



MONASH PIPE
EVALUATION PLATFORM



Australian Government
Department of Industry,
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Business
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MONASH
University

Civil
Engineering

Nomenclature

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Nomenclature: Monash Pipe Evaluation Platform

This document outlines the nomenclature used in the Monash Pipe Evaluation Platform. Abbreviations, notation and symbols along with descriptions of usage and references are also provided.

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1 Abbreviations

AC	Asbestos cement
CIPP	Cured-in-place pipe
CICL	Cast iron-cement lined
CI	Cast iron
DICL	Ductile iron-cement lined
DN	Pipe nominal diameter
OD	Pipe outside diameter
EP	Epoxy resin
“I”	as installed
“M”	as manufactured
MS	Mild steel
MSCL	Mild steel-cement lined
MAOP	Maximum allowable operational pressure
PA	Polyamide
PAN	Polyacrylonitrile
PE	Polyethylene
PEN	Poly(ethylene naphthate)
PET	Poly(ethylene terephthalate)
PPTA	Poly(p-phenylene terephthalamide)
RC	Reinforced concrete
UP	Unsaturated polyester resin
VE	Vinyl ester resin
<i>DR</i>	Dimension ratio

2 Notation

2.1 Host pipe

DN	Pipe nominal diameter (mm)
D_0	Pipe external diameter (mm)
D	Pipe internal diameter (mm)
D_M	Mean diameter of the host pipe (mm)
T_n	Pipe nominal wall thickness (mm)
T_{ext}	Estimated external uniform corrosion (mm)
T_{int}	Estimated internal uniform corrosion (mm)
T	Pipe wall thickness allowing for uniform corrosion (mm)
L_p	Length of the pipe (m)
L_{ps}	Length of the pipe spool (m)
σ_t	Ultimate tensile strength of host pipe material (MPa)
σ_y	Yield strength of steel (MPa)
E_p	Modulus of elasticity of host pipe material (GPa)
ν_p	Poisson's ratio of host pipe material
K_{IC}	Fracture toughness of host pipe material (MPa m ^{1/2})
N	Safety factor for host pipe
σ_p	Tensile stress in the host pipe (for AC pipe) (MPa)
$\sigma_{t,AC}$	Ultimate tensile strength of AC (MPa)
$2a$	Patch length (mm)
$2b$	Patch width (mm)



c	Patch depth (mm)
$2a'$	Critical patch length (mm)
$2b'$	Critical patch width (mm)
c'	Critical patch depth (mm)
k_1	Patch factor
k_2	Aspect ratio
r_s	Minimum corrosion rate (long-term) of metallic pipes (mm/y)
c_s	Intercept parameter for long-term corrosion of metallic pipes (mm)
τ	Transition period between short-term and long-term corrosion (y)
t	Time (years)
t_h	Time (hours)
SCF	Stress concentration factor
SCF'	Critical stress concentration factor
L_c	Critical crack length (mm)
r_{sv}	Radial corrosion rate for metallic pipes (mm/y)
r_{sh}	Lateral extension rate for metallic pipes (mm/y)
T_f	AC pipe remaining wall thickness at failure (mm)
y_f	Predicted year for failure of an AC pipe (year)
c_{ACi}	Internal deterioration rate for AC pipes (mm/y)
c_{ACe}	External deterioration rate for AC pipes (mm/y)
m_f	Fatigue constant for host pipe under cyclic surge pressure
C_f	Fatigue constant for host pipe under cyclic surge pressure
Q	Leak rate (L/s)
c_d	Discharge coefficient



- A Area of flow (mm^2)
- g Acceleration due to gravity (m/s^2)

2.2 *Soil properties*

- E_s Soil modulus (MPa)
- ϕ Soil friction angle ($^\circ$)
- k Lateral earth pressure coefficient
- γ_s Soil unit weight (kN/m^3)
- γ_w Unit weight of water (kN/m^3)

2.3 *Loading conditions*

- P Operating pressure (MPa)
- h Pressure head (m)
- P_T Test pressure (MPa)
- P_C Recurring cyclic surge pressure (MPa)
- P_S Surge pressure (MPa)
- P_{max} Maximum allowable pressure (MPa)
- P_{min} Minimum internal pressure (MPa)
- P_v Vacuum pressure (MPa)
- P_N External pressure on the liner (MPa)
- H Burial depth (mm)
- H_w Groundwater depth (mm)
- n_{PC} Number of recurring cyclic surge pressure cycles per day



n_{TPC} Total number of surge pressure cycles for the service life of pipe/lined pipe

n_f Cyclic surge factor

θ Rotation angle ($^{\circ}$)

P_G Groundwater load (MPa)

P_{GC} Groundwater load capacity (MPa)

q_t Total external pressure on pipes (MPa)

q_{tc} Liner capacity for total external pressure (MPa)

ΔT Temperature change ($^{\circ}\text{C}$)

W Traffic load (kN)

W_s Live load (MPa)

MAOP Maximum allowable operational pressure (MPa)

PN Nominal pressure (bar)

2.4 *Liner properties*

Liner Class (D, C, B, or A)

Liner type (CIPP or polymeric spray)

Reinforcement type (Glass or polymeric fibres) (for CIPP only)

T_L Liner thickness (mm)

D_L Liner external diameter (mm)

D_{Li} Liner internal diameter (mm)

σ_{max} Maximum stress in the liner (MPa)

σ_t Tensile strength of the liner (MPa)

E_L Short-term modulus of elasticity of the liner (GPa)



σ_{th}	Short-term tensile strength (hoop) of the liner (MPa)
σ_{ta}	Short-term tensile strength (axial) of the liner (MPa)
σ_A	Short-term tensile or compressive strength of the liner in the axial direction (GPa)
E_t	Short-term tensile modulus of elasticity of the liner (GPa)
E_{th}	Short-term tensile modulus of elasticity (hoop) of the liner (GPa)
E_{ta}	Short-term tensile modulus of elasticity (axial) of the liner (GPa)
E_A	Short-term tensile or compressive modulus of the liner in the axial direction (GPa)
σ_{fh}	Short-term flexural strength (hoop) of the liner (MPa)
σ_{fa}	Short-term flexural strength (axial) of the liner (MPa)
E_{fh}	Short-term flexural modulus of elasticity (hoop) of the liner (GPa)
E_{fa}	Short-term flexural modulus of elasticity (axial) of the liner (GPa)
ν_L	Poisson's ratio of the liner
α	Coefficient of thermal expansion/contraction (mm/mm/°C)
ϕ_s	Wet strength reduction factor
N_i	Factor of safety for liner imperfections
C	Compression modulus (GPa)
σ_{thl}	Long-term strength (hoop) of the liner and is the lesser value of either: the tensile rupture strength (hoop), $\sigma_{thl,r}$ (MPa) or fatigue strength (hoop), $\sigma_{thl,f}$ (MPa)
$\sigma_{thl,r}$	Tensile rupture strength (hoop) of the liner (MPa)
$\sigma_{tal,r}$	Tensile rupture strength (axial) of the liner (MPa)
x_l	Coefficient for strength reduction
c_l	Coefficient for strength reduction
E_{tl}	Tensile creep modulus of the liner (GPa)
E_{thl}	Tensile creep modulus (hoop) of the liner (GPa)



E_{tal}	Tensile creep modulus (axial) of the liner (GPa)
x_{lc}	Coefficient for creep modulus reduction
c_{lc}	Coefficient for creep modulus reduction
σ_{fhl}	Long-term flexural strength (hoop) of the liner (MPa)
σ_{fal}	Long-term flexural strength (axial) of the liner (MPa)
E_{fhl}	Flexural creep modulus (hoop) of the liner (GPa)
E_{fal}	Flexural creep modulus (axial) of the liner (GPa)
$E_{l,dry}$	Dry creep modulus of the liner (GPa)
$E_{l,wet}$	Wet creep modulus of the liner (GPa)
CRF	Creep retention factor of the liner
$\sigma_{thl,f}$	Fatigue strength (hoop) of the liner (MPa)
x_{lf}	Coefficient for fatigue strength reduction
c_{lf}	Coefficient for fatigue strength reduction
ϕ_c	Wet creep reduction factor

2.5 *Other*

σ_{ad}	Adhesion strength of the liner to host pipe substrate (MPa)
E_a	Young's modulus of the adhesive (GPa)
f	Friction coefficient
K	Enhancement factor
q	Host pipe ovality (%)
d	Initial hole (defect) size (mm)
d_f	Future hole (defect) size (mm)



u_g	Existing gap width of host pipe (mm)
u_{gp}	Gap formed due to axial movement or pulling force (mm)
β	Fraction of liner service life when out of service
L	Installation length of the liner (m)
R_W	Water buoyancy factor (unitless)
V	Flow velocity (m/s)
C_{HW}	Hazen Williams roughness coefficient
R_h	Hydraulic radius (m)
S	Slope of the energy grade line, or head loss per unit length of pipe (m/m)
NPV	Net present value (\$)
$C_n(t)$	Nominal cash flow (\$) at time t
$C_r(t)$	Real cash flow (\$) at time t
IN	Inflation rate (%)
I_o	Initial investment (\$)
R_{cost}	Cost of replace option (\$/m)
R_{mis}	Miscellaneous replace cost (\$)
L_{cost}	Cost of the liner (\$/m)
$C_{nothing}$	Cost of do nothing option (\$)
L_{mis}	Miscellaneous liner cost (\$)
C_n	Total cash flow for each year (\$)
i	Discount rate (%)

3 Descriptions of terms and usage criteria

3.1 *Host pipe*

Pipe ID number

The pipe ID number is used as a callout where pipe information can be stored against the pipe ID number. It will be index to get specific information on that pipe type.

Pipe material

Host pipe material type. This includes metallic pipes, cement pipes, plastic pipe, etc. In the Monash Pipe Evaluation Platform, the following pipe materials are implemented: Cast Iron (CI, CICL), Asbestos cement (AC) and Mild Steel (MS, MSCL).

Pipe segment installation year (Construction year)

Construction year of the pipe, burial year of the pipe or pipe installation year. The year that the pipe was installed, which should be matched against the specific Pipe ID number. The pipe segment installation year is used to gather cohort properties about the pipe and also to approximately evaluate the present condition of the pipe based on deterioration (corrosion and lime leaching) of the pipe.

Decommission date

Date the pipe was decommissioned and taken off line. Used for pipe ranking.

Lining type (Internal)

Any internal lining material used on the pipe. This can include cement mortar liner (CML), bitumen, CIPP or polymeric spray liner, etc. At this stage only CML are examined in the Monash Pipe Evaluation Platform.

Lining type (External)

External coatings are generally used for preventing soil corrosion on pipes. This can include coat tar, hot bitumen, hessian, polysleeving, Sintacote and gunite etc. At this stage external coatings are not examined in the Mon ash Pipe Evaluation Platform.

Pipe nominal diameter (DN)

Nominal diameter of the pipe or internal diameter of the pipe. Typically, the nominal diameter is expressed in mm conveniently rounded to roughly the manufactured internal diameter, however the imperial terms use inches. A DN150 pipe has an internal diameter of 150 mm (Imperial, DN6 is 6 inch). Note that in some pipes, such as AC the pipe outer diameter (OD or D_0) remains constant to allow for fitting compatibility, inner diameter reduces with an increase in pressure Class (wall thickness). Nominal diameter can be used as an approximate for internal diameter (D) if internal diameter is unknown. Otherwise, cohort values can be used to determine the host pipe internal and external diameters.

Pipe pressure class

Pipe pressure class designed to withstand a certain pressure over a certain number of years. A safety factor would be included. Pipe pressure class can be used to gather pipe wall thickness, which are used in determining remaining life of the host pipe. Pipes with a higher-pressure class, have a larger wall thickness to withstand higher internal pressures. Typically, pressure classes are expressed as A to D for cast iron pipes and A to F for Asbestos cement pipes.

Pipe external diameter (D_0)

External diameter of the host pipe, also known as pipe outside diameter (OD), not including external coatings (e.g. bitumen). Pipe external diameter can be found from pipe cohorts and standards. The external diameter units are expressed in mm.

Pipe internal diameter (D)

Pipe internal diameter is the internal diameter of the host pipe, not including liners (e.g. CML). Internal diameter is found from pipe cohorts and standards, however the pipe nominal diameter (DN) can also be used as an approximation if internal diameter is unknown. The internal diameter units are expressed in mm. Figure 1 shows the different terms used in pipe.

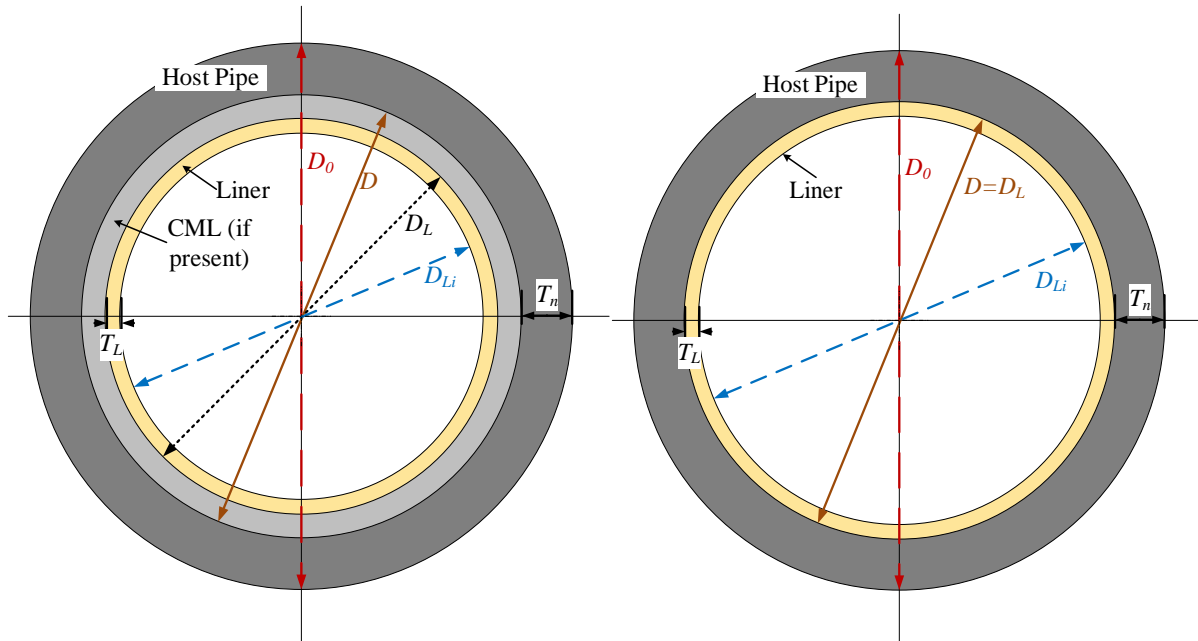


Figure 1. Labelling of pipe and liner term, left with CML, right without CML

Pipe wall thickness

The wall thickness of the host pipe, not including any coating or lining. This can be from three stages: Original nominal wall thickness (T_n), present wall thickness (T) and future wall thickness (T_f). Typically, the pipe thickness refers to the present wall thickness of the pipe. Units are in mm.

Mean diameter of the pipe (D_M)

Mean diameter of the pipe is the pipe internal diameter plus the pipe wall thickness ($D_M = D + T_n$). Units are in mm.

Estimated external uniform corrosion (T_{ext})

The pipe wall thickness reduction caused by external corrosion. $0 < T_{ext} < T_n$. Units are in mm.

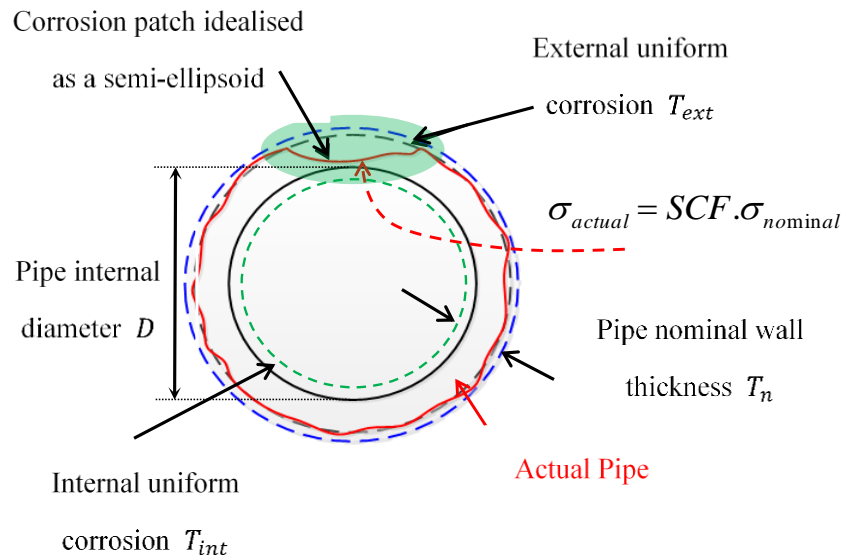


Figure 2. Cross section of a corroded pipe

Estimated internal uniform corrosion (T_{int})

The pipe wall thickness reduction caused by internal corrosion. $0 < T_{int} < T_n - T_{ext}$. Units are in mm.

Pipe wall thickness allowing for uniform corrosion (T)

The actual pipe wall thickness after accounting for external and internal corrosion. Note that $T = T_n - T_{ext} - T_{int}$. Units are in mm.

Length of pipe (L_p)

The length of the pipeline or pipe length. Units are in m.

Length of pipe spool (L_p)

The length of the pipe spool or pipe spool length. Measured for one spool of pipe from one end to the other, e.g. from bell to spigot. Units are in m.

Ultimate tensile strength of host pipe material (CI and AC) (σ_t)

Ultimate tensile strength is the maximum stress that a material can withstand while being stretched or pulled before breaking. Units are in MPa.

Yield strength of Steel (σ_y or *SMYS*)

Yield strength (σ_y) or specified minimum yield strength (*SMYS*) is the stress corresponding to the yield point at which the material begins to deform plastically. Units are in MPa.

Modulus of elasticity of host pipe material (E_p)

Also known as Young's Modulus or pipe elastic modulus. It is the slope of stress-strain curve in the elastic deformation region for the pipe material. Units are in GPa.

Poisson's ratio of the host pipe material (ν_p)

Poisson's ratio is the measurement of deformation in pipe material in a direction perpendicular to the direction of the applied force. Units are dimensionless.

Fracture toughness (K_{IC})

Fracture toughness is the resistance of a material to the propagation of cracks under an applied stress. Units are in $\text{MPa}\sqrt{m}$.

Factor of safety (N)

Design factor of safety to allow for variability in material properties and uncertainty in the models used. Typically, a factor of safety value of 2 was used in design, however in the Monash Pipe Evaluation Platform the factor of safety default value is set as 1.

Number of pipe internal diameter changes

Pipe diameter changes can occur when a pipe repair occurs, or a reducer valve is within a pipeline. If adhesion is needed for a liner, pipe diameter changes need to be examined. This is especially the case in lining where if a large diameter change occurs (such as a reducer valve), different sized liners or different sized spray heads must be used. Extra pits may need to be dug. Figure 1 includes both pipe with CML and without CML.

Patch length ($2a$)

Corrosion defects are approximated as semi-ellipsoids as shown in Figure 3. Patch length is the length of the corrosion patch along the pipe longitudinal axis. Units are in mm.

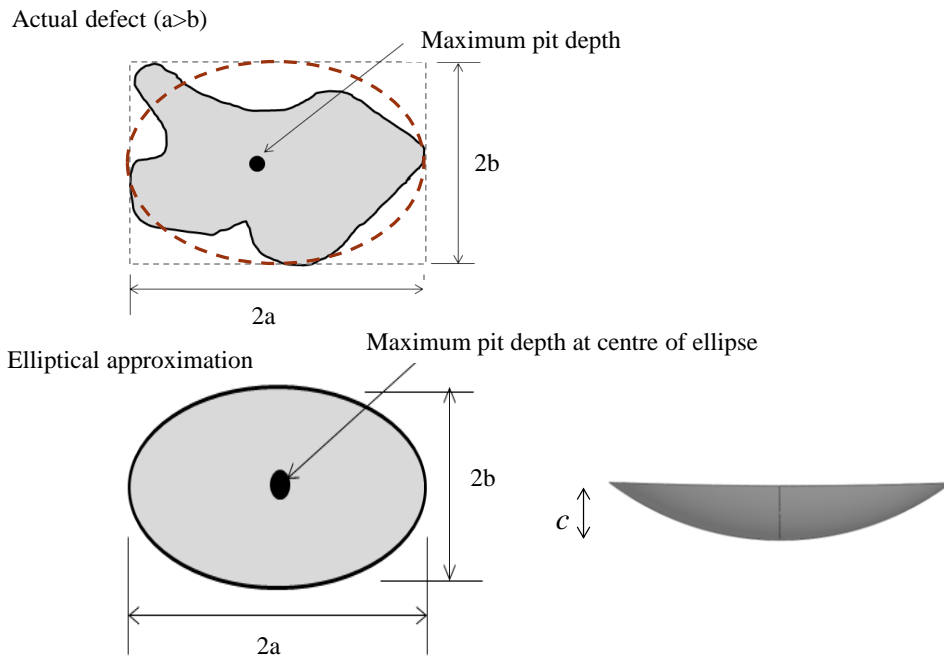


Figure 3. Approximation of irregular corrosion geometry by an ellipsoid

Patch width ($2b$)

Patch width is the width ($2b$) of the corrosion patch along the pipe circumference (Figure 3). Units are in mm.

Patch depth (c)

Patch depth c is the depth of the corrosion patch along the pipe radial direction (Figure 3). Units are in mm.

Critical patch length ($2a'$)

Due to corrosion progression, the corrosion patch dimensions will grow with time. When the corrosion patch grows to a critical size, the maximum stress at the bottom of the corrosion patch will reach the tensile strength of the pipe material. The corresponding patch length is called the critical patch length $2a'$. Units are in mm.

Critical patch width ($2b'$)

Similar to the critical patch length $2a'$, the critical patch width $2b'$ is the width of the patch at the bottom of which the maximum stress reaches the tensile strength of the pipe material. Units are in mm.

Critical patch depth (c')

Similar to the critical patch length a' and the critical patch width b' , the critical patch depth c' is the depth of the patch at the bottom of which the maximum stress reaches the tensile strength of the pipe material. Units are in mm.

Corrosion patch depth (c)

The time dependent corrosion patch depth (c) is calculated below

$$c = r_s(t - t_0) + c_s(1 - \exp(-(t_y - t_0)/\tau))$$

where:

r_s Long-term, steady state corrosion rate of metallic pipes (mm/y)

c_s Intercept parameter for long-term corrosion of metallic pipes (mm)

τ Transition period between short-term and long-term corrosion (y)

t Time (y)

t_0 Holiday period (Time till coating damage) (y)

The corrosion patch depth vs time can be visualised by the curve given in Figure 3.

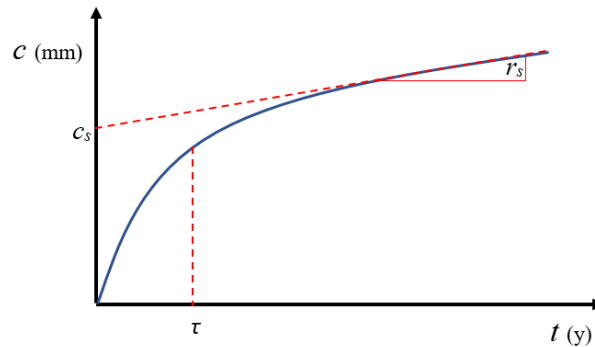


Figure 4. Corrosion patch depth vs. time

Relevant patch ratios:

Patch factor (k_1)

Patch factor is the ratio between the patch length ($2a$) and patch width ($2b$).

$$k_1 = a/b$$

Aspect ratio (k_2)

The aspect ratio is the ratio between half of the patch length (a) and patch depth (c).

$$k_2 = \frac{a}{c}$$

Radial corrosion rate for metallic pipes (r_{sv})

Radial corrosion rate is the increment of the corrosion patch depth per year. Corrosion patch depth (c_t) after t years $c_t = c_0 + r_{sv} \times t$, where c_0 is the current patch depth. Units are in mm/y.

Lateral extension rate for metallic pipes (r_{sh})

Lateral extension rate is the increment of corrosion patch length and width per year.

Half of the corrosion patch length (a_t) and half of the corrosion patch width (b_t) after t years can be calculated by $a_t = a_0 + r_{sh} \times t$, $b_t = b_0 + r_{sh} \times t$ respectively, where a_0 and b_0 are the current half of the patch length and half of the patch width respectively. Units are in mm/y.

Internal deterioration rate for AC pipes (c_{ACi})

Internal deterioration rate for AC pipes. Rates can be calculated from phenolphthalein testing or approximated based on utility data. Units are in mm/y.

External deterioration rate for AC pipes (c_{ACe})

External deterioration rate for AC pipes. Rates can be calculated from phenolphthalein testing or approximated based on utility data. Units are in mm/y.

Predicted year for failure of an AC pipe (y_f)

The predicted year of failure of an AC pipe or remaining service life, based on the operating pressure, diameter, nominal thickness, AC tensile strength and deterioration rate. Units are in y.

Fatigue constant (m_f)

A fatigue constant in Paris' law. $0 < m_f$. Fatigue testing (ASTM E647 2005) on either single-edge notched beam (SENB) or compact tension (CT) specimens should be conducted to determine this constant. Fatigue constant m_f is unitless.

Fatigue constant (C_f)

A fatigue constant in Paris' law. $0 < C_f$. Fatigue testing (ASTM E647 2005) on either single-edge notched beam (SENB) or compact tension (CT) specimens should be conducted to determine this constant. Units are in m/cycle.

Leak rate (Q)

Leak rate of a pipe is the measure of water escaping a pipe due to a defect. It can be measured in L/s. Water utilities may not measure this, however minimum night flow (MNF) can be converted into a leak rate for a zone. Leak rate is used only if water utilities have this value to determine a defect size based on the Orifice equation.

Discharge coefficient (c_d)

The Discharge coefficient is a non-dimensional constant used in the Orifice equation and is estimated to be 0.61. Unitless.

Area of flow (A)

The Area of flow is the cross-sectional area of the column of water exiting the pipe defect. It is typically assumed to be the defect area. Units are in mm^2 .

Acceleration due to gravity (g)

The acceleration due to gravity or gravitational acceleration is assumed to be $9.81 \text{ m}^2/\text{s}$.

3.2 Soil properties

Soil type

Soil type could be any of the following soils: sand, loamy sand, sandy loam, fine sandy loam, loam, silty loam, sandy clay loam, fine sandy clay loam, clay loam, silty clay loam, sandy clay, light clay, silty clay, medium clay, heavy clay. The soil type names are from AS 4419 (2018). The users can select a soil type from the list and the soil properties will be prefilled.

Soil modulus (E_s)

The soil modulus or modulus of elasticity or Young's modulus of soil is an elastic soil parameter used in the settlement, compression or movement of soils. Soil modulus is the slope of stress-strain curve in the elastic deformation region for the soil. Units are in MPa. The soil modulus varies with different soil types. Approximate soil modulus values are based on AS 2566.1 (1998).

Soil friction angle (Φ)

The soil friction angle is the angle of internal friction of the soil grains. It is the ability of a soil or rock to withstand shear stress. The friction angle varies between different soil types, such as clay, silt and sand. For a given soil, it is the angle on the graph (Mohr's Circle) of the shear stress and normal effective stresses at which shear failure occurs. The drained friction angle is used for the purpose of our calculations. Units are in degrees ($^{\circ}$).

Lateral earth pressure coefficient (k) (at rest)

The lateral earth pressure coefficient at rest and can be calculated by:

$$k = 1 - \sin \Phi$$

where Φ is the soil friction angle.

Soil unit weight (γ_s)

Soil unit weight is the ratio of the total weight of soil to the total volume of soil. Soil unit weight or bulk unit weight is the unit weight of soil and varies for different soil types. The values are typically between 15 kN/m^3 to 20 kN/m^3 . Units are in kN/m^3 .

Unit weight of water (γ_w)

The unit weight of water or specific weight is the unit weight per unit volume of water. It is a constant of 9.81 kN/m^3 .

3.3 Loading conditions

The following pressure conditions are found in Figure 5.

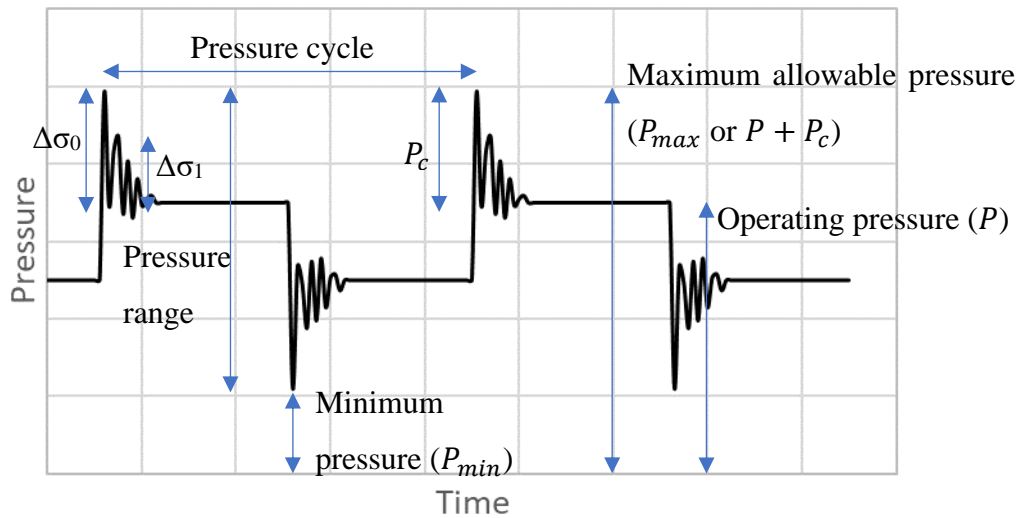


Figure 5. Different pressure types

Operating pressure (P)

The operating pressure or maximum work/working pressure is the maximum internal pressure sustained that the liner is anticipated to be subjected to, including diurnal pressure fluctuations but not including recurring cyclic surge pressure. Units are in MPa.

Maximum allowable pressure (P_{max} or MAP) (Maximum of P_T or $P + P_S$ or $P + P_c$)

The maximum combination of internal pressures (sustained pressure, occasional surge and/or test pressure) that the pipe of lining system is anticipated to be exposed to. Units are in MPa.

Minimum internal pressure (P_{min})

The minimum pressure applied the pipe due to recurring surge pressures. Units are in MPa.

Pressure head (h)

The operating pressure converted to a meter head value, particularly used in leak rate calculations. Units are in m.

Test pressure (P_T)

Hydrostatic pressure applied to the installed pipeline system in order to assess its integrity and leak tightness. Units are in MPa.

Recurring cyclic surge pressure (P_c)

Frequent repetitive pressure variations or cyclic surge pressures (water hammer) that are common in pressure pipe network systems (pump start-up or shut-down and normal valve opening and closings). Units are in MPa. For smaller surge pressure changes a larger amount of cycles are tolerable but for larger pressure cycles, less pressure cycles are tolerable. Cyclic surges are not common in gravity systems or if variable speed pumps are used. Surge pressure is used for host pipe remaining life calculations and liner life extension calculations. If cyclic surge pressure is unknown a factor of 0.5x operational pressure can be used.

Occasional surge (emergency or transient) pressure (P_s)

Short-term internal surge events in the pipe, which are random and isolated. Can occur during an emergency (rapid shut-down or closure of valve) or malfunction (power failure, component or pipe failure, etc.). Not examined when designing for fatigue, however can use for designing maximum and minimum pressure in the system. Units are in MPa.

Vacuum pressure (P_v)

A negative pressure that a pipe may experience when subjected to a sudden displacement in water, such as dewatering, which results in a vacuum pressure. Value used in the Monash Pipe Evaluation Platform is 0.1 MPa. Units are in MPa.

Burial depth (H)

Depth of the pipe from the ground surface level to the crown of the pipe. Soil loads apply additional pressure on the pipe. Units are in mm.

Height of water above pipe, measured from pipe crown (H_w)

Height of water above pipe, measured from pipe crown is the depth of the groundwater to the crown of the pipe. Units are in mm. Groundwater can apply additional pressure on the outer pipe wall. Groundwater depth in the form of pressure is used for pipe failure analysis and lined pipe analysis.

Number of recurring cyclic surge pressure cycles per day (n_{PC})

Number of pressure transients per day are used to determine if the host pipe or liner will fail from fatigue. Consistent pressure transients may reduce the life of the host pipe and liner. The default value is set at 2 per day, for pump start-up and pump shutdown.

Total number of surge pressure cycles for service life of pipe/lined pipe (n_{TPC})

The total number of pressure transients expected for the service life of the pipe/lined pipe. The number is calculated from the number of recurring pressure transients per day multiplied by the number of days in the service life of the pipe. A pressure transient factor (n_f) of 2 (conservative case) or the following equation is used to account for the second cycle onwards in a pressure transient.

$$n_f = 1 + \frac{1}{\left(\frac{\Delta\sigma_0}{\Delta\sigma_1}\right)^{3.2}}$$

Where n_f is the cyclic surge factor, $\Delta\sigma_0$ is the primary pressure transient wave stress change and $\Delta\sigma_1$ is the secondary pressure transient wave stress change.

The total number of pressure transients is therefore

$$n_{TPC} = n_f \times n_{PC} \times \text{no. of days}$$

Where no. of days is the liner intended service-life expressed in days. The number of days for a 50-year service life would be ~18250 days.

Rotation angle (θ)

Rotation angle that the lined pipe is likely to rotate to if a broken back failure occurs in the host pipe. Units are in degrees ($^\circ$). Used in determining the gap spanning under ring fracture or damaged failed joints under internal pressure.

Groundwater load (P_G)

The groundwater load is used in limit state design. Units are in MPa. For rigid host pipes, the following equation is used

$$P_G = \left(\frac{\gamma_w \cdot (H_w + D_M)}{10^6} + P_v \right) \cdot N$$

Groundwater load capacity (P_{GC})

The groundwater load capacity or external pressure capacity is used in limit state design, where the groundwater load shall be no larger than the groundwater load capacity ($P_G \leq P_{GC}$). Units are in MPa. The groundwater load capacity is

$$P_{GC} = \frac{2000 \cdot K \cdot CRF(\beta t) \cdot E_{fn}}{(1 - \nu_L^2)} \cdot \frac{C}{\left(\frac{D}{T_L} - 1\right)^3}$$

External pressure on the liner (P_N)

External pressure on the liner is used for adhesion checks, where the external pressure on the liner shall be no larger than the adhesion strength of the liner to host pipe substrate ($P_N \leq \sigma_{ad}$). Units are in MPa.

Total external pressure on pipes (q_t)

Total external pressure on the liner is used for buckling under external loads, and is a combination of the groundwater pressure, soil weight and live load (pressure). Units are in MPa.

Liner capacity for total external pressure (q_{tc})

Liner capacity for total external pressure is used for buckling under external loads, where the total external pressure on the liner shall be no larger than the liner capacity for total external pressure ($q_t \leq q_{tc}$). Units are in MPa.

Temperature change (ΔT)

The temperature change or fluctuations expected to occur in the host pipe and liner. Units are in °C. Used to calculate any thermal effects due to, such as expansion due to temperature increase.

Traffic load (W)

Traffic loads are wheel loads applied on the ground surface. Units are in kN. The loads can be converted into a pressure (w_q) applied on the pipe based on AS 2566.1 (1998).

Live load (pressure) at the burial depth (w_q)

Surface live load at the pipe burial depth based on calculations found in AS 2566.1 (1998). Live loads are used for host pipe remaining life calculations and liner life extension calculations. Units are in MPa.



Maximum allowable operating pressure (*MAOP*)

The maximum pressure that can be sustained, with a design factor, by the type or class of pipe for its estimated useful life under the anticipated working conditions. From AS/NZS 4130.

Note: values are not used in design for the Platform. Units are in kPa.

Nominal pressure (*PN*)

Nominal pressure alphanumeric designation for the nominal pressure class, designated in bars, which is the maximum sustained hydraulic internal pressure for which the pipe is designed in the absence of other loading conditions. For example, PN12 indicates a nominal pressure of 12

Bar or 1,200 kPa.

3.4 Liner properties

Liner class

Liner class following ISO 11295 (2017). The following classes are used:

D – Non-structural liner that provides an internal barrier layer

C – Semi-structural liner that survives long-term hole and gap spanning

B – Semi-structural liner with inherent ring stiffness

A – Fully structural independent liner

Liner type

The liner type used in the Platform either cured-in-place pipe (CIPP) or polymeric spray liner.

Reinforcement type

The reinforcing fibres used in the CIPP liner. Can be categorised as either GFRP (Glass fibres) or FRP (Polymeric fibres). The reinforcement type indicates whether the liner is susceptible to fatigue or not.

Liner thickness (T_L)

The liner thickness required for the specified liner service life. Units are in mm. Liner thickness can be noted as just the reinforcing layer thickness (T_r) (for CIPP only) or total liner thickness (T_L), however this must be noted by the applicator to avoid interchanging of terms. Liner thickness can be determined from structural design.

Liner external diameter (D_L)

The liner external diameter in mm. The liner external diameter can be equal to the pipe inner diameter (D) if no CML is present. If a CML is present, D and D_L need to be used for calculation.

Liner internal diameter (D_{Li})

The internal diameter of the pipe after lining. Can be calculated by

$$D_{Li} = D_L - 2T_L$$

Maximum stress in the liner (σ_{max})

The maximum stress in the liner only. For limit state calculations the maximum stress in the liner should not be greater than the tensile strength. Units are in MPa.

Short-term tensile strength of the liner (σ_t , σ_{th} and σ_{ta})

Short-term (initial) tensile strength of the liner (from wet testing – testing conducted with saturated specimens) is the ultimate tensile strength of the liner. Testing is conducted in both axial and hoop directions (if liner is bi-directional, where subscript h is in the hoop direction and subscript a is in the axial direction). Testing is conducted from tensile tests (AS 1145 2001, ASTM D638 2014, ASTM D3039 2017) and units are in MPa.

Short-term tensile or compressive strength of the liner in the axial direction (σ_A)

Short-term (initial) tensile strength in the axial direction or short-term (initial) compressive strength in the axial direction of the liner. Used in determining the stress in the liner caused by temperature changes. In the Monash Pipe Evaluation Platform $\sigma_A = \sigma_{ta}$. Units are in MPa.

Short-term tensile modulus of elasticity of the liner (E_L , E_t , E_{th} and E_{ta})

Short-term (initial) tensile modulus of elasticity or Young's modulus of the liner (from wet testing – testing conducted with saturated specimens) is the stress divided by strain of the linear proportion of the stress strain curve. Testing is conducted in both axial and hoop directions (if liner is bidirectional, where subscript h is in the hoop direction and subscript a is in the axial direction). Testing is conducted from tensile tests (AS 1145 2001, ASTM D638 2014, ASTM D3039 2017) and units are in GPa.

Short-term tensile or compressive modulus of the liner in the axial direction (E_A)

Short-term (initial) tensile modulus of elasticity in the axial direction (E_{ta}) or short-term (initial) compressive modulus of elasticity (E_{ca}) in the axial direction of the liner. Used in determining the stress in the liner caused by temperature changes. In the Monash Pipe Evaluation Platform $E_A = E_{ta}$. Units are in MPa.

Short-term flexural strength of the liner (σ_{fh} and σ_{fa})

Short-term (initial) flexural strength of the liner (from wet testing – testing conducted with saturated specimens) is the ultimate flexural strength of the liner. Testing is conducted in both axial and hoop directions (if liner is bidirectional, where subscript h is in the hoop direction and subscript a is in the axial direction). Testing is conducted from flexural tests (ISO 14125 (1998), (AS 1145 2001, ASTM D790 2017)) and units are in MPa.

Short-term flexural modulus of elasticity of the liner (E_{th} and E_{ta})

Short-term (initial) tensile modulus of elasticity or Young's modulus of the liner (from wet testing – testing conducted with saturated specimens) is the stress divided by strain of the linear proportion of the stress strain curve. Testing is conducted in both axial and hoop directions (if liner is bidirectional, where subscript h is in the hoop direction and subscript a is in the axial direction). Testing is conducted from flexural tests (ISO 14125 (1998), (AS 1145 2001, ASTM D790 2017) and units are in GPa.

Poisson's ratio of the liner (ν_L)

Poisson's ratio is the measurement of deformation in pipe liner material in a direction perpendicular to the direction of the applied force. Units are dimensionless.

Coefficient of thermal expansion/contraction (α)

Coefficient of thermal expansion/contraction is the change in size with change in temperature. The units are in mm/mm/°C.

Wet strength reduction factor (ϕ_s)

If the liner is subjected to plasticisation due to water saturation a wet strength reduction factor must be applied to reduce short-term and long-term strength properties. Ideally, testing should be conducted in wet conditions if liner plasticises when saturated. This is more common in polymeric spray liners than CIPP liners. The wet factor reduction ranges from 0-1, however the default value is set as 1 in the Monash Pipe Evaluation Platform as the tests are assumed to be conducted in water.

For example:

$$\phi_s = \frac{\sigma_{t,wet}}{\sigma_{t,dry}}$$

where $\sigma_{t,wet}$ is the wet tensile strength of the liner (MPa) and $\sigma_{t,dry}$ is the dry tensile strength of the liner (MPa). These properties can be interchanged with σ_{th} and σ_{ta} if property tests were conducted in water. The use of tensile/flexural and hoop/axial shall be consistent for both wet and dry properties to determine strength reduction factors.

Wet creep reduction factor (ϕ_c)

If the liner is subjected to plasticisation due to water saturation a wet creep reduction factor must be applied to reduce long-term modulus properties. Ideally, testing should be conducted in wet conditions if liner plasticises when saturated. This is more common in polymeric spray liners than CIPP liners. The wet factor reduction ranges from 0-1, however the default value is set as 1 in the Monash Pipe Evaluation Platform as the tests are assumed to be conducted in water.

For example:

$$\phi_c = \frac{E_{l,wet}}{E_{l,dry}}$$

where $E_{l,wet}$ is the wet creep modulus of the liner (GPa) and $E_{l,dry}$ is the dry creep modulus of the liner (GPa). These properties can be interchanged with E_{th} and E_{ta} if property tests were conducted in water. The use of tensile/flexural and hoop/axial shall be consistent for both wet and dry properties to determine creep reduction factors.

These calculations are also required for short-term modulus.

Factor of safety for liner imperfections (N_i)

Factor of safety for liner imperfections (variable wall thickness in polymeric spray lining and folds in CIPP lining), depends on the imperfection type. The following factors of safety for liner imperfections were selected:

- Uneven thickness (polymeric spray), $N_i = 1.5$
- Folds (CIPP), $N_i = 2$

Tensile rupture strength of the liner ($\sigma_{tl,r}$, $\sigma_{thl,r}$ and $\sigma_{tal,r}$)

Tensile rupture strength or long-term tensile strength (hoop or axial) of the liner at x years is based on creep rupture (ASTM D2990 2001) or hydrostatic design basis (ASTM D2992 2018) for a specified design life (years). The normalised curve can be multiplied by the initial tensile strength in MPa. Wet conditions should be used.

The following equation is used to approximate the deterioration curve based on hydrostatic design basis or creep rupture testing. The equation uses the 97.5% lower prediction limit

results, to account for variability in the results and is simplified to a logarithmic curve. Alternatively, the hydrostatic design stress value can be used if the service life is 50 years.

$$\sigma_{tl,r} = \sigma_t(x_l \ln(t_h) + c_l)$$

where, $\sigma_{tl,r}$ is the tensile rupture strength at a particular service life (σ_{tl} can be substituted for $\sigma_{thl,r}$ and $\sigma_{tal,r}$ for the hoop and axial values respectively), σ_t is the short-term tensile strength (σ_t can be substituted for σ_{th} and σ_{ta} for the hoop and axial values respectively), x_l and c_l are creep rupture deterioration constants and t_h is the time in hours.

Note: The same formula can be applied to approximate the long-term flexural strength by substituting short-term wet flexural strength values, however flexural creep rupture testing is preferred.

Coefficient for strength reduction (x_l)

Deterioration coefficient for creep rupture or hydrostatic design basis normalised stress vs. time (hours) curve. Will be a negative value to correspond with rupture strength of the liner.

Coefficient for strength reduction (c_l)

Deterioration coefficient for creep rupture or hydrostatic design basis normalised stress vs. time (hours) curve. Will be a positive number.

Tensile creep modulus of the liner (E_{tl} , E_{thl} and E_{tal})

Creep modulus (hoop or axial) is defined as the ratio of applied stress to the time-dependent strain and is determined based on creep testing (ASTM D2990 2001) or hydrostatic strain basis (ASTM D2992 2018) for a specified design life (years). Wet conditions should be used.

The tensile creep modulus (E_{tl}) was estimated using Findley's power law from creep tests up to 20,000 hours and extrapolated up to 100 years. The creep modulus in tensile and axial can be found by multiplying the corresponding creep retention factor (CRF) by the initial or short-term modulus.

$$E_{tl} = CRF \cdot E_t$$

where E_{tl} is the tensile creep modulus and E_t is the short-term tensile modulus. The following equation can be used to determine the CRF and subsequently the long-term tensile modulus at any point in time.

$$CRF = x_{lc}(t_h)^{c_{lc}}$$

where x_{lc} and c_{lc} are factors to determine creep modulus factor based on a power law decay, and t_h is the time in hours.

Note: The same formula can be applied to approximate the flexural creep modulus by substituting short-term wet flexural strength values, however flexural creep testing is preferred.

Creep retention factor (*CRF*)

The creep retention factor (*CRF*) is the creep modulus divided by the initial or short-term modulus of the liner (in either hoop or axial directions).

$$CRF = \frac{E_{tl}}{E_t}$$

Deterioration coefficient for creep (x_{lc})

Deterioration coefficient for creep modulus vs. time (hours) curve based on testing results and Findley's power law. Will be a positive number.

Deterioration coefficient for creep (c_{lc})

Deterioration coefficient for creep modulus vs. time (hours) curve based on testing results and Findley's power law. Will be a negative number.

Cyclic surge factor (n_f)

A surge factor (n_f) is used to incorporate the effect of secondary cycles from cyclic surge pressure (see Figure 5 Cyclic surge pressure). A simplistic approach is to use a pressure cycle is equal to 2 primary cycles due to the decaying surge. Alternatively, the following equations can be used to calculate a factor for number of pressure transients (Joseph 1979, PIPA 2018).

$$n_f = 1 + \frac{1}{\left(\frac{\Delta\sigma_0}{\Delta\sigma_1}\right)^{3.2}}$$

where n_f is the cyclic surge factor (from 1 to 2), $\Delta\sigma_0$ is the magnitude of the initial pressure cycle wave and $\Delta\sigma_1$ is the magnitude of the secondary pressure cycle.

Total number of pressure transients for the life of the pipe/lined pipe (n_{TPC})

The total number of pressure transients can be calculated based on the following equation

$$n_{TPC} = n_{PC} \times n_f \times t \times 365$$

where n_f is the cyclic surge factor (from 1 to 2) and t is the time in years, where in this case is the liner design service life in years.

Fatigue strength (hoop) of the liner ($\sigma_{thl,f}$)

Fatigue strength or long-term tensile fatigue deterioration strength (hoop) at x years is based on fatigue curves based on ISO 13003 (2003) or cyclic pressure design basis (ASTM D2992 2018) for a specified design life (years). The normalised stress vs. number of cycles to failure (N_f) curve can be multiplied by the initial tensile strength in MPa. Wet conditions should be used.

The following equation is used to approximate the deterioration curve based on cyclic pressure design basis or fatigue cyclic testing. The equation uses the 95% lower prediction limit results, to account for variability in the results and is simplified to a logarithmic curve. Alternatively, the hydrostatic fatigue stress value can be used if the service life is 50 years.

$$\sigma_{thl,f} = \sigma_{th}(x_{lf} \ln(n_{TPC}) + c_{lf})$$

where, $\sigma_{thl,f}$ is the long-term fatigue strength at a particular service life, σ_{th} is the (wet) short-term tensile strength, x_{lf} and c_{lf} are fatigue deterioration constants and n_{TPC} is the total number of surge pressure cycles for life of pipe/lined pipe.

Coefficient for fatigue strength reduction (x_{lf})

Deterioration coefficient for fatigue or cyclic pressure design basis normalised stress vs. time (hours) curve. Will be a negative value to correspond with deteriorated strength of the liner.

Coefficient for fatigue strength reduction (c_{lf})

Deterioration coefficient for fatigue or cyclic pressure design basis normalised stress vs. time (hours) curve. Will be a positive number.

3.5 Other

Friction coefficient (f)

The friction between the liner and the host pipe (or CML). The friction coefficient ranges between 0 to 0.577 and depends on the adhesion of the liner to the host pipe (or CML). The parameter is used in equations to determine the stress on the liner, or minimum thickness required for liner service life. Units are dimensionless. The recommended ranges of friction coefficients for the interfaces between host pipes and polymeric liners are as follows:

Host pipe material	Friction coefficient (f)
AC or CML	0.1–0.2
Metallic	0.3–0.4

Enhancement factor (K)

Enhancement factor of the soil and existing pipe adjacent to the new pipe; a minimum value of 7.0 is recommended where there is full support of the existing pipe (dimensionless) (AWWA 2019).

Host pipe ovality (Δ)

Ovality is generally not a consideration for pressure pipe designs. However, when a pipe taken out of service is subjected to external pressures, ovality may be relevant. In absence of physical measurements, reasonable assumptions of ovality should be made based on host pipe material properties and in situ conditions. For example, ovality may never be observed on a rigid host pipe over the course of its design life, while a flexible pressure pipe may or may not ovalize (or deflect) when taken out of service (AWWA 2019). Units are percentage (%).

Ovality reduction factor (C)

Ovality reduction factor is a reduction factor based on the liner ovality. The units are dimensionless. The following equation is used to determine the ovality reduction factor

$$C = \left(\frac{1 - \Delta/100}{[1 + \Delta/100]^2} \right)^3$$

where Δ is the host pipe ovality (%).

Initial hole (defect) diameter (d)

Initial hole or defect size (treat graphitised material as a defect), idealised to be circular in a metallic pipe. The units are in mm. Used in calculating hole spanning capability in a Class B to C liner.

Future hole (defect) diameter (d_f)

Future hole or defect size (treat graphitised material as a defect), idealised to be circular in a metallic pipe. As time progresses the initial hole size will grow due to corrosion in the host pipe. The future size is used to determine whether the liner can bridge the hole for the liner service life. The Units are in mm. Used in calculating hole spanning capability in a Class B to C liner.

Initial gap width of host pipe (u_g)

Initial width of a gap in the host pipe, such as a gap at a joint, broken back failure, or where there is no host pipe, that a liner can span. Units are in mm. The term is used in gap spanning calculations where the liner is exposed to extra stresses from no host pipe support.

Gap formed due to axial movement or pulling force (u_{gp})

Width of the gap formed in the host pipe, such as a gap at a joint, broken back failure, or where there is no host pipe when the host pipe is pulled along the longitudinal axis. Units are in mm. The term is used in gap spanning calculations where the liner is exposed to extra axial stresses caused by pipe extension.

Fraction of liner service life when out of service (β)

The fraction of time a liner will be out of service. Used in determining if buckling of the liner may occur. Unitless. Typical values would range from 0.00005 (one day) to 0.0016 (one month).

Installation length of the liner (L)

Installation length of the continuous liner without any breaks or joints. Also known as shot length. Units are in m.

Water buoyancy factor (R_w)

Water buoyancy factor is used to determine a factor of pressure transferred onto the pipe from the saturated soil (soil and groundwater). It is a function of burial depth and height of groundwater. Unitless.

Flow velocity (V)

Flow velocity inside the host pipe. Units are in m/s. Used in the Hazen Williams equation for flow rate changes.

Hazen-Williams roughness coefficient (C_{HW})

Roughness coefficient values for different pipe and liner materials. A simplified schema for the roughness coefficient was used for the Monash Pipe Evaluation Platform (CI-70, CICL-120, AC-140, DICL-120, MS-100, MSCL-120), and Polymeric spray lining and CIPP lining have used a H-W coefficient of 150.

Hydraulic radius (R_h)

The cross-sectional area of the pipe divided by the wetted perimeter. For a circular pipe with full-flow, this is equal to $D/4$ where D is the pipe diameter. Units are in m.

Slope of the energy grade line (S)

Slope of the energy grade line or head loss per unit length of pipe. Units are in m/m.

Condition grade

A number from 1 to 5 indicating the severity of the deterioration of the pipeline. 5 being the most severely deteriorated and 1 being a pipe in pristine condition.

Failure types

Failure types are classified into groups for the purpose of assigning different severity ratings based on number of past failures. Failure types include broken back, longitudinal split, piece blown off, hole, leak, joint failure, tapping failure, fitting failure and other.

Severity rating

A rating assigned to a failure type ranging from A – D with A being the most severe and D the least severe.

Dominant type of failures

The dominant type of failures is the most common failure mode experienced by a pipe section that has failed many times in the past (see: **Number of past failures**). It is defined as the failure mode with the highest number of occurrences and can be extracted from a pipe failure database.

The dominate type of failure could be any of the following failure types: broken back, longitudinal split, piece blown out, hole in pipe, leak, joint leak, water quality, tapping band, third party damage, etc.

Pipe age

Pipe age is the period of time from pipe installation to the current time for condition assessment (years). It can be calculated based on the pipe installation year.

Number of past failures

Number of past failures for a pipe section. Number of failures are used in both pipe ranking and liner recommendations. The number of past failures may also be associated with a number of recent years. *E.g.* Number of failures in the last three years.

Defect type and size

Typically assumed as diameter in a circular defect, however for the Monash Pipe Evaluation Platform three different defect types and sizes are examined. Defect type and size units are in mm. The defect types are:

Circular (d) – diameter in mm

Ellipsoidal ($2a$) – smaller width in mm

Gap (u_g) – width of the gap in mm

Number of repairs

Number of repairs can be used to infer the condition of the pipe or the potential existing gaps in the pipe.

Number of bends

Number of bends include bends over 22.5° . Polymeric spray liners are not suitable in pipes with bends over 22.5° . Whereas CIPP liners are not suitable for bends over 45° . The higher number of bends mean the more runs need to be conducted, hence higher amounts of entry and exit pits, increasing the cost of lining.

Number of service connections

Number of service connections such as taps, laterals, etc. Liner types with service connections must be examined. Certain liner types are less suitable when the number of service connections are high.

Dimension ratio (standard dimension ratio) (DR or SDR)

It is defined as the ratio of the liner outer diameter (D_L) to the minimum thickness of the liner (T_L), $DR = \frac{D_L}{T_L}$

Barlow's formula (modified)

This formula was originally derived to determine the internal pressure that a pipe can withstand before failure based on the dimensions of the pipe (thickness and diameter), for thin walled cylinders. It was modified for liner purposes (AWWA 2019) to determine if the liner can survive long-term pressures if the host pipe is fully deteriorated.

$$P = \frac{\sigma_{thl} T_L}{D_L - T_L} = \frac{2\sigma_{thl}}{(DR - 1)N}$$

Net present value (NPV)

Net present value (NPV) method estimates future net cash flows of an investment (or project), whereby the cash flows are discounted using a discount rate. The discount rate is based on the project risk level. Units are in \$.

Nominal cash flow at time t ($C_n(t)$)

Nominal cash flow (\$) at time t (or total cash flow for each year).

Real cash flow (\$) at time t ($C_r(t)$)

Real cash flow (\$) at time t .

Inflation rate (IN)

The rate at which the prices increase over time, resulting in the lower purchasing value of money. Units are in %.

Initial investment (I_o)

The total cost of the investment, e.g. replace option cost (\$/m) multiplied by the length of pipe section (m). Units are in \$.

Cost of replace option (R_{cost})

The cost to replace the pipe using a traditional replacement method. Units are in \$/m.

Miscellaneous replace cost (R_{mis})

Miscellaneous costs involved for a pipe replacement option, e.g. maintenance, failures, leak repairs, etc. Units are \$/year.

Cost of the liner (L_{cost})



The initial cost to rehabilitate the pipe using a liner method such as CIPP or spray. Units are in \$/m.

Cost of do nothing option (C_{nothing})

The cost of the do nothing approach. This is fixed as \$0/m.

Miscellaneous liner cost (L_{mis})

Miscellaneous costs involved for a liner rehabilitation option, e.g. maintenance, failures, leak repairs, etc. Units are \$/year.

Total cash flow for each year (C_n)

Units are in \$.

Discount rate (i)

The interest rate used to determine the present value of the liner/replacement option. Units are in %.

Years of analysis

The amount of years to examine the NPV calculations for.

New replacement lifetime

The expected life of a new replacement pipe asset, e.g. 50 years. Units are in years.

Liner lifetime

The service life of the liner, e.g. 50 years. Calculated from long-term analysis using information from the lined pipe composite. Units are in years.

Repair/maintenance cost per failure

The average repair/maintenance cost per failure in the pipe using the do nothing approach. Units are in \$.

Break information (break rate)

Data analysis can be used by water utilities to import a file that includes the year and number of breaks per 100 km (can be gathered from risk modelling or data-driven pipe packages).

Estimated number of failures per year / 100 km

The estimated number of failures per year/100 km. This value can be gathered from Water utilities data analysis. Units are in failures/y/100 km.

DISCLAIMER

1. Use of the information and data contained within the Monash Pipe Evaluation Platform is at your sole risk.
2. If you rely on the information in the Nomenclature, then you are responsible for ensuring by independent verification of its accuracy, currency, or completeness.
3. The information and data in the Nomenclature is subject to change without notice.
4. The Nomenclature developers may revise this disclaimer at any time by updating the Nomenclature
5. Monash University and the developers accept no liability however arising for any loss resulting from the use of the Nomenclature and any information and data.

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