T2.8 SURGE/MOMENTUM CHANGES DUE TO VALVE OPERATION

T2.8.1 Overview

The first step assessment process involves identifying all the significant valves on a particular line. Excitation due to surge and momentum changes is only considered for fast acting valves **[T2-3]**, which excludes all manually operated valves. Typical automatic valves that need to be considered in the assessment include:

- Emergency Shut Down Valves (ESD)
- Flow Control Valves (FCV)
- Pressure Control Valve (PCV)
- Blow Down Valves (BDV)
- Relief Valves (RV)

The assessment of excitation due to surge and momentum changes can be split into the three following operational cases:

- Dry Gas valve operation valve opening
- Liquid or Multiphase valve closure
- Liquid or Multiphase valve opening

For a dry gas any potential surge pressure due to a rapid valve closure is taken up via compression of the gas, hence the likelihood of failure due to a gas valve closing is considered negligible. Therefore the Likelihood of Failure for this operation is zero.

The assumption is made that the line is adequately supported for any reaction loads and that any anchors have significant strength.

T2.8.1.1 Extent of Excitation: Liquid or Multiphase valve closure

The main line LOF value predicted below should be applied to the entire main line length upstream of the valve, up to the next major vessel or significant pipe diameter change (“L” in **Table T2-5**) and up to two partial or full pipe supports downstream of the valve, (not spring hangers or constant load supports).

T2.8.1.2 Extent of Excitation: Liquid or Multiphase valve Opening

The main line LOF value predicted below should be applied to up to two partial or full pipe supports both upstream and downstream of the valve (not spring hangers or constant load supports).

During this type of valve operation there is a likelihood of Cavitation and Flashing and assessments detailed in **Section T2.9** and **T2.10** respectively are required.

T2.8.1.3 Extent of Excitation: Dry Gas Rapid Valve Opening

The main line LOF value predicted below should be applied to up to two partial or full pipe supports both upstream and downstream of the valve (not spring hangers or constant load supports).

T2.8.2 Information Requirements

The following table lists the information required for analysis of the excitation due to surge and momentum changes of different valve operations.

Proposed values of some of the input parameters listed are presented in **Appendix B** for some typical fluid types encountered in process systems. These are marked in the "comment" section of the table.

Piping Information	Symbol	Units	Comment	Liquid or Multiphase		Gas
				Valve Closure	Valve Opening	Valve Opening
Fluid density	ρ	kg/m^3		✳	✳	
Ratio of Specific Heat Capacities	γ		(C_p/C_v) Refer to **Appendix B** for Sample Input Parameter Values			✳
Speed of sound	c	m/s	Refer to **Appendix B** for Sample Input Parameter Values	✳		
External Main Line Diameter	D_{ext}	mm		✳		✳
Internal Main Line Diameter	D_{int}	mm		✳		✳
Young's Modulus of the main line material	E_{ml}	N/m^2		✳		
Fluid Bulk Modulus	K	N/m^2		✳		
Upstream Pipe Length	L_{up}	m	From valve to next major vessel or change in pipe diameter (greater than 2:1 diameter change) If the length is greater than 100m than a detailed surge analysis is required. Refer to **Appendix B** for Sample Input Parameter Values	✳		
Molecular Weight	Mw	grams/mol	Refer to **Appendix B** for Sample Input Parameter Values			✳
Upstream Static Pressure	P_1	Pa		✳	✳	
Pump head at zero flow	$P_{shut\text{-}in}$	Pa		✳		
Vapour Pressure	P_v	Pa	Refer to **Appendix B** for Sample Input Parameter Values			
Static Pressure drop	ΔP	Pa				
Universal Gas Constant	R	J/K.kmol	Value of 8314			✳
Main line Wall Thickness	T	mm		✳	✳	✳
Valve Closing Time	T_{close}	sec	Refer to **Appendix B** for Sample Input Parameter Values	✳		
Upstream Temperature	Te	K				✳
Steady State Fluid Velocity	v	m/s		✳		
Mass Flow Rate	W	kg/s			✳	✳
Pipe Support Type			Refer to **Section T2.2.3.3**	✳	✳	✳
Main line Wall Thickness for Schedule 40 Piping		mm		✳	✳	✳
Valve Type			Refer to **Appendix B** for Sample Input Parameter Values	✳		

Table T2-4 Information Requirements

Also,

$$\Psi = \frac{Actual\ pipe\ wall\ thickness}{Schedule\ 40\ pipe\ wall\ thickness}$$

θ is the correction for the support type, refer to **Section T2.2.3.3** for definition of support type:

Support Type	Stiff	Medium Stiff	Medium	Flexible
θ	4	2	1	0.5

T2.8.3 Calculation of Likelihood of Failure (LOF)

T2.8.3.1 Dry Gas Rapid Valve Opening

For a rapid opening of a gas valve the transient forces are due to the sudden change in momentum.

Calculate the peak force (kN) F_{max} using:

$$F_{\max} = \frac{W}{1000}\sqrt{\frac{2\cdot\gamma\cdot R\cdot Te}{(\gamma+1)\cdot Mw}}$$

↓

Calculate the limit force (kN) F_{min} using:

$F_{lim} = (16.8\times\Psi^3 - 1.81\times\Psi^2 + 525\times\Psi + 25.3) \times D_{ext} \times \theta \times \pi \times D_{int}^2/(4 \times 10^9)$

↓

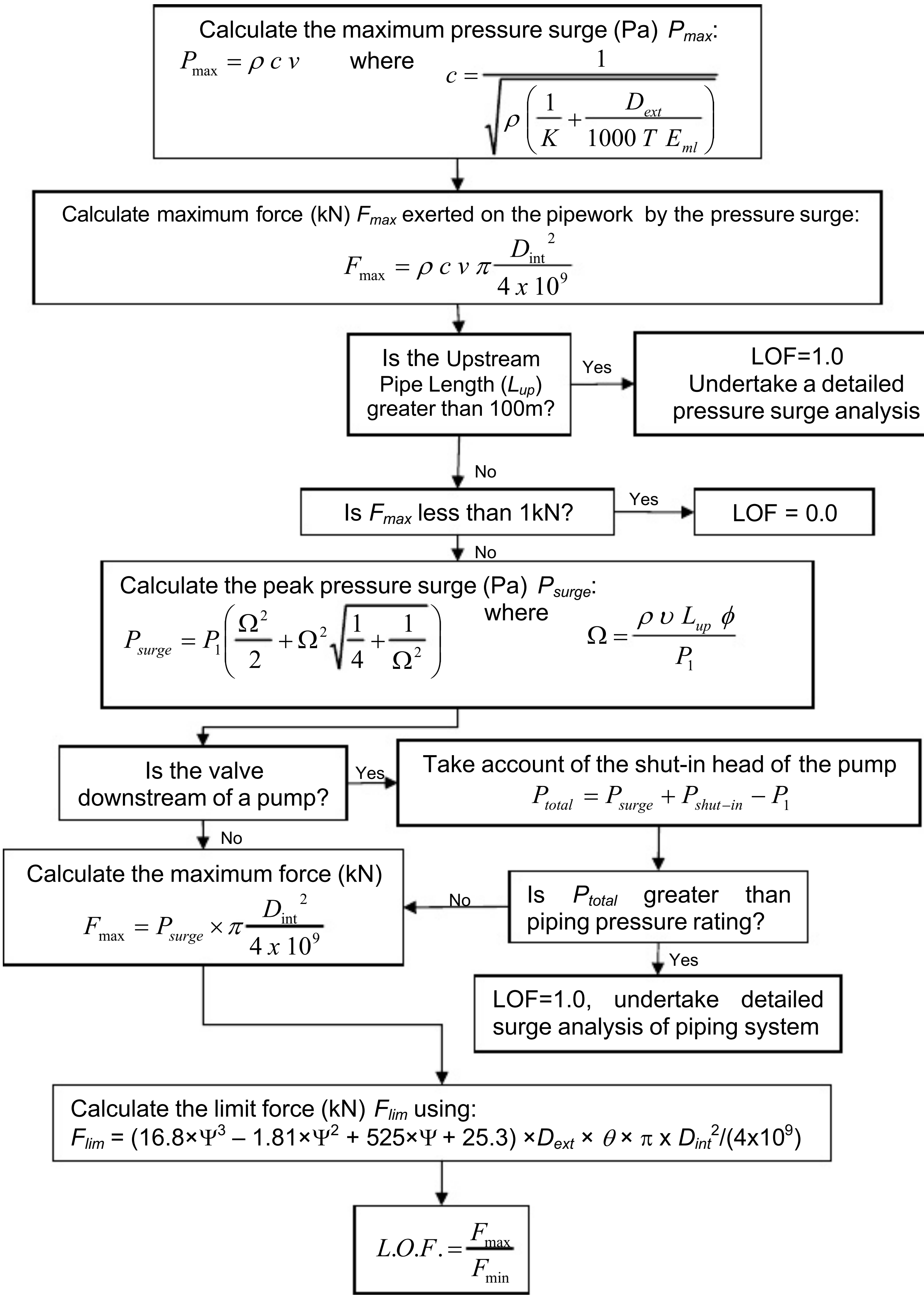
$$L.O.F. = \frac{F_{\max}}{F_{\lim}}$$

Flowchart T2-6 Dry gas rapid valve opening assessment

T2.8.3.2 Liquid or Multiphase Valve Closure

The peak pressure surge (P_{max}) generated during a valve opening or closure should remain within the design pressure rating for the line. If this is not the case a detailed surge analysis should be carried out in addition to the following assessment (refer to **TM-09**).

This initial assessment considers the worst case event of a ‘sudden’ valve closure, and the effect of the pressure surge on the pipe. If this is considered acceptable then no further analysis is required as pressure surge is unlikely to affect the integrity of the pipe. Sudden valve closure is defined as a valve closure time that is less than ($2L_{up}/c$).



Flowchart T2-7 Liquid or Multiphase valve closure assessment

where, ϕ is the function defining the flow area of the valve as a function of time. The function can be simplified for specific valve types by assuming that the peak pressure surge occurs at the point when the valve is closed, at a time T_{close}. The following table summarises the resulting α functions for different valve types. These are valid for valve closure times of up to 30 seconds.

Valve Type	ϕ
Full bore ball	$\frac{-1.281}{T_{close}} - 0.27$
Reduced bore ball	$\frac{-1.268}{T_{close}} - 0.362$
Butterfly	$\frac{-2.877}{T_{close}} - 0.275$
Globe	$\frac{-2.266}{T_{close}} - 0.32$
Gate	$\frac{-3.41}{T_{close}} - 0.315$

Note, If the type and/or closing time of the valve are not known then assume a globe valve and a valve closing type of 1 second per inch of pipe diameter.

T2.8.3.3 Liquid or Multiphase Valve Opening

High dynamic forces due to the rapid change in momentum, considering the valve opening scenario in a liquid or multiphase system, is outlined in the steps below. Note: for this case cavitation and flashing need to be taken into account using the approach outlined in **Sections T2.9** and **T2.10**, respectively.

Calculate the peak force (kN) F_{max} using:

$$F_{\max} = \frac{1}{1.58} W \sqrt{\frac{\Delta P}{\rho}}$$

↓

Calculate the limit force (kN) F_{min} using:
F_{lim} = (16.8×Ψ^3 – 1.81×Ψ^2 + 525×Ψ + 25.3) ×D_{ext} × θ × π x D_{int}^2/(4 x 10^9)

↓

$$L.O.F. = \frac{F_{\max}}{F_{\lim}}$$

Flowchart T2-8 Liquid or Multiphase valve opening assessment