

Australian Standard[®]

Water storage tanks for fire protection systems



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The following are represented on Committee FP-008:

- Association of Hydraulic Services Consultants Australia
 - Australasian Fire and Emergency Service Authorities Council
 - Australian Canvas and Synthetic Products Association
 - Australian Chamber of Commerce and Industry
 - Australian Industry Group
 - Consult Australia
 - Consumers Federation of Australia
 - Engineers Australia
 - Fire Protection Association Australia
 - Insurance Council of Australia
 - Pump Industry Australia
-

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Australian Standard[®]

Water storage tanks for fire protection systems

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PREFACE

This Australian Standard was prepared by Standards Australia Committee FP-008, Fire Pumpsets and Fire Tanks.

Technical Sub-committee FP-008-02, Fire Tanks, provided invaluable assistance in the development of this Standard, especially in the sections relating to design action (loads), tank design and tank foundations.

This Standard was developed taking into consideration local and international Standards.

Maintenance of water storage tanks for fire protection purposes is covered in Section 11 of this Standard, but will be removed by amendment when the same requirements are published in Australian Standard titled, *Routine servicing of fire protection systems and equipment*, currently under development (see Note to Clause 1.1).

The term ‘informative’ has been used in this Standard to define the application of the appendix to which it applies. An ‘informative’ appendix is only for information and guidance.

This Standard incorporates commentary on some of the clauses. The commentary directly follows the relevant Clause shown in italic font-type and enclosed in a panel. The commentary is for information only and does not need to be followed for compliance with the Standard. Commentaries explain the purpose of a Clause and give, in some cases, background information.

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FOREWORD

This Standard has been developed to provide reliable water storage for fire protection purposes. Water storage tanks that are not designed correctly nor adequately maintained are prone to failure.

Design provisions for bolted steel tanks are covered in this Standard. Design provisions for tanks made from other materials are not covered by this Standard and may be included in future editions.

This Standard applies to suction tanks for sprinkler, hydrant and hose reel systems as well as for break tanks and dual-use fire protection storage tanks.

Steel tanks consist of a floor (either steel, concrete or liner), cylindrical or rectangular shell fabricated from steel plates joined together, and a roof, all of which rest upon a foundation. Tanks are filled with water from an outside source. Water is withdrawn in emergency situations through piping connected to a pump. Accessory items are provided to fill and drain the tank, monitor the water level, gain access for inspection and repair, provide means for accessing the water and to prevent positive or negative pressures, etc.

For tanks manufactured from materials other than bolted steel and bolted cast iron, the accessories and maintenance provisions of this Standard apply.

STANDARDS AUSTRALIA

Australian Standard
Water storage tanks for fire protection systems

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out the minimum requirements for the design, construction, installation, commissioning and maintenance of bolted steel circular and rectangular water tanks for the storage of water for fire protection systems. This Standard also provides guidance on water sources and qualities that influence tank design and construction, together with water conservation measures.

NOTE: 'Maintenance' will be removed by amendment when the second edition of AS 1851 is published.

This Standard is limited to—

- (a) the tank structure;
- (b) the tank foundation; and
- (c) tank penetrations and related accessories.

The requirements cover—

- (i) bolted steel and bolted cast iron tanks with and without liners.
- (ii) all other fire service tanks' accessories (Section 7).

This Standard applies to the following systems, where applicable:

- (A) Automatic fire sprinkler systems to AS 2118.1.
- (B) Fire hydrant systems to AS 2419.1.
- (C) Fire hose reel systems to AS/NZS 1221.
- (D) Combined sprinkler and hydrant systems in multistorey buildings to AS 2118.6.
- (E) Residential sprinkler systems to AS 2118.4.
- (F) Fire pumpsets to AS 2941.

This Standard does not apply to the design and application of the following:

- (1) Plastic tanks.
- (2) Fibreglass tanks.
- (3) Agricultural and rainwater tanks.
- (4) Drinking water tanks.
- (5) Wooden tanks.
- (6) Non-ferrous metal tanks.
- (7) Bladder tanks.
- (8) Welded steel tanks.
- (9) Concrete tanks.

1.2 OBJECTIVE

The objective of this Standard is to provide a reliable and durable structure for the storage of water for fire protection purposes, to ensure the structure remains functional throughout the service life of the building and the installed fire protection systems (typically 25 to 30 years).

1.3 NORMATIVE REFERENCES

The following are the normative documents referenced in this Standard.

NOTE: Documents referenced for informative purposes are listed in the Bibliography.

AS

1110	ISO metric hexagon bolts and screws—Product grades A and B
1110.1	Part 1: Bolts
1111	ISO metric hexagon bolts and screws—Product grade C
1111.1	Part 1: Bolts
1170	Structural design actions
1170.4	Part 4: Earthquake actions in Australia
1397	Steel sheet and strip—Hot-dip zinc-coated or aluminium/zinc-coated
1579	Arc-welded steel pipes and fittings for water and waste-water
1657	Fixed platforms, walkways, stairways and ladders—Design, construction and installation
1722	Pipe threads of Whitworth form
1722.2	Part 2: Fastening pipe threads
1726	Geotechnical site investigations
1830	Grey cast iron
2001	Methods of test for textiles
2001.2.3.1	Part 2.3.1: Physical tests—Determination of maximum force and elongation at maximum force using the strip method
2001.2.3.2	Part 2.3.2: Physical tests—Determination of maximum force using the grab method (ISO 13934-2:1999, MOD)
2074	Cast steels
2118	Automatic fire sprinkler systems
2118.1	Part 1: General systems
2118.4	Part 4: Residential
2118.6	Part 6: Combined sprinkler and hydrant
2419	Fire hydrant installations
2419.1	Part 1: System design, installation and commissioning
2870	Residential slabs and footings
2941	Fixed fire protection installations—Pumpset systems
3566	Self-drilling screws for the building and construction industries
3566.1	Part 1: General requirements and mechanical properties
3600	Concrete structures
3798	Guidelines on earthworks for commercial and residential developments
4087	Metallic flanges for waterworks purposes
4100	Steel structures

AS/NZS

1170	Structural design actions
1170.0	Part 0: General principles
1170.1	Part 1: Permanent, imposed and other actions
1170.2	Part 2: Wind actions
1170.3	Part 3: Snow and ice actions
1221	Fire hose reels
1252	High strength steel bolts with associated nuts and washers for structural engineering
1594	Hot-rolled steel flat products
2865	Safe working in a confined space
3500	Plumbing and drainage
3500.1	Part 1: Water services
3679	Structural steel
3679.1	Part 1: Hot-rolled bars and sections
4600	Cold-formed steel structures
4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles

1.4 APPLICATION

This Standard is intended for the following end users:

- (a) Fire system designers.
- (b) Tank designers.
- (c) Tank installers.
- (d) Tank manufacturers.
- (e) Maintenance contractors.
- (f) Fire consultants.
- (g) Fire engineers.
- (h) Hydraulics engineers.
- (i) Civil engineers.
- (j) Structural engineers.
- (k) Plumbers.
- (l) Fire brigades.
- (m) Water authorities.
- (n) Building owners/occupiers.
- (o) Insurers.
- (p) Property developers.
- (q) Building consultants and architects.

1.5 DEFINITIONS

For the purposes of this Standard the definitions below apply.

1.5.1 Access opening

An access or passage wide enough for a single person.

1.5.2 Actions

The cause of stress or deformations in a structure.

1.5.3 Bearing-type connections

Connection-effected, using either snug-tight bolts, or high-strength bolts, tightened to induce a specified minimum bolt tension, in which the design action is transferred by shear in the bolts and bearing on the connected parts at the strength limit state.

1.5.4 Competent person

A person who has acquired through training, qualification, experience, or a combination of these, the knowledge and skill enabling him/her to correctly perform the required task, and who is registered or licensed by a recognized body acknowledging the training, qualification, experience or skills.

1.5.5 Cylindrical steel tank

Thin walled circular shaped structure used to contain liquid as defined in this Standard.

1.5.6 Design life

The period of time that a tank is expected to perform its function without repair or rectification but with maintenance and is less than the service life.

1.5.7 Division wall

A wall or partition in a rectangular panel tank capable of dividing the water contents into separate volumes.

1.5.8 Effective capacity

The volume of water above the invert of the outlet pipe when the water surface in the tank is 20 mm below the overflow level.

1.5.9 Externally bolted panel tank

Rectangular panel tank [as defined by this Standard (see Clause 1.5.15)] where the flanges of the panels are not exposed to the fluid contents of the tank.

1.5.10 Freeboard

Air gap from the top edge of the tank to the spill level as given in AS/NZS 3500.1.

1.5.11 Horizontal seam

Overlapping bolted seam of a cylindrical tank panel which runs horizontal around the perimeter of the tank.

1.5.12 Imposed actions

A variable action resulting from the intended use or occupancy of the structure.

1.5.13 Internally bolted panel tank

Rectangular panel tank as defined by this Standard (see Clause 1.5.15) where the flanges of the panels are exposed to the fluid contents of the tank.

1.5.14 Liner

An independent internally supported water containment membrane.

1.5.15 Panel

That part of a cylindrical or rectangular steel panel tank extending between and including adjacent vertical and horizontal seams.

1.5.16 Rectangular panel tank

A tank with a rectangular or square footprint which is an assembly of cold formed bolted panels with upturned flanges.

1.5.17 Service life

The period of time that the tank is expected to perform as originally designed and installed with planned rectification and maintenance at the appropriate intervals.

1.5.18 Shell course (ring)

A set of panels in a circular tank that is between adjacent horizontal seam bolts or the top or bottom of the tank and the next set of horizontal seam bolts.

1.5.19 Sloshing wave

Wave generated by seismic action.

1.5.20 Snug tight

The tightness of a bolt achieved by a few impacts of an impact wrench or by the full effort of a person using a standard podger spanner.

1.5.21 Stay bracket

The interface between the stay support and the tank panel as defined in this Standard (see Clause 1.5.22 and 1.5.15).

1.5.22 Stay support

The main tension member of a stay support system as defined in this Standard (see Clause 1.5.23). Where round bar is used as a stay support this support is referred to as a stay rod.

1.5.23 Stay support system

An assembly of structural members used to constrain a rectangular tank panel wall, typically consisting of a tension member spanning the length or width of a rectangular tank anchored at a corner of four adjoining tank panels.

1.5.24 Stay washer

The washer used to distribute the tension load from a stay support to the pan of a tank panel.

1.5.25 Structural elements

Physically distinguishable parts of a structure (e.g. wall, column, beam, connection).

1.5.26 Tank wall

The shell of a tank.

1.5.27 Terrain category

Terrain over which the approach wind flows towards a structure as defined by AS/NZS 1170.2.

1.5.28 Vertical seam

Overlapping bolted seam of a cylindrical tank panel which runs vertically.

1.6 NOTATION

Symbols used in this Standard, including their definitions, are listed below.

Where non-dimensional ratios are involved, both the numerator and denominator are expressed in identical units.

The dimensional units for length and stress in all expressions or equations are to be taken as millimetres (mm) and megapascals (MPa) respectively, unless specifically noted otherwise.

A superscripted ‘*’ placed after a symbol denotes a design action effect due to the design load for the strength limit state.

a	= acceleration coefficient from AS 1170.4
C_1	= acceleration coefficient for the tank contents
C_{fig}	= aerodynamic shape factor as given in AS/NZS 1170.2
D	= diameter of tank, in metres
d	= nominal diameter of suction line, in metres
d_p	= distance from the edge of the tank to the centre of the concrete plinth used to elevate the tank, in millimetres
D_v	= minimum diameter of vortex plate, in millimetres
E	= Young’s modulus (= 200 GPa for steel)
E_d	= design action effect
EI_z	= flexural rigidity of the stiffener effective cross-section about its vertical axis
E_u	= ultimate earthquake action as defined in AS/NZS 1170.0
F	= compressive force on the circumferential stiffener, in kilonewtons
F_c	= elastic buckling resistance of a circumferential stiffener
F_{lp}^R	= portion of liquid used to resist overturning (Clause 4.8.2)
f_y	= yield strength of the wall sheet material, in megapascals
G	= permanent action (self weight or ‘dead’ action) as defined in AS/NZS 1170.0
G^c	= portion of the permanent load tending to cause instability
G^R	= portion of the permanent load and factored live load tending to resist instability
h	= vertical distance from the spill level of the tank to the bottom of the lower horizontal seam of the tank panel under consideration
H	= height of rectangular tank panel, in millimetres (Clause 4.3.3.4) = total height of tank shell, in metres (Clause 4.6.2.1)
H_a	= actual clearance under vortex plate, in millimetres
h_{fl}	= depth of rectangular tank panel flange, in millimetres
H_m	= minimum clearance under vortex plate, in millimetres
h_p	= vertical height of rectangular tank panel for a rectangular tank, in millimetres
h_s	= effective height for wind pressure, in metres
h_w	= maximum water depth in the tank, in metres
I_z	= equivalent flexural properties per unit projected width
I_0	= equivalent flexural properties per unit projected width

$I_{\theta z}$	= equivalent flexural properties per unit projected width
K	= period factor
K_p	= probability factor for earthquake from AS 1170.4
L	= length of the support beam under consideration, in millimetres
l	= height of buckle, in metres
l_p	= length of a panel flange under consideration, in millimetres
$l_{p1,p2}$	= respective lengths of adjacent horizontal panel flanges joined at the point of a stay support, in millimetres
l_{per}	= perimeter of the washer, in millimetres
l_w	= lesser width dimension of a washer, in millimetres
M	= overturning moment applied to the bottom of tank shell, in kilonewton metres
M_b	= nominal member moment capacity, in kilonewton metres
M_{lp}^*	= design liquid pressure moment on a tank panel flange, in kilonewton metres
M_s	= nominal sectional moment capacity as given in AS/NZS 4600
M_{sb}^*	= design liquid pressure moment on a support beam, in kilonewton metres
m	= number of buckling wavelengths around the tank circumference
N_f	= tensile capacity of a bolt securing a stay support
N_f^*	= design tensile load
N_{lp}^*	= design liquid pressure load
N_t	= nominal section capacity in tension determined by the criteria given in AS 4100
n_r	= number of stay rods in the panel row under consideration
n_s	= number of bolts subjected to a shear load due to the liquid pressure action when used to attach one end of a single stay support to a tank panel flange or stay bracket
n_t	= number of bolts subjected to a tensile load due to the liquid pressure action when used to attach one end of a single stay support to a tank panel
P_1	= impulsive pressure component, in kilonewton metres
P_2	= convective pressure component, in kilonewton metres
P_c	= buckling pressure for uniform isotropic tanks, in kilopascals
P_f	= limit state buckling pressure, in kilopascals
P_T	= total hydrodynamic pressure, in kilonewton metres
p_t	= the wind action from Section 4, in kilopascals
Q	= imposed action (due to occupancy and use, 'live' action)
Q_{max}	= maximum required flow rate, in litres per minute
R	= tank radius, in metres
R_R	= radius to the centroid of the circumferential stiffener
S	= site factor from Table 4.6. Assumed to be 1.5 unless otherwise specified by purchaser
SG	= specific gravity of water

T_w	= first mode sloshing wave period, in seconds
t	= base metal thickness of the wall sheet joined at a vertical seam, in millimetres (Clause 5.4.2.5) panel thickness, in metres (Clause 5.3.2.2)
t_p	= base metal thickness of the thinnest panel joined at a flange, in millimetres
t_z	= equivalent membrane properties per unit projected width
t_θ	= equivalent membrane properties per unit projected width
$t_{\theta z}$	= equivalent membrane properties per unit projected width
V	= volume of contents, in cubic metres
V_B	= lateral shear, at base of tank, in kilonewtons
V_{eq}^*	= an anchor subject to a design seismic induced shear load
V_f	= shear capacity of a bolt securing a stay support
V_f^*	= design shear load of a bolt securing a stay or roof support or stay bracket to a tank panel
W_1	= weight of effective mass of tank contents that moves in unison with the tank shell, in kilonewtons
W_2	= weight of effective mass of the first mode sloshing contents of the tank, in kilonewtons
W_r	= total weight of the tank roof plus permanent loads, in kilonewton metres
W_s	= total weight of tank shell floor (if any), and significant appurtenances, in kilonewtons
W_T	= total weight of tank contents
W_u	= ultimate wind action as defined in AS/NZS 1170.0
X_1	= height from the bottom of the tank shell to the centroid of lateral earthquake force applied to W_1 , in metres
X_2	= height from the bottom of the tank shell to the centroid of lateral earthquake force applied to W_2 , in metres
X_s	= height from the bottom of the tank shell to the centre of gravity of the shell, in metres
Y	= depth of water from the surface to the bottom of a ring or the design point being considered, in metres
α	= dimensionless quantity to simplify Equation 5.3.2.2(1)
Δ_D	= change in diameter of a bolted cylindrical tank from a relaxed state when subjected to a liquid pressure action, in millimetres
λ	= meridional bending half wavelength
π	= mathematical constant = 3.14159
ρ	= density of contents, in kilonewtons per cubic metre
ν	= Poisson's ratio (= 0.3 for steel)
Φ	= capacity reduction factor as given in AS 4100 (Clause 5.4.2.2)
Φ_b	= capacity reduction factor for bending = 0.9 or as given in AS/NZS 4600
ϕR	= design capacity of the structural component
ψ_c	= combination factor for imposed action as given in AS/NZS 1170.0

1.7 TANK TYPES AND DESCRIPTIONS

Fire tanks consist of the components referred to throughout this Standard and a typical cylindrical tank is illustrated in Figure 1.7.1 and a typical rectangular panel tank is illustrated in Figure 1.7.2.

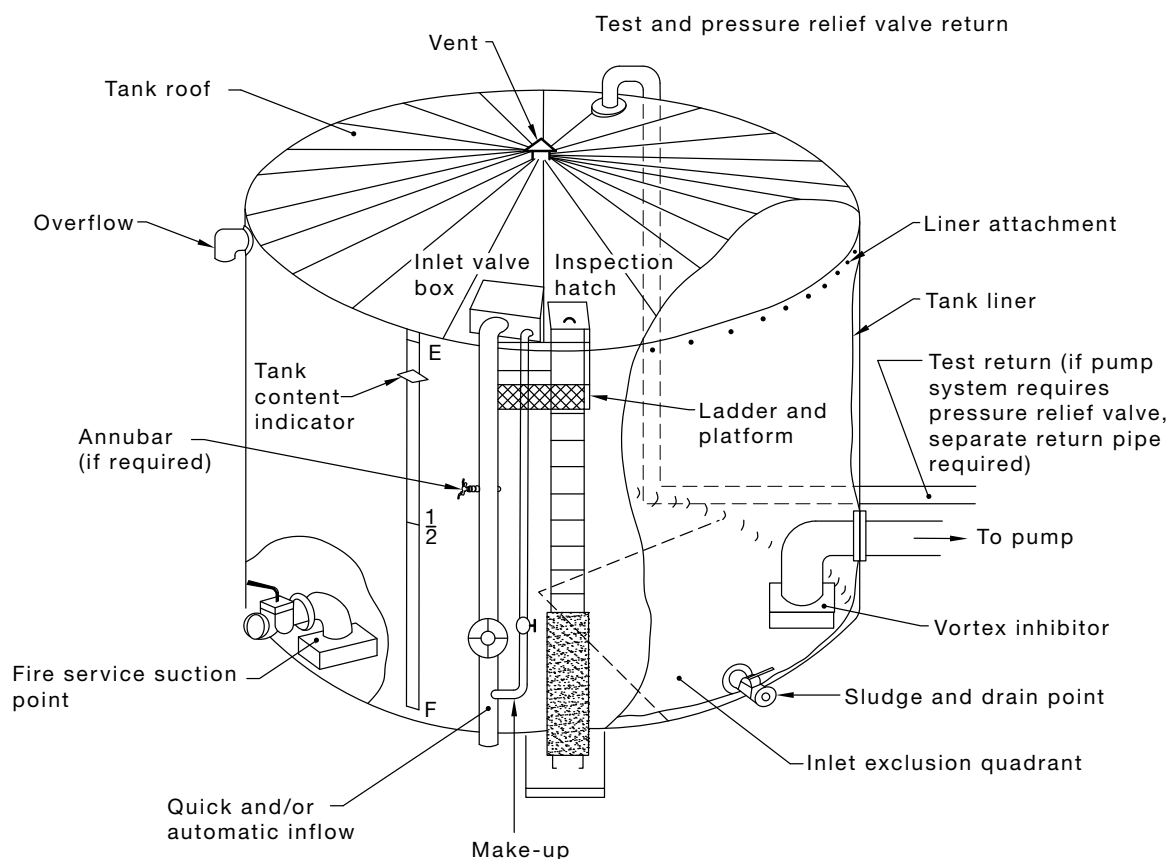


FIGURE 1.7.1 TYPICAL FIRE WATER STORAGE TANK SHOWING MAIN DESIGN FEATURES—CYLINDRICAL TANK

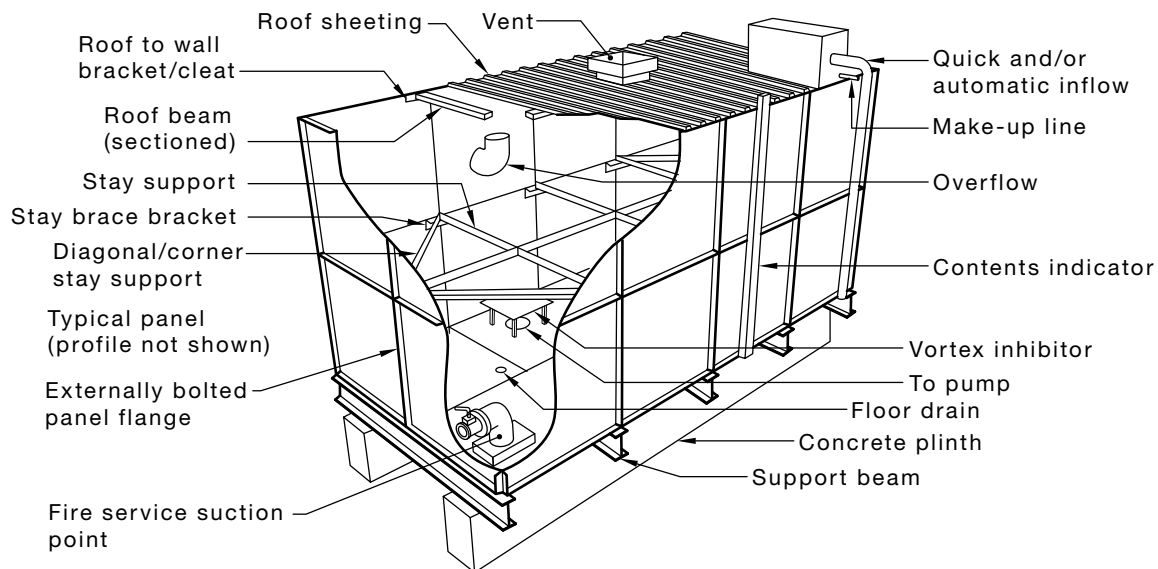


FIGURE 1.7.2 TYPICAL FIRE WATER STORAGE TANK SHOWING MAIN DESIGN FEATURES—RECTANGULAR PANEL TANK

SECTION 2 WATER SOURCES

2.1 GENERAL

This Section provides the requirement for water quality on which tank design decisions shall be based to minimize corrosion. It also sets out a list of acceptable water sources.

NOTES:

- 1 The quality of water should be suitable for human contact. This is to ensure that the health of the attending fire brigade personnel is not adversely impacted.
- 2 See Appendix C for a form that seeks information on water source and quality.

2.2 WATER SOURCES

Water sources for fire protection system use shall be compatible with the systems being supplied as specified in the respective design and installation Standards.

NOTES:

- 1 Design and installation Standards include AS 2118 (series), AS 2419.1, AS 2941 and AS/NZS 1221 (hose reels).
- 2 The following are acceptable water sources:
 - (a) Drinking water from public water supply.
 - (b) Filtered rain water.
 - (c) Treated process water (industrial).
 - (d) Bore water (treated as needed).
 - (e) Recycled water, subject to approval by the applicable water authority (non-drinking).
 - (f) Dam, river or lake water (filtered, silt removed).

SECTION 3 MATERIALS

3.1 GENERAL

All materials incorporated in any structure to meet this Standard shall be new and in first-class condition, and shall comply with all the requirements of this Standard.

3.2 STRUCTURAL ELEMENTS

3.2.1 Bolts

Bolts and nuts for joining tank panels shall conform to AS 1110.1, AS 1111.1 or AS/NZS 1252.

3.2.2 Plates and sheets

Plate and sheet material for hot-rolled steel tank panels shall comply with AS/NZS 1594. Plate and sheet materials for cold-rolled steel tank panels shall comply with AS 1397.

3.2.3 Structural shapes

Hot rolled structural shapes for use under this Standard shall comply with AS/NZS 3679.1 series. Cold-rolled structural shapes shall comply with AS/NZS 4600.

3.2.4 Castings

Cast iron castings shall conform to AS 1830. Steel castings shall conform to AS 2074.

3.3 PIPE AND FITTINGS

3.3.1 Pipe

Inlet, outlet, overflow and other pipes and all fittings for water use shall comply with requirements of AS 2118.1, AS 2419, AS 2941 or AS/NZS 3500.1, as appropriate. If steel pipe is not otherwise specified, pipe and fittings shall comply with or exceed requirements of AS 1579.

3.3.2 Wall joints

Unless otherwise specified, joints may be either screwed or flanged. Screw joints shall comply with AS 1722.2 or other approved national or international Standards. Flanged joints shall comply with the requirements of AS 4087.

NOTE: This Clause does not apply to termination points external to the tank.

3.4 CORROSION PROTECTION

All tank components, plates, nuts and bolts, fittings, bracing and accessories shall be compatible with respect to corrosion (dissimilar metals) and/or the quality of the water. Any dissimilar components shall be separated by suitable non-metallic insulation. Tank components shall have sufficient corrosion protection to achieve the required service life. Where corrosion protection is provided by galvanizing it shall be in accordance with AS/NZS 4680.

3.5 GASKETS AND SEALANTS

3.5.1 Material

The selection of gasket and sealant materials to be used in fire tanks shall be based on but not limited to the following:

- (a) Water quality (pH, chemical composition, chlorine and oxygen levels, water hardness, water temperature).

- (b) Serviceability for a range of external temperatures from -5°C to $+70^{\circ}\text{C}$.
- (c) Shrinkage allowance, which shall be factored in the design to ensure serviceability over the design life of the gasket.
- (d) Environmental conditions (humidity, UV light).

3.5.2 Gaskets—Longevity

Gasket material shall remain elastic to obtain a leak-proof seal at all seams, joints and penetrations, and remain intact over the tank's service life, typically 25 to 30 years.

3.6 TANK LINERS

3.6.1 Material

Tank liners shall be made from a material compatible with the contents of the tank and shall have a minimum thickness of 0.75 mm for unreinforced and a minimum nominal thickness of 0.6 mm for scrim reinforced. Scrim reinforced material shall have a minimum tensile strength of 1000 N per 50 mm as determined in accordance with the test specification set out in AS 2001.2.3.1 and AS 2001.2.3.2. Selection of the type of material shall be based on but not limited to the following:

- (a) Water quality (pH, chemical composition, chlorine and oxygen levels, water hardness, water temperature).

NOTE: Guidance on information to be sought on water source and quality is given in Appendix C.

- (b) Multi-use or dedicated tank (fluctuating water level).
- (c) Tank sizing (height and diameter).
- (d) Serviceability for a range of external temperatures from -5°C to $+70^{\circ}\text{C}$.
- (e) Shrinkage allowance, which shall be factored in the design to ensure shrinkage does not affect the liner's performance, after the tank is drained and refilled in accordance with Section 11, over the design life of the liner. Allowable shrinkage shall be limited to a maximum of 3% over the design life of the liner.
- (f) Elongation (cold-flow). Liners shall be supported or reinforced to minimize elongation over the design life of the liner. Allowance shall be made in the design to ensure elongation does not affect the liner's performance after the tank is drained and refilled in accordance with Section 11 over the design life of the liner.
- (g) Environmental conditions for the exposed portion of the liner (humidity, UV light).

NOTE: Any potential change in water quality over the life of the tank should be taken into consideration.

3.6.2 Fixing

Liners shall be positively attached, bolted or screwed to the top circumference of the tank on a maximum spacing of 300 mm to minimize sagging. For tanks with ribbed or corrugated walls, the fixing system (fastening, plus edge reinforcement, plus liner) shall have a failure strength exceeding 550 N per fixing. All liners for ribbed or corrugated tanks with a wall height greater than 4.0 m shall have intermediate liner supports in the walls. Liners for tanks with a height greater than 6.0 m in height with smooth walls shall be scrim-reinforced material only and the fixing system shall be adequate to support the self-weight of the liner.

Where tek screws are used through a cold-rolled tank, the rim of the tank shall have a rolled rectangular hollow section (RHS) hoop reinforcement to prevent the rim rolling in and to increase the thickness through which the screws are fitted. Tek screws shall be at least 12–14 size to AS 3566 class 4. Bolts shall be at least 10 mm diameter to AS 1110.1 or AS 1111.1.

3.6.3 On-site fabrication

On-site fabrication work shall be performed by a competent person and match the performance of the factory-built liner.

3.6.4 Liner design life

The selected tank liners shall have a minimum design life of 10 years for a static water supply (see Clause 11.3.2).

NOTES:

- 1 When a tank is out of service for the replacement of a liner, consideration should be given to an alternative water supply.
- 2 The design life of the liner may be extended with appropriate maintenance subject to an increased frequency of inspections.
- 3 There are liner materials available that have a design life much higher than the minimum 10 years, some approaching the service life of the tanks.

SECTION 4 DESIGN ACTIONS (LOADS)

4.1 GENERAL

This Section sets out general design actions imposed on tanks for fire protection purposes.

Tanks shall be designed to withstand structural design actions as given in AS/NZS 1170 series, which includes AS 1170.4, including permanent actions, liquid pressure actions imposed by the fluid contents filled to just overflowing, imposed actions and wind actions. In addition, tanks that are located in areas in which a seismic event is likely to occur, or tanks that are located in alpine regions, shall be designed to withstand the anticipated earthquake or snow actions. Load combinations for stability and strength shall be as given in Clause 4.8.

The design life of water tanks for fire protection systems for the determination of design actions within this Section shall be a minimum of 25 years and a minimum importance level of 2 as specified in AS/NZS 1170.0.

NOTE: Tanks providing water for fire services are considered equally as important as the buildings they protect and hence the minimum importance level is given as 2 but could be higher (refer to AS/NZS 1170.0). This then leads to the annual probability of exceedance for the various design action (refer to AS/NZS 1170.0).

4.2 PERMANENT ACTION

Permanent actions shall be in accordance with AS/NZS 1170.1.

The permanent action shall be the estimated weight of all permanent construction and fittings. The unit weights used shall be 76.9 kN/m^3 as given in AS/NZS 1170.1 for steel and 24 kN/m^3 for concrete. For special materials, the appropriate weight shall be determined and utilized.

4.3 LIQUID PRESSURE ACTION

4.3.1 General

The liquid pressure actions shall be in accordance with AS/NZS 1170.1.

The liquid pressure actions shall be the actions imposed on the tank's structure and footings when the tank is filled with water to the spill level as defined by AS/NZS 3500.1. The unit weight of water used shall be 1000 kg/m^3 .

4.3.2 Liquid pressure action—Cylindrical water storage tanks

For the purpose of determining the wall panel actions and vertical seam connection actions for each shell course, the liquid pressure action due to the water contents shall be taken from the lowest point of each shell course and applied undiminished over the entire height of that shell course.

4.3.3 Liquid pressure action—Rectangular water storage tanks

For the purpose of determining the member stresses for each tank panel course and tank panel deflections, the liquid pressure action due to the water contents shall be taken from the lowest point of each tank panel course and applied undiminished over the entire height of that tank panel course.

4.3.3.1 Tank stay support and roof supports

Design liquid pressure load (N_{lp}^*) applicable to a stay support attached to the top edge of a tank panel shall be no less than—

$$N_{lp}^* = 5.9 h h_p (l_{p1} + l_{p2}) \times 10^{-12} \quad \dots 4.3.3.1$$

where

h = vertical distance from the spill level of the tank to the bottom of the lower horizontal seam of the tank panel under consideration

h_p = vertical height of tank panel under consideration

$l_{p1,p2}$ = respective lengths of adjacent horizontal panel flanges joined at the point of a stay support

For the purpose of determining pressure actions, stay supports attached to the bottom edge of a tank panel shall be treated as if they are attached to the top edge of the next lowest panel.

For cast iron panel tanks using stay supports (usually round bar), $l_{p1} = l_{p2}$ equals the length of the tank wall to be supported by the stay support under consideration.

4.3.3.2 Tank stay support and roof support bolts

The design tensile load (N_f^*) of a bolt securing a stay or roof support or stay bracket to a tank panel shall be no less than—

$$N_f^* = \frac{N_{lp}^*}{n_t} \quad \dots 4.3.3.2(1)$$

The design shear load (V_f^*) of a bolt securing a stay or roof support to a tank panel flange or stay bracket cleat shall be no less than—

$$V_f^* = \frac{N_{lp}^*}{n_s} \quad \dots 4.3.3.2(2)$$

where

N_{lp}^* = design liquid pressure load

n_t = number of bolts subjected to a tensile load due to the liquid pressure action when used to attach one end of a single stay support (or stay bracket) to a tank panel

n_s = number of bolts subjected to a shear load due to the liquid pressure action when used to attach one end of a single stay support to a tank panel flange or stay bracket

4.3.3.3 Tank panel flanges

Design liquid pressure moment (M_{lp}^*) acting on a tank panel flange shall be no less than the following:

$$M_{lp}^* = 1.5 h h_p l_{p2} \times 10^{-9} \quad \dots 4.3.3.3$$

where

h = vertical distance from the spill level of the tank to the bottom of the lower horizontal seam of the tank panel under consideration

h_p = vertical height of tank panel under consideration

l_p = length of a panel flange under consideration

for floor panels $l_p = h_p$.

For a wall panel, this moment shall be applied to the top flange and the two vertical flanges only. The bottom flange of any panel shall be treated as the top flange of the next lowest panel.

4.3.3.4 Tank support beams

A rectangular tank elevated by concrete plinths shall be fully supported by steel beams at every panel flange in one direction. For the concrete plinth arrangement given in Figure 4.3.3.4, the design liquid pressure moment (M_{sb}^*) on a support beam shall be taken as the more adverse effect as given by—

$$M_{sb}^* = -5.9 H h_p d_p^2 \times 10^{-9} \quad \dots 4.3.3.4(1)$$

or

$$M_{sb}^* = 5.9 H h_p (0.25 L^2 - L d_p) \times 10^{-9} \quad \dots 4.3.3.4(2)$$

where

l_p = length of a panel flange under consideration, in millimetres

H = height of the rectangular tank panel, in millimetres

L = length of the support beam under consideration, in millimetres

d_p = distance from the edge of the tank to the centre of the concrete plinth used to elevate the tank, in millimetres

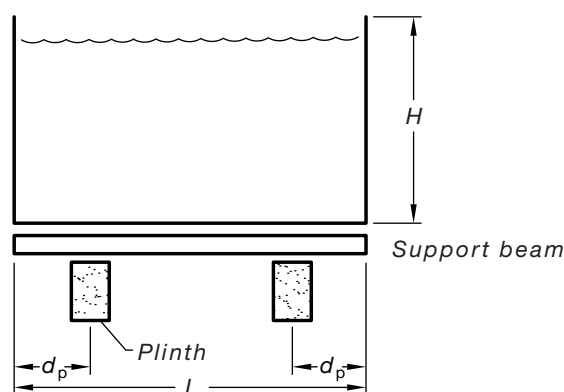


FIGURE 4.3.3.4 SUPPORT BEAM ARRANGEMENT FOR RECTANGULAR TANK ELEVATED ON CONCRETE PLINTHS

4.4 IMPOSED ACTIONS

4.4.1 General

Imposed actions shall be in accordance with AS/NZS 1170.1. The distributed and concentrated imposed actions shall be considered separately and the design carried out for the most adverse effect.

4.4.2 Roofs

The tank roof shall not be accessible except for normal maintenance, repair, painting and minor repairs. The AS/NZS 1170.1 roof category shall be R2 for the derivation of imposed actions on the roof structure.

4.4.3 Fixed platforms, walkways, stairways and ladders

Fixed platforms, walkways, stairways and ladders shall be designed for the permanent action of the structure plus a superimposed live action as given in AS 1657. Where the fixed platforms, walkway, stairway or ladder is likely to be loaded in excess of these requirements, the design action shall be based on the requirements of AS/NZS 1170.1.

4.5 WIND ACTION

4.5.1 General

Wind action, as given in AS/NZS 1170.2, shall be applicable to all exposed surfaces of the tank, including the tank roof, tank shell and fixtures (platforms, walkways, stairways and ladders). In the absence of local terrain information, a terrain category of 2.5 shall be assumed.

NOTE: Although a terrain category of 2.5 is not cited in AS/NZS 1170.2, this simple interpolation was considered necessary because of the large jump between terrain categories 2 and 3, with many cases of tanks expected to be exposed to terrain that lays somewhere in between, where a 2 would be over conservative while a 3 would be the opposite.

4.5.2 Stability—Cylindrical water storage tanks

For the purpose of determining tank stability under wind actions, the tank shall be considered to be emptied of its contents. For calculating the stability of the tank, the aerodynamic shape factor (C_{fig}) (see Note) shall be taken as 0.63 (based on an elevation area $D \times H$). The overturning load due to drag on the tank wall may be assumed to act at a height of $0.5H$ from the tank base with overturning moments acting about Point 0, as shown in Figure 4.5.2.

NOTE: C_{fig} = aerodynamic shape factor as given in AS/NZS 1170.2.

Uplift due to the wind action on the entire roof area shall be considered to be acting simultaneously to the above overturning load. Wind action on the tank roof shall be as given in AS/NZS 1170.2.

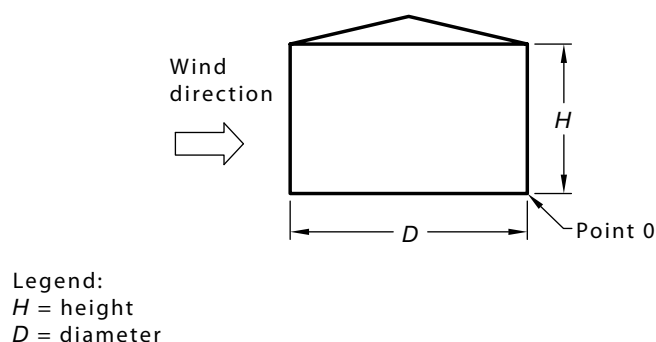


FIGURE 4.5.2 EXTERNAL PRESSURE COEFFICIENTS ON WALLS OF CIRCULAR TANKS

4.5.3 Buckling—Cylindrical water storage tanks

The tank wall shall be stiffened so that it will not buckle from wind action while it is in an empty state. External pressure around the perimeter of a circular tank wall shall be as given in AS/NZS 1170.2.

The tank may be stiffened by increasing the panel thickness, profiling, the use of laminations or the installation of circumferential stiffeners as described in Section 5.

4.5.4 Wind actions on roof columns

Where roof columns are provided, the roof columns shall accept a portion of the uplift due to wind action proportioned in accordance with its location in the roof structure. Where only one roof column is used, the uplift due to wind action on the column shall be not less than 50% of the uplift over the entire roof area. In addition, centrally positioned columns on roofs with pitches of 10° or greater shall experience local pressure factors as given in AS/NZS 1170.2.

A comparable portion of the permanent action due to the roof structure weight shall be used to resist the uplift.

4.6 EARTHQUAKE ACTION

4.6.1 Seismic design consideration

Tanks shall be anchored in order to resist earthquake loads. Anchorage shall be designed so that the anchor bolts yield before the attachment to the tank wall fails.

4.6.2 Overturning moment and base shear

4.6.2.1 General

Overturning moment and base shear arising from earthquake loads shall be calculated in accordance with the effective-mass procedure, as described in this Clause.

C4.6.2.1 *The method utilized for calculating earthquake loads considers impulsive and convective components of the tank contents as described below. Consideration of these components includes calculation of a sloshing wave height, and also enables the resulting actions to be significantly reduced from what they would be if the entire tank contents were considered to be acted upon simultaneously by the earthquake loads.*

The effective-mass procedure considers two response modes of the tank and its contents:

- (a) *Impulsive component, which is the high-frequency amplified response to lateral ground motion of the tank shell and roof together with a portion of the liquid contents that moves in unison with the shell.*
- (b) *Convective component, which is the low-frequency amplified response of a portion of the liquid contents in the fundamental sloshing mode. The design requires the determination of the hydrodynamic mass associated with each mode, and the lateral force and overturning moment applied to the shell resulting from the response of the masses to lateral ground motion.*

The base shear and overturning moment due to earthquake forces applied to the bottom of the shell shall be determined in accordance with the following equations:

- (a) *Base shear:*

$$V_B = 4K_p a [0.14(W_s + W_r + W_1) + SC_1 W_2] \quad \dots 4.6.2.1(1)$$

- (b) *Overturning moment:*

$$M = 4K_p a [0.14(W_s X_s + W_r H + W_1 X_1) + SW_2 X_2 C_1] \quad \dots 4.6.2.1(2)$$

where

V_B = lateral shear, at base of tank, in kilonewtons

M = overturning moment applied to the bottom of tank shell, in kilonewton metres

K_p = probability factor for earthquake from AS 1170.4, Table 3.1
The value of K_p for fire tanks shall be 1.25.

a = acceleration coefficient from AS 1170.4

W_s = total weight of tank shell floor (if any), and significant appurtenances. The floor (if any) shall not be included in the calculation for resisting moment, in kilonewtons

X_s = height from the bottom of the tank shell to the centre of gravity of the shell, in metres

W_r = total weight of the tank roof plus permanent loads, if any, as specified by the purchaser. Only that portion of the roof that bears on the shell shall be considered for the resisting moment, in kilonewton metres

H = total height of the tank shell, in metres

W_1 = weight of effective mass of tank contents that moves in unison with the tank shell, in kilonewtons

X_1 = height from the bottom of the tank shell to the centroid of lateral earthquake force applied to W_1 , in metres

S = site factor from Table 4.6 (assumed to be 1.5 unless otherwise specified by purchaser)

W_2 = weight of effective mass of the first mode sloshing contents of the tank, in kilonewtons

X_2 = height from the bottom of the tank shell to the centroid of lateral earthquake force applied to W_2 , in metres

C_1 is determined as follows:

(i) For the condition where $T_w < 4.5$ s:

$$C_1 = \frac{1}{6T_w} \quad \dots 4.6.2.1(3)$$

(ii) For the condition where $T_w \geq 4.5$ s:

$$C_1 = \frac{0.75}{T_w^2} \quad \dots 4.6.2.1(4)$$

T_w = first mode sloshing wave period, in seconds, which is determined as follows:

$$T_w = 1.811KD^{1/2} \quad \dots 4.6.2.1(5)$$

where K = period factor

$$K = \frac{0.578}{\sqrt{\tanh \frac{3.67}{D/h_w}}} \quad \dots 4.6.2.1(6)$$

where

h_w = maximum water depth in the tank, in metres

(c) Determination of effective masses of tank contents and their centroids:

$$W_T = \rho V \quad \dots 4.6.2.1(7)$$

where D = diameter of tank, in metres

W_T = total weight of tank contents

ρ = density of contents, in kilonewtons per cubic metre

V = volume of contents, in cubic metres