, turbines or valves.

Controlled operation of equipment:

- Automatic operation of pumps, turbines or valves (including start and stop ramps for pumps),
- Manual operation of pumps, turbines or valves (including emergency (e-stops)).

There are many potential scenarios under the broad conditions listed above which need to be specifically addressed for either the new or existing surge mitigation equipment being assessed.

The hydraulic failure of infrastructure is usually associated with:

1. High surge pressures and rupture or displacement of pipework or damage to other equipment,
2. Low (negative) surge pressures and buckling of pipework,
3. Water column separation and subsequent collapse, rupture or displacement of pipework or damage to other equipment. *

* this mode is an extension of effects from modes 1 and 2. It results after one or more negative pressure (-9 m) vapour pockets are created by an initial surge event (column separation) and these vapour pockets interact with subsequent positive pressure waves from the continued evolution of the surge event. The interaction of the vapour pockets with any subsequent positive pressure waves can result in the collapse of vapour pockets (column re-join) and the release of destructive energy.

Failures can be sudden (major rapid rupture) or gradual (pipeline lining degradation, pipeline movement at joints, fatiguing and/or leakage).

Fatigue of infrastructure also occurs if it is subject to repeated surge events which may not lead to sudden failures. For example, pump components may be subject to additional stresses during flow reversals leading to fatigue cracking, wear or seizure. Also, for example, the cement mortar lining inside lined pipes (e.g. mild steel, cast iron or ductile iron pipelines) may be damaged by column separation and re-join events. In this regard, the provision of surge mitigation infrastructure acts to reduce damage to pipeline linings and thereby extend the life of the linings and the pipeline asset.

4 Applicable Surge Control Measures

The following options can be used in isolation or together to prevent or mitigate surge in water and wastewater systems. The options are grouped depending on whether they involve:

- No Surge Mitigation – No equipment control limits or specific surge mitigation infrastructure,
- Controlled Operation of Equipment – Controlled operation of equipment under typical start (open) / stop (close) scenarios,

- Surge Mitigation Infrastructure - Uncontrolled operation of equipment (e.g. under power loss scenarios or manual intervention error).

The general order of preference for measures under each section is listed below for guidance from the first to last preference. However, the suitability or applicability of any of the measures will depend on the details of a particular system configuration and this shall govern the combinations of measures adopted by a panel designer or contractor. All surge mitigation measures, or combinations of measures, proposed by a panel designer or contractor, shall be approved by the Responsible Discipline Lead before finalising the design.

4.1 Water Systems

This following clauses specify the requirements for each of the above surge control measures as they relate to water systems.

4.1.1 No Surge Mitigation

1. Design systems such that surge pressure variations do not require any mitigation measures (shall be checked under all possible operational scenarios),
2. Increase the pressure rating or structural/mechanical strength of infrastructure (to deal with maximum dynamic positive and negative surge pressures),
3. Use backup or split power and control systems for pumps or turbines (e.g. redundant or split power feeds for pump station, hydraulic backup control lines for turbines and UPS battery backup for controls).

4.1.2 Controlled Operation of Equipment

1. Use soft starters, variable speed drives or “smart” drives (version of variable speed drive) for pumps to control start and stop ramp times,
2. Use pump discharge control valves,
3. Use turbine inlet control valves,
4. Use failure mode protection for control (modulating valves) – e.g. dual diaphragm, backup controls, separated control pressure set points for 2 or more parallel PRVs/PSVs and other similar measures,
5. Use physical limiters (gears, hydraulic constrictions or otherwise) to restrict the maximum rate at which any valve can be opened or closed.

4.1.3 Uncontrolled Operation

1. Use one-way* surge towers,
2. Use one-way* surge tanks (either dedicated or modified existing water supply tanks),
3. Use surge pressure vessels (compressed air or bladder type),
4. Use anti-slam measures on check or air valves (including using no-slam check valves as a preferred option),
5. Use bypass check valve (or other actuated valve) loops around pump trains,
6. Use fast acting pressure relief valves – direct relief (spring), surge anticipating and other similar valve types,

7. Use vacuum relief valves to allow air entrainment to relieve negative surge pressures,
8. Use burst or rupture discs (these shall only be used with the express written approval of the Responsible Discipline Lead),
9. Use flywheels (these shall only be used with the express written approval of the Responsible Discipline Lead).

* one-way does not preclude the use of bypass pipework around surge tower or tank outlet non-return (check) valves so that positive wave energy can be damped into the tower or tank during surge pressure wave cycles.

4.2 Wastewater Systems

The following clauses specify the requirements for each of the above surge control measures as they relate to water systems.

4.2.1 No Surge Mitigation

1. Design systems such that surge pressure variations do not require any mitigation measures (shall be checked under all possible operational scenarios),
2. Increase the pressure rating or structural/mechanical strength of infrastructure (to deal with maximum dynamic positive and negative surge pressures),
3. Use backup or split power and control systems for pumps (e.g. redundant or split power feeds for pump stations and UPS battery backup for controls).

4.2.2 Controlled Operation of Equipment

1. Use soft starters, variable speed drives or “smart” drives for pumps to control start and stop ramp times,
2. Use pump discharge control valves,
3. Use failure mode protection for control (modulating valves) – e.g. actuated gate or knifegate, plug or pinch valves,
4. Use physical limiters (gears, hydraulic constrictions or otherwise to restrict the maximum rate at which any valve can be opened or closed.

4.2.3 Uncontrolled Operation

1. Use one-way surge tanks (typically loaded with potable water to avoid odour issues),
2. Use surge pressure vessels filled with nitrogen gas,
3. Use anti-slam measures on check or air valves (including using no-slam check valves),
4. Use bypass check valve (or other actuated valve) loops around pump trains,
5. Use vacuum relief valves to allow air entrainment to relieve negative surge pressures,
6. Use burst or rupture discs (these shall only be used with the express written approval of the Responsible Discipline Lead),
7. Use flywheels (these shall only be used with the express written approval of the Responsible Discipline Lead).

5 Design Requirements

5.1 General

Dynamic hydraulic modelling shall be undertaken for all infrastructure (new or existing water or wastewater) if surge pressures are likely to exceed the limits stipulated in this standard or to result in higher or lower surge pressures than those currently experienced by existing infrastructure. Assessment can be undertaken manually using conservative equations (e.g. the Joukowsky equation), if such calculations conclusively show that surge pressures do not require prevention or mitigation. Any assessment indicating that surge pressures are not significant shall be certified by the designer or contractor and a copy provided to the Responsible Discipline Lead.

In the absence of the above assessment, or in the event that it shows that surge pressures do require prevention or mitigation, surge analysis of the new or existing system containing pumps, turbines or valves shall be undertaken with one of the following software packages:

1. Hammer (Bentley Software Platform),
2. Watham,
3. Hytrans,
4. Flowmaster,
5. Other software approved by the Responsible Discipline Lead.

All possible scenarios implied under the following conditions shall be analysed:

1. Uncontrolled operation of equipment including loss of power or control (automatic or manual) to pumps, turbines or valves and/or mechanical failure of pumps, turbines or valves,
2. Controlled operation of equipment including automatic operation of pumps, turbines or valves (including start and stop ramps for pumps and turbines) and/or manual operation of pumps, turbines or valves (including e-stops).

5.2 Model Configuration

If a dynamic hydraulic model is required (refer to clause 5.1), the following additional requirements shall apply:

1. A steady state model shall be developed within the dynamic model for a range of maximum to minimum system curve or hydraulic operating conditions (this model shall use parameters consistent with those used in any separate steady state model used to undertake hydraulic analysis for the system),
2. The dynamic model shall then be run for each of the scenarios identified above with the maximum and minimum steady state conditions as starting points.

5.2.1 System Classifications

The system being modelled shall be classified as having:

1. one or more pump/turbine/automatic (actuated) valve elements separated by one or more reservoir or tank boundary conditions such that no consecutive pump/turbine/automatic valve elements occur in the system (no direct in-line pump, turbine or valve stations),

2. one or more consecutive pump/turbine/automatic (actuated) valve elements and one or more reservoir or tank boundary conditions such that consecutive pump/turbine/automatic valve elements occur in the system (direct in-line pump, turbine or valve stations).

5.2.2 Scale of Dynamic Model

Either wave speed adjustment or time step interpolation schemes shall be used for all models.

For both classifications 1 and 2 (defined in clause 5.2.1), any dynamic model developed shall be appropriate to the scale of system analysed in accordance with the following:

1. For analysis of systems from pump, turbine or valve boundary conditions to other system boundary conditions (e.g. reservoirs, tanks or other pumps/turbines/valves), models with the following discretisations:
   a. a maximum discretisation of 10 m is applicable for systems with pipelines > 1 km and < 5 km in length,
   b. a maximum discretisation of 50 m is applicable for systems with pipelines > 5 km in length,
2. For analysis of partial systems (e.g. pipework within 1,000 m of and/or inside a pump, turbine or valve station), artificial boundary conditions shall be set up to replicate system pressures accurately before a surge event and models with the following discretisations:
   a. a maximum discretisation of 1m is applicable for systems with pipelines < 100 m in length,
   b. A maximum discretisation of 5m is applicable for systems with pipelines > 100 m and < 1,000 m in length.

This type of model should be used to assess the potential for local surge pressure problems in pump, turbine or valve station pipework (e.g. check valve slam potential and/or local column separation and re-join effects).

A sensitivity analysis shall be conducted to evaluate the effect of changes in maximum model discretisation lengths and confirm that the discretisation adopted does not introduce problematic levels of numerical dispersion in the model predictions.

Pumps, turbines and valves should be physically realistic when included in the model (multiple pumps, turbines and valves should not be included as lumped single devices). For example, if there are multiple parallel pumps then these should each be included in the model separately, with distinct and physically representative suction and discharge pipework, and not lumped as a single pump.

Multiple pumps and valves in facilities should be modelled to determine surge pressures in the case of the failure of any number of devices in combination from one to all devices.

5.3 Model Parameters

5.3.1 Calculation of Wave Speed

Pipeline wave speeds should be calculated using the following:

$$a^2 = \frac{K/\rho}{1 + (K/E)(D/e)c_1}$$

in which a = pipeline wavespeed, K = bulk modulus of water (at the relevant temperature(s), as per Table 1), ρ = density of water, E = modulus of elasticity of pipeline wall material (as per Table 2), D =

internal diameter of the pipeline, e = thickness of the pipeline wall and c_1 = restraint factor for rigid and flexibly jointed pipe

$$c_1 = 1 - \vartheta^2$$

where ϑ = Poisson ratio for restrained (rigidly jointed) pipe and c_1 = 1.0 for unrestrained (flexibly jointed) pipe.

Pipeline restraint conditions should be determined as either unrestrained or partially/fully restrained before use in the wave speed equation:

1. Unrestrained – typically socketed or slip-on collar joints for metallic, plastic or cement pipes with flexible joints sealed with o- rings
2. Restrained – typically fully welded or concrete encased joints for metallic, plastic or cement pipes with rigid joints

Table 1 – Variation of Bulk Modulus and Density of Water/Wastewater with Temperature

Temperature	Bulk Modulus (GPa)	Density (kg/m3)
15°C	2.15	999.1
20°C	2.17	998.2
25°C	2.22	997.0
30°C	2.25	995.7
40°C	2.28	992.2

Table 2 - Values for Elastic Modulus and Poisson Ratio for Different pipes

Pipe Type	Elastic Modulus (GPa)	Poisson ratio
Mild Steel (MS)	190-210	0.27-0.30
Cast Iron (CI)	80-170	0.20-0.30
Ductile Iron (DI)	160-170	0.25-0.30
Asbestos Cement (AC)	32	0.10-0.20

The elastic modulus for cast iron (CI) pipe in Table 2 varies significantly with the age and manufacturing conditions for the pipe. Sensitivity analysis should be undertaken for the range of possible wave speeds for this pipe type. The elastic modulus for asbestos cement (AC) pipe in Table 2 is given for an AC pipe in new condition with the entire wall section still assumed to be cement impregnated. If the AC pipe is suspected to have leached some of its cement to either external and/or internal pipe environments then this shall be taken into account in calculating the wave speed by varying the wall thickness parameter in the wave speed equation.

SA Water has many cement mortar lined (CML) pipes in its systems. For example, the following pipe types are common:

- MSCL – mild steel cement mortar lined
- CICL – cast iron cement mortar lined
- DICL – ductile iron cement mortar lined

The presence of CML can increase the wave speed of a section of pipework provided the CML is still intact and well bonded with the internal wall surface of the lined pipe. If the degree of bonding or integrity of the CML is not known in an existing pipeline then a sensitivity analysis shall be taken with the CML ignored and CML present and fully bonded. The effect of the CML shall be taken into account using the following equation to determine an equivalent thickness of additional metal to be added to the actual metal wall thickness to give a total equivalent wall thickness for use in the wave speed equation:

$$e_{total\ equivalent} = e_{metal} + e_{CML} \times \frac{E_{CML}}{E_{metal}}$$

SA Water has many plastic (PVC, PE, HDPE, PP and other) pipes in its systems. The wave speed for these types of pipes is typically lower than for metallic and cement pipes due, in part, to the viscoelastic nature of the plastic materials and the response of the viscoelastic pipe walls to dynamic changes in pressure. The appropriate wave speed for these pipes shall be calculated with reference to the relevant manufacturer's technical specifications. Furthermore, fatigue cycle calculations should be completed by the designer or contractor to ensure that the typical system operation pressures and/or surge pressures will not lead to the premature failure of plastic pipes.

5.3.2 Viscoelastic Pipes

The calculation of the surge response of a system with viscoelastic pipes requires the use of specialised software routines which do not appear to be standard within the proprietary modelling packages listed in clause 5.1 above. Responses from viscoelastic pipes exhibit more damping than non-viscoelastic pipes and so the use of proprietary software without specialised software routines for viscoelastic effects may lead to calculation errors. If a designer or contractor intends to use proprietary software without specialised software routines for viscoelastic effects for plastic pipes then the Responsible Discipline Lead shall be informed of this decision and the supporting technical justification.

5.3.3 Surge Vessel Gas Exponent

The gas exponent for air and/or nitrogen contained within surge vessels shall be taken as 1.2 within the following equation used to determine the relative water/wastewater to gas proportions in surge vessels over the range of applicable steady state and surge pressures:

$$H \times V^n = C$$

in which H = absolute pressure, V = volume of gas, n = gas exponent = 1.2 and C = a constant

5.3.4 Pump Parameters

Pump flow, head and efficiency characteristics should be based on manufacturer supplied information.

Pump inertia shall be based on manufacturer supplied information when available. Where pump inertia information is unavailable from the manufacturer the pump inertia shall be calculated, for each individual pump (not lumped pumps), using the following equations (by Thorley):

$I_{pump} = 1.5 \times 10^7 \times (P/N^3)^{0.9556}$ (kgm^2)

$I_{motor} = 118 \times (P/N)^{1.48}$ (kgm^2)

in which P = brake horsepower of pump operating at its best efficiency point (kW) and N = rotational speed (rpm)

Inertia for other rotating elements (e.g. flywheels) shall be calculated using:

$$I = mr^2$$

in which m = mass of rotating element (kg) and r = radius from the centre of the rotating mass to the centre of rotation (m)

Rotational speed (initial) should be set to the speed relevant to the scenario being modelled (maximum being full speed of the motor(s)).

The use of soft starters or variable speed drives (VSDs) on pumps will not control ramp times in the event of power or VSD failure. Uncontrolled deceleration of the pump, limited only by the inertia of the pumps and motor, shall be used to model this scenario.

The ramp times for pumps should not take into account surge requirements alone. The length of time pumps can be operated below the pump's minimum continuous operating flow during start and stop ramps shall be determined from the pump manufacturer data (see TS 146b). The manufacturer supplied information should be used as a fixed parameter in the surge modelling. This consideration is important when procuring pumps to ensure that the pump operating requirements and the required surge control are compatible.

Reverse flow through pumps should not be modelled.

5.3.5 Turbine Parameters

Turbine flow, head and efficiency characteristics shall be based on manufacturer supplied information.

Turbine inertia shall be based on manufacturer supplied information.

Turbine quadrant curves shall be obtained from the manufacturer and used in the surge modelling of reaction turbines. The quadrant curves describe the relationship between flow, pressure, speed, direction of rotation and gate opening for all possible operating conditions from normal turbine function through to load rejection conditions.

5.3.6 Valve Parameters

5.3.6.1 Check Valves

Check valves (including those used on pump discharges and on the outlets from one-way surge towers and/or tanks) shall be modelled, using manufacturer supplied information, to determine flow versus position open and opening and closing time requirements and to confirm that each check valve:

1. operates correctly during a surge event and mitigates, rather than worsens, surge pressures in the system,
2. operates in such a way as to not create surge effects by slamming.

Check valve reverse velocity versus deceleration curves shall be obtained from manufacturers and specifically used to determine the potential for check valve slam under all operating conditions.

5.3.6.2 Direct Acting Relief Valves

Direct spring (or other) actuated fast acting relief valves shall only be used with the formal (written) approval of the Responsible Discipline Lead. Technical data sheets from the proposed valve manufacturer showing valve response time versus discharge coefficient versus percentage opening need to be correctly used in the dynamic model which needs to be verified by the designer or contractor and a notice of such verification sent to the Responsible Discipline Lead.

5.3.6.3 Surge Anticipating Valves

Surge anticipating valves can be used to mitigate positive surge waves that are predicted after an uncontrolled or controlled surge event. Appropriate arrangements for such mitigation shall include allowance for the maximum discharge rate, total time and total volume required to dissipate the surge energy before discharge to a receiving environment. The preference is for discharges to be directed to a tank(s) if available.

Direct fast acting relief valves and surge anticipating valves both require the discharge of the fluid contained in the system and cannot generally be used for wastewater systems (any proposal to use these devices for wastewater systems may only be used with the formal (written) approval of the Responsible Discipline Lead).

5.3.6.4 Miscellaneous

Fixed (physical) restrictions in valves (e.g. needle valves or orifices in globe valve pilot control lines) guarantee controlled opening and closing rates. However, the effect of blockage in an individual or all control lines shall be considered in determining whether this would result in a critical surge scenario.

All valves modelled, and subsequently installed, shall be subject to commissioning tests, to confirm the physical performance of all valves sufficiently matches the modelled theoretical behaviour, in accordance with TS 146c. The use by designers of default valve parameter values from modelling software is not recommended.

6 Specification Requirements

6.1 General Requirements

The required pressure ratings, and maximum and minimum operating pressures, for all surge mitigation infrastructure including towers, tanks, surge vessels, air release valves, vacuum relief valves, pressure relief valves, surge anticipating valves, check valves, rupture discs and all connecting pipework between elements shall be specified by the panel designer or contractor.

The physical and chemical composition of the fluid contained within the system to be protected and associated surge mitigation infrastructure shall be confirmed by the panel designer or contractor with SA Water’s Treatment Group. External and internal coatings for surge vessels and valves shall be specified where either the external environment or internal fluid characteristics (physical or chemical) are likely to abrade, erode, corrode or otherwise reduce the operational life of the infrastructure if no coating is applied.

Example datasheets for surge vessels, air release, vacuum relief, pressure relief, surge anticipating and check valves, flywheels and rupture discs have been developed by the Responsible Discipline Lead and can be accessed via the SA Water website under the Technical Standards page. These datasheets provide for the specification of the operational requirements of the surge mitigating infrastructure by the panel designer or contractor, the communication of physical and chemical fluid properties to equipment vendors, the specification of particular SA Water materials requirements for equipment components, mechanical and static/dynamic hydraulic requirements, coating requirements, factory and field testing requirements and other miscellaneous matters.

Further information relating to the specification of the listed valves is included in TS 144. Both TS 144 and TS 147 shall be referenced in any specification used for the procurement of valves installed in accordance with this standard.

A minimum warranty period of 12 months from the time of first operation of the equipment supplied by a vendor shall apply and not 12 months from the time of delivery.

6.2 Water Systems

6.2.1 One-Way Surge Towers and Tanks

Any new one-way surge tower or tank(s) shall have outlet pipework connected to the side or bottom outlet from the tower or tank(s) and shall have one or more check valves installed, subject to clause 7.2 below, to permit flow out of the tower or tank(s) should low surge pressures arise in the system. Smaller diameter inlet pipework may be installed around the check valves but needs to remain normally closed unless the connected system pressures are such that the tower or tank(s) will not drain through the pipework.

The conversion of existing system tanks into one-way surge tanks requires the connection of pipework to the side or bottom outlet from the tanks and the installation of one or more check valves, subject to clause 7.2 below, to permit flow out of the tanks should low surge pressures arise in the system. Smaller diameter inlet pipework may be installed around the check valves but needs to remain normally closed unless the connected system pressures are such that the tower or tank(s) will not drain through the pipework.

Volumetric turnover of the water stored within the one-way surge tower or tank(s) shall be considered by the panel designer or contractor and sufficient infrastructure and operating procedures developed to ensure that water stored within the towers or tanks is turned over at an acceptable frequency. This frequency needs to be determined by the panel designer or contractor based on feedback from SA Water regarding the minimum quality of water that needs to be maintained in the tower or tank(s) (e.g. for a tower or tanks on raw water systems the frequency of turnover required will be less than that for a tower or tanks connected to potable water systems).

The maximum and minimum tank water levels shall be used, in combination with all surge scenarios, to determine the range of differential pressure conditions over which the outlet check valve(s) must operate. The minimum opening flow, and varying degrees of valve percentage open, over the range of differential pressure conditions between the tower(s) or tank(s), and the connected pipeline(s), shall also be confirmed by the panel designer or contractor, and the check valve vendor, to ensure the outlet check valve(s) does not restrict the ability of the surge tower(s) or tank(s) to minimise surge pressure variations in the connected pipeline(s).

The percentage open, and time to reach this open position, is to be specified in a returnable schedule by the check valve vendor, and confirmed as appropriate by the panel designer or contractor, for each differential pressure condition under each surge scenario. The panel designer or contractor shall undertake surge modelling to determine the range of acceptable opening times for the check valve(s) under each surge scenario.

The degree of check valve opening, for all surge scenarios, must be significant enough to enable monitoring using position switches mounted on an external lever arm on the check valves (this lever arm shall be specified). These position switches shall be fitted and signals included in the control system so that the operation of the check valve(s) can be confirmed after a surge event and can be periodically checked under normal operating conditions to confirm continued functionality and that any tower or tank turnover requirements are being achieved for water quality purposes (not related to surge). If the check valve selected cannot be fitted with an external lever arm then flow switches shall be fitted instead of position switches to achieve the functionality described above.

If a single outlet check valve is installed, and meets the requirements of clause 7.2 , then an accompanying vacuum relief valve shall be installed on the downstream (discharge) side of the check valve.

6.2.2 Surge Vessels

A surge vessel(s) shall be designed so that the operating fluid level in the vessel(s) is between a minimum of 50 % and maximum of 70 % of the total volume of the vessel(s) under all operating conditions except during a surge event. During a surge event the operating fluid level in the vessel(s) can vary between a minimum of 10 % and a maximum of 90 % of the total volume of the vessel(s) provided that compression of the contained gas to a volume of 10 % does not result in overpressure conditions. Fluid depth shall not fall below 10 % of the overall depth within the vessel(s) or reach a minimum level from which air will escape the vessel(s) and enter the connected pipeline(s). If the above minimum 10 % volumetric criteria and 10 % depth or air escape depth criteria do not yield the same minimum level criteria then the criteria with the greater minimum required depth shall apply. The panel designer or contractor shall conduct sufficient surge analysis and calculations to confirm that the specified surge vessel(s) comply with the above described criteria.

The outlet from each pressure vessel is to be configured with a check valve of the same diameter as the connecting pipework to the vessel allowing flow out of the vessel and a smaller bypass around the check valve enabling flow back into the vessel with a restricted diameter or included orifice sized to achieve a loss coefficient of 2.5:1 for the flow into and out of the vessel, respectively. The above specified loss coefficient shall be confirmed by the panel designer or contractor and changed if surge modelling indicates that a different loss coefficient is required. The outlet check valve from each vessel shall be quick opening and not stick shut. The required opening time shall be confirmed by the panel designer or contractor, based on surge modelling or other technical analysis, and the check valve specified to meet the identified required opening time. Anti-slam measures may need to be specified for the outlet check valves.

A depth versus volume relationship is to be determined for the surge vessels to an accuracy of ± 1 % volumetric error at any depth and used to convert readings from depth instruments into volumes (for the purpose of design or otherwise).

Surge vessels shall be provided with:

1. Differential pressure cells, ultrasonic or equivalent depth indicators; and
2. Sight glass or magnetic flip depth indicators; and
3. Pressure relief valve(s).

Surge vessels shall be specified in accordance with AS 1210-2010 and shall have a manufacturers plate affixed stating the pressure rating of the vessels.

Surge vessels shall have external and internal coatings in accordance with the requirements stipulated in applicable SA Water Engineering Materials Standards.

Surge vessels shall be able to withstand the maximum and minimum anticipated surge pressures when all except one duty vessels fail (e.g. due to check valves jamming or vessels being empty due to control system failure/error). The surge vessels shall also be designed to withstand the maximum and minimum possible surge pressures in the system without any operable surge vessels or other mitigating equipment and with the vessels exposed to these pressures (e.g. because check valves are stuck open, or have been removed, or through bypasses around the outlet check valves). Surge vessels shall also be specified to withstand the maximum shutoff head in a pumped system.

Surge vessels can be specified in vertical or horizontal orientations. The depth versus volume relationship, and hence the sensitivity of the control system to signals from level instruments, is enhanced if the surge vessels are vertically orientated although this is not critical if accurate level instruments are used. Surge vessels can be specified with metallic or reinforced concrete pedestals and shall have fixed ladders, platforms and handrails to enable access to all equipment and manholes in accordance with AS1657.

Differential pressure transducers shall be used for signalling liquid level in the surge vessels to the control system. Visual indication shall also be provided outside using sight glasses or magnetic flip tag indicators. The differential pressure transducer connection points to the surge vessels shall be installed within the top and bottom 10 % (by depth) of the surge vessels unless otherwise approved by the Responsible Discipline Lead (in writing).

At least two top, side or bottom manholes shall be provided to facilitate internal inspection. Confined space WHS requirements apply to the sizing and specification of these manholes.

Baffling plates inside the surge vessels shall be considered for both vertical and horizontal configurations to damp surface waves inside the vessels. These baffling plates shall not reduce accessibility for periodic internal inspections.

A pressure/air release valve shall be ported into the top of the surge vessel to relieve over pressurisation of the surge vessels and allow for controlled release of pressurised air to adjust the level of water in the surge vessels. The pressure setting for the valve (for the pressure relief function) shall be set 10 % below the rating of the surge vessels with an accuracy of ± 1 %. The size of the pressure relief valve shall be proportioned to achieve the maximum rate of relief required to stop over pressurisation of the surge vessels under steady state conditions (e.g. failure or loss of control of air supply compressors).

If air compressors are required (for non-bladder type surge vessels) then these compressors shall be specified in accordance with the requirements of TS 148. Neither receivers nor driers are required for the compressed air (or gas) from any required compressors. Compressed air (or gas) pipelines are to comprise materials that are resistant to corrosion and rated to the same pressure level as the vessels.

6.2.3 Air Release, Vacuum and Pressure Relief Valves

Vacuum relief valves are only to be used as backups to one-way tank and surge vessel mitigation for pipelines that are less than DN 250 mm and less than 500 m long. Vacuum relief valves shall not to operate unless the one-way tank or surge vessel mitigation fails (for water systems). Vacuum relief valves shall be combined with air release valves (i.e. double acting valves shall be selected) and located at system highpoints as identified in any surge analysis and otherwise to release accumulating air.

Double acting valves combining the vacuum relief and air release functions are preferred and twin head valves (i.e. a duty vacuum relief/air release and standby in the same valve head) are required where the valve is acting as the duty surge mitigation device (i.e. where the valve is not a redundant standby device).

The maximum and minimum pressure differential and rate of air entrainment to the connected pipeline shall be specified for each vacuum valve, based on the results of the surge modelling, so that the correct diameter vacuum port is specified. Maximum air inlet velocities shall not exceed vendor recommendations and shall not lead to noise levels greater than specified in the EPA’s 2007 policy regarding noise.

The maximum and minimum pressure differential and the rate of air expulsion from the connected pipeline shall also be specified for each air release valve under steady state and surge conditions so that the correct diameter air release port is specified. Enclosed pipes to capture mixed air and water expulsion from the valve shall be connected to nearest adequately sized approved drain or sewer and the capacity of this pipework, or the hydraulic conditions to which it is subject, shall not limit the rate at which air expulsion can occur from the valve. Maximum air outlet velocities shall not exceed vendor recommendations and shall not lead to noise levels greater than specified in the EPA's 2007 policy regarding noise.

Pumps drawing from free water surfaces up vertical columns or pipework, and then discharging through check valves, shall be assessed to determine whether surge will occur as the pumps start against potential air columns. If this potential exists, then air release valves (anti-slam) shall be provided between the pumps and the check valves at the top of the vertical columns or pipework to release air on pump start. Maximum air outlet velocities shall not exceed vendor recommendations and shall not lead to noise levels greater than specified in the EPA's 2007 policy regarding noise.

Direct acting (spring or other actuated) type surge relief valves shall have opening and closing resistance (spring stiffness or other), response time and diameter specified to achieve optimum surge relief. The surge model justifying the use of these valves shall be submitted to the Responsible Discipline Lead for assessment. The feasibility of discharging from the direct acting surge relief valve and requirements for energy dissipation and disposal of this discharge are to be identified by the panel designer or contractor and communicated to the Responsible Discipline Lead before any decision to use a surge anticipating valve is confirmed. Direct acting direct pressure relief valves are only to be used as backups to other forms of surge mitigation and require the formal (written) approval of the Responsible Discipline Lead.

Surge anticipating valves shall have opening and closing pressure settings, response time and diameter specified to achieve optimum surge relief. These parameters shall be guaranteed by the valve vendor before the valve is considered for surge relief and modelled. The feasibility of discharging from the surge anticipating valve and requirements for energy dissipation and disposal of this discharge are to be identified by the panel designer or contractor and communicated to the Responsible Discipline Lead before any decision to use a surge anticipating valve is confirmed. Surge anticipating valves are only to be used as backups to other forms of surge mitigation and require the formal (written) approval of the Responsible Discipline Lead.

6.2.4 Check Valves

Check valves shall function if being used to mitigate surge by regulating outflow from a one-way surge tower or tank or by acting in a bypass loop around an in-line booster pump station. This function shall be monitored and alarmed through SCADA using position of flow indication switches.

An analysis in accordance with this Technical Standard shall be undertaken by the panel designer or contractor to confirm whether check valve slam will potentially occur and then decide which of the following measures are appropriate to eliminate the slam potential (or reduce it to an acceptable level):

1. Assessment of potential sources of check valve slam including interaction with other mechanical equipment active in a system (including other surge mitigation equipment),

2. Correct check valve type selection and obtaining position versus discharge and speed of operation data (including the use of system deceleration versus reverse velocity curves when selecting a check valve type),

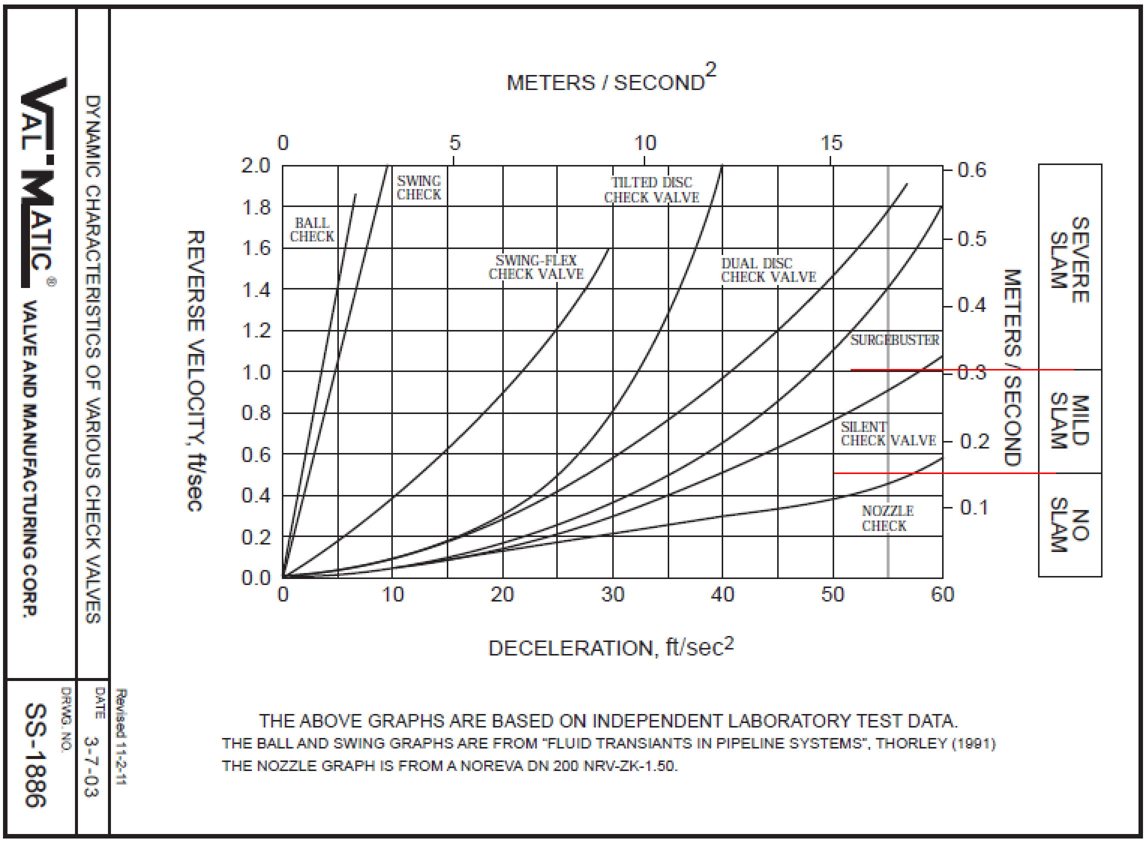
3. Use of hydraulic dampening system to cushion check valve operation over last 15 % of stroke (only if reverse flow through associated pump or turbine is confirmed as acceptable by the relevant equipment vendors),

4. Use of lever arms and counterweights to enable adjustment of check valve operation.

Check valves on pump discharges shall be checked for check valve slam characteristics before being procured. The characteristic deceleration of the system in which the check valve is to be installed shall be determined using a theoretical surge model or by direct measurement for the case of power failure to or emergency stop (e-stop) of a pump. The maximum permissible reverse velocity through the check valve shall be calculated on the basis of the maximum positive pressure the connected pipework can withstand based on its current condition. The characteristic deceleration of the system and the maximum permissible reverse velocity can then be used, together with check valve vendor supplied deceleration versus reverse velocity curves, to select the appropriate type of check valve for a particular system (whether new or existing).

An example deceleration versus reverse velocity curve is shown in Figure 1 below for a combination of check valve types of approximately 200 mm diameter.

Figure 1 - Typical Deceleration Reverse Velocity Curves for DN200 mm Check Valve Types



Non-dimensionalised deceleration versus reverse velocity curves can be used to assess the potential for a check valve to slam where curves are not available for a particular check valve diameter.

The use measured system deceleration data and information is preferred to the use of theoretical surge models to predict system deceleration. If a theoretical model is used to predict system deceleration then the type of check valve assumed, and the method of representing its dynamic characteristics in the theoretical model, shall be documented and provided to the Responsible Discipline Lead for comment by the panel designer or contractor.

Measured system deceleration data is preferred but only relevant when selecting new check valves for an existing system with existing check valves in operation. Measured system deceleration information cannot be obtained for new infrastructure where the pump station has not yet been constructed.

Information regarding the discharge through a check valve versus degree open, hydraulic losses (to enable energy assessment), maximum and minimum differential pressures to achieve degrees open, response time to achieve different degrees open and closed, sealing performance, lever arm options, monitoring instrumentation (position and flow switches) and anti-slam features (counterweights, hydraulic dampening or nozzle/silent type check valves) shall be provided in a datasheet supplied by the panel designer or contractor to the vendor.

Guards shall be provided for all check valves which have external moving elements (e.g. shaft lever arm with or without counterweights and position monitoring). Guards shall be designed, constructed and operated in accordance with the requirements stipulated in AS 4024.1601-1604 as relevant.

External indicators of disc position shall be included where the check valve shaft is able to be fitted with a lever arm or the shaft position can otherwise be monitored. The indication of shaft position shall be used to confirm check valve operation (upon open and close) and for no-flow alarming.

6.2.5 Flywheels

The mechanical impact of a flywheel on a pump/motor or turbine/generator shall be documented in writing and warranted by the pump or turbine vendor without compromising the design life of the pump/motor or turbine/generator.

Resonant frequencies for supporting base frames shall be assessed and calculations and a report confirming that no adverse dynamic interactions between the pump/motor or turbine/generator and flywheel will occur over all operating speeds and during start and stop ramps is required.

The time over which a pump or turbine is driven by a flywheel after discharge check or inlet/outlet control valves have closed needs to be calculated and the performance of the pump or turbine confirmed with the manufacturer for this duration while the flywheel may be spinning but no flow is occurring (heat generation calculations shall be provided if the heat rise in the recirculating cooling water (or other medium) is predicted to rise by more than 5° C).

Flywheels shall be constructed from metals that do not suddenly fracture and are approved by the Responsible Discipline Lead is required before any material selection is finalised. Guards shall be provided for all flywheels. Guards shall be designed, constructed and operated in accordance with the requirements stipulated in AS 4024.1601-1604 as relevant.

Flywheels shall be mounted on bearings and pedestals independently of pump/motor bearing systems. Flexible couplings shall be installed between the motor/flywheel and pump/flywheel.

Flywheels for turbine generators can be independently mounted or overhung (cantilevered) on the generator shaft.

Temperature and vibration monitoring (in axial, horizontal and vertical directions) shall be provided for all bearings. SCADA monitoring and alarming of temperature and vibration in the axial, horizontal and vertical directions for all bearings is required with the alarm and shutdown levels set as described in clause 7.6 of this Technical Standard.

Flywheels shall be independently balanced to a minimum grade of G2.5. Flywheel balance shall be reconfirmed once the flywheel is installed within a pump/motor or turbine/generator string in its final position. Vibration testing shall be undertaken on the flywheel bearings during local commissioning of any pump or turbine string in accordance with the methodology described in TS 146c.

6.2.6 Rupture Discs

Rupture discs shall only to be used as backups to other forms of surge mitigation and require the formal (written) approval of the Responsible Discipline Lead.

6.3 Wastewater Systems

6.3.1 One-Way Surge Towers and Tanks

The use of a dedicated one-way surge tower or tank would be unusual in a wastewater system and shall only be pursued by a panel designer or contractor after a justification is presented to the Responsible Discipline Lead and written confirmation is provided by the Responsible Discipline Lead permitting the use of a one way surge tower or tank.

6.3.2 Surge Vessels

The requirements for surge vessels in water systems generally apply, as stipulated in clause 6.2.2, except that:

1. Nitrogen gas is to be used instead of compressed air (unless a bladder is used),
2. Any pressure relief valve provided on the top of the surge vessels shall direct wastewater discharge to a suitable location.

Air compressors shall not to be used with the nitrogen gas. Surge vessels shall be periodically re-filled after leakage or loss to the connected system during a surge event (or otherwise). The nitrogen gas level in the surge vessels shall be operationally monitored and if it falls more than 20 % below the minimum level stipulated in clause 6.2.2 then an operational alarm shall be raised. The surge vessel fluid level shall not be used to inhibit the operation of a wastewater pump station unless there is no nitrogen gas left in the surge vessels at all in which case an alarm requesting immediate attendance shall be raised.

All valves, including any surge vessel outlet check valves, need to be specified for wastewater application.

Outlet check valves are not commonly used on SA Water surge vessels in wastewater systems and this needs to be taken into account when the surge analysis is undertaken by the panel designer or contractor to size the surge vessels and otherwise confirm their operation during a surge event.

Surge vessels with bladder inserts shall be considered if they avoid the use of nitrogen gas.

6.3.3 Air Release, Vacuum and Pressure Relief Valves

Vacuum relief valves can be specified for wastewater pressure pipelines < DN 500 mm as the sole surge relief infrastructure with sufficient numbers installed to protect the entire pipeline length from negative pressures less than -5 m in the case of any one of the installed vacuum valves failing to operate. An air release function is required at each vacuum relief valve location and at any other highpoints along the pipeline where accumulated gas cannot be swept along the pipeline by the normal range of velocities within it. Double acting valves combining the vacuum relief and air release functions are preferred and twin head valves (i.e. a duty vacuum relief/air release and standby in the same valve head) are required where the valve is acting as the duty surge mitigation device (i.e. where the valve is not a redundant standby device).

The requirements stipulated in clause 6.2.3 apply in relation to maximum and minimum differential pressures across the vacuum (and air release) valves under steady state and surge conditions. This is required to assist in the specification of the correct diameter for the air release port. Enclosed pipes to capture mixed gas and wastewater expulsion from the valve shall be used and connected to the nearest adequately sized sewer. The capacity of this connecting pipework, or the hydraulic conditions to which it is subject, shall not limit the rate at which air expulsion can occur from the valve. Maximum gas inlet or outlet velocities shall not exceed vendor recommendations and shall ensure that noise levels are less than those acceptable to the Environmental Protection Authority for the location in which it is installed and at the boundary of the SA Water property on which it is installed.

Direct acting and surge anticipating valves shall only be pursued by a panel designer or contractor after a justification is presented to, and express written approval gained of the Responsible Discipline Lead permitting the use of these valves on wastewater systems.

6.3.4 Check Valves

All the requirements of clause 6.2.4 are applicable except for those relating to check valves on the outlets of a surge tower or tank.

Wastewater pump discharge check valve slam potential is to be assessed by the panel designer or contractor after analysis in accordance with the procedure described in clause 6.2.4 has been undertaken. Pump discharge check valves include check valves located in valve pits located separately from conventional pump station dry wells or submersible pump station wet wells. It is noted that swing check valves are the most common form of check valve used in SA Water wastewater systems.

6.3.5 Flywheels

The use of a flywheel would be unusual for a wastewater pump and shall only be pursued by a panel designer or contractor after a justification is presented to the Responsible Discipline Lead and written confirmation is provided by SA Water permitting the use of a flywheel.

6.3.6 Rupture Discs

The use of a rupture disc would be unusual in a wastewater system and shall only be pursued by a panel designer or contractor after a justification is presented to the Responsible Discipline Lead and written confirmation is provided by SA Water permitting the use of a rupture disc.

7 Operating Requirements

7.1 Maximum and Minimum Surge Pressure Limits

The maximum surge pressure shall not exceed the DPL for all components and at any location within the system.

The minimum surge pressure shall not drop below 0 m for all components and at any location within the system to minimise the creation of air pockets in both water and wastewater systems and avoid possible contamination via the ingress of external groundwater into potable water systems.

However, if this minimum surge pressure cannot be achieved using dedicated surge mitigation infrastructure or otherwise, and the likelihood and impact of column separation is considered acceptable, then a minimum surge pressure to -9 m (full vacuum) may be accepted by SA Water. A minimum surge pressure of -9 m will only be accepted if the panel designer or contractor can certify, based on surge analysis, that:

1. column separation will not result positive pressures exceeding the DPL for all components and at any location within the system; and
2. SA Water Assets are provided sufficient technical information by the panel designer or contractor with which to conduct a risk assessment to determine the short and long term impacts of the anticipated surge pressures on the life of all connected pipeline and mechanical equipment assets.

Surge pressure of -9 m shall only be adopted with the express written approval of the Responsible Discipline Lead.

7.2 Duty and Standby Surge Mitigation Infrastructure

The duty and standby requirements for surge mitigation infrastructure are:

1. Duty and standby one way surge tower outlet check (non-return) valves are required where the protected pipeline (or network pipelines) are greater than DN250 mm and/or 500 m in length. The standby outlet check valve shall be maintained operationally on-line at all times except when maintenance is being conducted. The standby outlet check valve shall only be taken offline after:

    a. the functionality of the duty outlet check valves is confirmed; and

    b. the capacity of the single duty outlet check valve to operate to prevent problematic surge pressures is reconfirmed.

    The standby outlet check valve shall not be taken offline for more than 2 weeks.

2. Standby surge pressure vessels are not used (i.e. all installed surge pressure vessels are to operate as duty or assist). However, more than one duty surge pressure vessel shall be used, to achieve the total required pressure vessel capacity, where the protected pipelines (or network pipelines) are greater than DN250 mm and/or 500 m in length or otherwise where unacceptable pressure would occur in the connected system. A single outlet check valve on each surge vessel (if designed or installed) is satisfactory.

    Where more than one surge vessel is to be installed or exists, no more than one duty surge pressure vessel shall be taken offline at a time for maintenance or replacement. The removal of one duty surge vessel from operation for maintenance or replacement shall be considered by the panel designer or contractor when determining the number and size of surge pressure vessels to be initially installed to ensure that the maximum and minimum surge pressure limits will be provided under all operating conditions with all duty (N) and all except one duty (N-1) surge vessels on-line,

3. Standby vacuum relief valves are not installed in SA Water systems, except on a limited number of pipeline systems, and are not required for pipeline (or network pipelines) protection unless the diameter of the pipeline (or network pipelines) exceeds DN600 mm and vacuum relief valves are installed without surge tower, surge tank(s) or surge vessels. If the protected pipeline exceeds DN600 mm, and no surge tower, surge tank(s) or surge vessels exist or will exist, then duty and standby vacuum relief valves shall be installed. This clause only applies to existing systems. New systems shall be delivered with secondary vacuum relief valves only in accordance with clause 7.5 of this standard,

4. Standby spring relief or surge anticipating valves are not installed in SA Water systems unless required as the outcome of a specific risk assessment conducted by SA Water. If a standby spring relief or surge anticipating valve is required for a particular high risk installation, where either the surge pressures exceed the DPL of connected infrastructure and/or an existing asset requires additional and redundant protective measures, the standby valve shall be commissioned with an offset operating threshold which prevents simultaneous operation with the duty valve but which ensures the standby valve operates to achieve the required level of surge protection in the event of the failure of the duty valve.

7.3 One Way Surge Tower or Tank(s)

The status of check valves installed in the outlets to surge towers and/or tanks needs to be monitored through SCADA to confirm that the check valves are functional.

In-situ instruments shall be installed for the detection of check valve lever arm movement, where installed check valves have external lever arms, and otherwise for the detection of flow using flow switches, so that check valve functionality can be inferred. Pressure transmitters shall also be installed in the system upstream and downstream of the one way surge towers and/or tanks such that periods during which the tower or tank level is greater than that in the connected downstream system can be identified.

A SCADA alarm to operations shall occur if the pressure differential across the check valves measured from the pressure transmitters is such that the check valves shall open to a pre-determined (i.e. calculated) position but they fail to do so. If the check valves do not open at all, when the pressure differential across the check valves indicates that the check valves shall open, then the connected system shall be interlocked to prevent operation.

Periodic recirculation and/or disposal of the fluid in the one way surge tower or tanks shall be facilitated as part of normal system operation.

7.4 Surge Vessels

The signals from the depth indicators (optionally converted to volumes) are to be continually monitored in the control system (SCADA) to ensure that the appropriate ratio of fluid to air (or nitrogen) is maintained in the duty vessels for all pump or valve operating points.

A SCADA alarm to operations shall occur if the level of fluid in the duty vessel(s) increases to more than 3 % above the required volume (at any particular system operating pressure) and an interlock preventing operation of the system shall be provided if the level of the fluid in the duty vessel(s) increases to more than 7.5 % above the required volume (at any particular system operating pressure). The required volume is the calculated volume of fluid in the vessel, at any particular operating pressure, which provides optimum surge mitigation. A relationship between the required volume, operating pressure and depth in the surge vessels shall be established by the panel designer or control and included in the as-commissioned control system for the surge vessels.

A SCADA alarm to operations shall occur if the level of fluid in the duty vessel(s) falls below more than 3 % below the required volume (at any particular system operating pressure) and an interlock preventing operation of the system shall be provided if the level of the fluid in the duty vessel(s) decreases to more than 7.5 % below the required volume (at any particular system operating pressure).

A relationship between the system operating pressure and depth and/or volume in the duty vessel(s) shall be calculated and confirmed during commissioning of the system.

Compressors (duty standby) shall operate to add compressed air to the pressure vessels (if not bladder type) should the level of fluid in the duty vessel(s) increase above the required volume by more than 2 % across different system pressures (this allows for the loss of compressed air via leakage or into solution over time).

Relief (release) valves are to operate to release compressed air from the pressure vessels should the level of fluid in the duty vessel(s) fall below the required volume by more than 2 % across different system pressures.

Compressors and relief (release) valves shall not operate during pumping operations and shall only be operated prior to (or after) pumping operations.

Periodic recirculation and/or disposal of the fluid in the vessels should be facilitated by operations.

7.5 Air Release, Vacuum and Pressure Relief Valves

Air release and vacuum relief valves shall not be used as the primary means of surge mitigation where, in the event that one or more valves do not operate, column separation and rejoin occurs, or pressures otherwise will exceed the pipeline capacity, in the connected system.

Air release and vacuum relief valves can be used as a secondary or backup means of surge mitigation providing a one way surge tower, one way surge tank, surge vessel or flywheel is provided as the primary means of surge mitigation.

Where air release and vacuum relief valves are used to mitigate positive or negative surge pressures (including column separation) they shall be periodically inspected and monitored to confirm that they are operational. Inspection and testing shall be as follows:

1. Physical inspection of the valves to check for corrosion, leaks or other signs of deterioration at a 6 monthly maximum interval,
2. Surge testing to confirm that the valves operate to release air from and allow air into the connected pipeline at a 12 monthly maximum interval. This testing only needs to be sufficient to confirm that the valves operate and can be completed by relying on observations at each valve site during the testing. The minimum surge that requires the valves to operate shall be induced in the system during these tests.

The above on-going inspection and monitoring requirements during operation shall be taken into account by and presented to SA Water Operations before any decision is made to use air release and vacuum relief valves in preference to other forms of surge mitigation.

Direct acting surge pressure relief valves (spring, hydraulic and/or pneumatically actuated) can be used as the primary means of surge mitigation where other forms of surge mitigation are ineffective or impractical to install (e.g. suction pipework pressure relief where tanks and pressure vessels are ineffective).

Where direct acting surge pressure relief valves are used to mitigate positive or negative surge pressures (including column separation) they shall be periodically inspected and monitored to confirm that they are operational. Inspection and testing shall be as follows:

1. Physical inspection of the valves to check for corrosion, leaks or other signs of deterioration at a 6 monthly maximum interval,
2. Surge testing to confirm that the valves operate to release water from the connected pipeline, and surge pressures are sufficiently mitigated, at a 12 monthly maximum interval. This testing needs to be conducted with surge pressure loggers connected upstream and downstream of the valves. The minimum surge that requires the valves to operate shall be induced in the system during the tests.

Surge anticipating pressure relief valves can be used as the primary means of mitigating a positive surge pressure where other forms of surge mitigation are ineffective or impractical to install. The requirement for the release of water from the connected pipeline through the surge anticipating valve (after opening following a low pressure wave event) shall be taken into account. Periodic inspection and monitoring is required as for direct acting surge pressure relief valves.

7.6 Flywheels

Flywheels are not to be installed without the express written approval of the Responsible Discipline Lead.

Vibration monitoring on all flywheel bearings shall be provided with accelerometers mounted to detect horizontal and vertical vibration. This vibration monitoring shall be implemented in a way that is consistent with TS 146c and enables a vibration alarm to be sent through SCADA to operations if the vibration level for any size flywheel exceeds 2.5 mm/s RMS for any monitoring accelerometer. System interlocking shall be provided such that if the vibration level exceeds 4.2 mm/s RMS for any size flywheel, and any monitoring accelerometer, then the equipment and/or system is shut down.

Guards shall be provided around the flywheels in accordance with AS 4024 such that inadvertent (or other) contact with the flywheels cannot occur while they are operating. Local e-stops are ineffective for flywheel installations as the flywheel slows the deceleration of rotating elements.

7.7 Check Valves

Check valves installed on the outlet(s) of one way surge towers or tanks shall be operationally monitored as described in clause 7.3.

Check valves installed on bypass lines around a pump and/or turbine for the purpose of surge mitigation shall have instruments installed for the detection of check valve lever arm movement, where installed check valves have external lever arms, and otherwise for the detection of flow using flow switches, so that check valve functionality can be monitored.

Check valves installed on a pump and/or turbine discharge shall have instruments installed for the detection of check valve lever arm movement, where installed check valves have external lever arms, and otherwise for the detection of flow using flow switches, so that check valve functionality can be monitored.

A SCADA alarm to operations shall occur if a check valve on:

- the outlet of a one way surge tower and/or tank fails to operate,
- a bypass line around a pump and/or turbine fails to operate,
- a pump and/or turbine discharge fails to operate.

Check valves installed on surge vessel outlets are not required to have instruments for the detection of check valve operation provided that more than one duty surge vessel exists. If only one duty surge vessel exists, or is proposed, then the Responsible Discipline Lead shall be contacted to confirm the supporting rationale.

7.8 Maintenance Considerations

Indicative maintenance considerations when evaluating the costs and benefits of different forms of surge mitigation for surge are tabulated in Table 3.

Table 3 - Indicative Maintenance Considerations for Different Forms of Surge Mitigation

Surge Mitigation	Indicative maintenance implication
Thicker pipe wall	None
VSDs or smart drives	Maintenance of electrical equipment
Control valves	Maintenance of valves, actuators and control systems
Physical limiters	Long term deterioration and replacement options
One way tower	Water quality, tower structure, outlet pipework, check valves and monitoring/control systems. Regular inspection and testing to confirm functionality of outlet check valves

Surge Mitigation	Indicative maintenance implication
One way tank	Water quality, tank structure, outlet pipework, check valves and monitoring/control systems. Regular inspection and testing to confirm functionality of outlet check valves
Pressure vessels	Vessel certification (periodic), corrosion, inlet and outlet air valves (if applicable), compressors (if applicable), check valves and monitoring/control systems
Air/vacuum valves	Regular inspection and testing to confirm functionality depending on criticality
Check valves	Monitoring on each operation via SCADA if on pump or turbine discharges (e.g. for no flow circumstance). Regular inspection and testing to confirm functionality depending on criticality for other locations and configurations
Flywheels	Vibration monitoring system alarmed through SCADA, bearing temperatures alarmed through SCADA, regular inspection and testing to confirm functionality

7.9 Re-Start Procedure After Surge Event

Re-start procedures after a surge event (e.g. power loss or e-stop to a pump or turbine), including automatic re-start capability through to requirements for manual operator intervention, shall be developed as part of the design of the surge mitigation infrastructure by the panel designer or contractor. Measures to be considered include those for determining the state of the relevant system after the surge event (including the possibility of a major failure of a pipeline or mechanical equipment), pump or turbine station reset times and the minimum time required for air release valves to operate and allow the full recharge the pipeline(s) (particularly if double acting vacuum relief and air release valves are present in a system).

8 Testing and Commissioning

All equipment that relates to the prevention or mitigation of surge pressures shall be subject to factory, electrical, hydrostatic, balancing, site and any other additional testing required ensuring that the equipment operating requirements specified in clause 7 are met. The pre-commissioning documentation provided by the panel designer or contractor shall confirm that all required equipment tests have been satisfactorily completed.

Local commissioning plans, developed by the panel designer or contractor, or SA Water operations and workshops, for new capital or maintenance works, shall include provision for specifically testing all equipment that relates to the prevention or mitigation of surge pressures where the infrastructure used for local commissioning can be used to facilitate such testing (refer to TS 146c for local commissioning requirements).

System commissioning plans, developed by the panel designer or contractor for new infrastructure or maintenance works shall include provision for specifically testing all equipment that relates to the prevention or mitigation of surge pressures and shall enable the system response to be determined under all relevant failure modes (refer to TS 146c for system commissioning requirements). Sufficient monitoring equipment (flow, pressure, proximity, speed, temperature and/or vibration) shall either be permanently or temporarily installed to enable the system response to surge pressures, and other failure mode manifestations, to be fully quantified, understood and demonstrated before the infrastructure is handed over or returned to normal operation.

Theoretical surge models shall be calibrated and, where necessary, corrected during testing and commissioning so that an accurately calibrated surge model is then available for future reference and operational considerations. A copy of the final calibrated surge model (in its native format) shall be provided to the Responsible Discipline Lead for SA Water use.

9 On-going Monitoring

The requirements for the on-going monitoring of surge mitigation infrastructure are described in this Technical Standard and include:

1. One way towers and tanks – monitoring of check valve operation and position as well as minimum and maximum water levels in the towers or tanks,
2. Pressure vessels – monitoring of liquid level in the vessels and status of any compressors,
3. Air valves – periodic inspection and testing of air release and vacuum relief valves,
4. Pressure relief valves – periodic inspection and testing of pressure relief valves,
5. Flywheels – continuous bearing temperature and vibration monitoring,
6. Check valves (other than on one way tower or tank outlets) – monitoring of check valve operation and position.

All operating manuals shall include specific lists of regular inspections and tests that are stipulated in the Technical Standard.