Assets Planning and Delivery Group
Engineering

DESIGN STANDARD DS 31-01

Pipework - Mechanical

VERSION 1
REVISION 7

OCTOBER 2024

FOREWORD

The intent of Design Standards is to specify requirements that assure effective design and delivery of fit for purpose Water Corporation infrastructure assets for best whole-of-life value with least risk to Corporation service standards and safety. Design standards are also intended to promote uniformity of approach by asset designers, drafters and constructors to the design, construction, commissioning and delivery of water infrastructure and to the compatibility of new infrastructure with existing like infrastructure.

Design Standards draw on the asset design, management and field operational experience gained and documented by the Corporation and by the water industry generally over time. They are intended for application by Corporation staff, designers, constructors and land developers to the planning, design, construction and commissioning of Corporation infrastructure including water services provided by land developers for takeover by the Corporation.

Nothing in this Design Standard diminishes the responsibility of designers and constructors for applying the requirements of the Western Australia's Work Health and Safety (General) Regulations 2022 to the delivery of Corporation assets. Information on these statutory requirements may be viewed at the following web site location:

Overview of Western Australia's Work Health and Safety (General) Regulations 2022 (dmirs.wa.gov.au)

Enquiries relating to the technical content of a Design Standard should be directed to the Senior Principal Engineer, Mechanical Section, Engineering. Future Design Standard changes, if any, will be issued to registered Design Standard users as and when published.

Head of Engineering

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Users should use and reference the current version of this document.

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REVISION STATUS

The revision status of this standard is shown section by section below:

REVISION STATUS						
SECT.	**VER./ REV.**	**DATE**	**PAGES REVISED**	**REVISION DESCRIPTION (Section, Clause, Sub-Clause)**	**RVWD.**	**APRV.**
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DESIGN STANDARD DS 31-01

Pipework - Mechanical

CONTENTS

1 SCOPE AND GENERAL

1.1 Scope

Design Standard DS 31-01 is the first part of a two part standard which collectively provides design requirements for pipework and valves. The second part of the Standard is:

DS 31-02 Valves and Appurtenance – Mechanical.

DS 31-01 outlines the Corporation's mechanical design standards, guidelines and preferred engineering practice for pipework associated with mechanical works for water supply, wastewater and drainage. This Standard is a pipework design standard and not a pipeline design standard.

For standards relating to design of reticulation or distribution pipelines the Designer should refer to the relevant parts of DS 63 and DS 60 respectively. Further, this Standard is not intended for gas and high temperature or steam applications.

1.2 Purpose

The Corporation's mechanical design standards are documented in its DS 30 Standards series. Designers shall comply with these standards for the design and specification of mechanical components of assets being acquired for the Corporation.

The purpose of the DS 30 Standards series is to provide:

(a) Standards and guidelines applicable in the design of Corporation assets,

(b) Explanatory or specific design information,

(c) Information relating to Corporation preferences and practices which have evolved from over a century of experience in the water industry.

1.3 Design Process

The Designer shall comply with the requirements of the relevant mechanical design process contained in DS 30.

1.4 Standards

All materials and workmanship shall comply with latest revisions of the relevant codes and standards.

Water Corporation Strategic Product Specifications (SPS), or in their absence the latest editions of Australian Standards, or Water Services Association of Australia (WSAA) Codes, shall be referenced for design and specification. In the absence of relevant Australian Standards or WSAA Codes, relevant international or industry standards shall be referenced.

1.5 Referenced Documents

Corporation Standards and Specifications, and Australian Standards and International Standards referred to in the DS 30 Standards series are listed in full in Appendices A and B of DS 30-01.

1.6 Occupational Safety and Health Codes

The Designer shall comply with occupational safety and health codes in accordance with the requirements set out in the Occupational Safety and Health section of DS 30-02.

1.7 Notation

Statements governed by use of the word ‘shall’ are mandatory or ‘normative’ requirements of the Standard. Statements expressed by use of the words ‘should’ or ‘may’ are ‘informative’ but not mandatory and are provided for information and guidance. Notes in Standard text are informative. Notes that form part of Standard Tables are normative. An Appendix to the Standard that is designated ‘normative’ contains mandatory requirements. An Appendix that is designated ‘informative’ is provided for information and guidance only. The term ‘specified’ includes requirements of the Standard and requirements stated or referenced in other project documentation.

1.8 Nomenclature

1.8.1 Definitions and Relationships

For definitions of the terminology and relationships referred to in this Standard the reader is referred to the Engineering Definitions and Relationships section of DS 30-01.

1.8.2 Preferred Terminology

For the preferred terms to be used in designs the reader is referred to the Preferred Terminology section of DS 30-01.

1.8.3 Abbreviations

For definitions of the abbreviations referred to in this Standard the reader is referred to the Abbreviations section of DS 30-01.

1.8.4 Standard Units and Relationships

The units and relationships used for mechanical designs based on this standard shall be in accordance with those specified in the SI Units, Relationships and Prefixes section of DS 30-01.

1.8.5 Drawing Symbols

A comprehensive list of mechanical drawing symbols for pipework and valves is referenced in DS 80.

2 DESIGN CRITERIA

2.1 General

In addition to the following general design criteria the Designer shall refer to the relevant parts of DS 30 and DS 30-02 for further general design information.

2.2 Cement Mortar Lining (CML)

2.2.1 Corrosion Mitigation

CML applied inside steel and ductile iron pipe provides good corrosion protection in water applications at relatively low cost and with low friction coefficient. When CML is saturated with water it produces a high pH, which has the effect of inhibiting corrosion at the steel or cast iron interface.

For general information and corrosion mitigation requirements refer to the Corrosion section of DS 30-02.

2.2.2 Degradation and Cracking

The alkalinity of the CML degrades over time at a rate depending on the pH of the water. When the alkalinity has been fully depleted corrosion of the pipe material will occur. The residual alkalinity of existing cement mortar lining can be checked by using a phenolphthalein dye test.

For wastewater applications corrosion is generally not a significant factor unless hydrogen sulphide gas (H_2S) is present. This can occur as sewage ages and can be liberated in partially filled mains or at manholes, outfalls or other turbulence producing structures.

H_2S gas in contact with the CML absorbs into bio-films on the surface of the lining. The bacteria in the biofilm metabolise the sulphur component of the H_2S gas and produces sulphuric acid (H_2SO_4) which can rapidly corrode the lining.

Shrinkage cracking of CML is a normal occurrence and the acceptable magnitude of cracking should be checked for compliance in accordance with relevant product standards. For hair line cracks, of less than 0.18 mm, cracking normally closes over by autogenous healing after immersion. Cracks of a width up to 2 mm and a depth of up to half the thickness of the lining are acceptable for conveying potable water. For pipelines carrying wastewater or saline water, the maximum tolerable crack width shall not exceed 0.2mm. For more information on cement mortar lining requirement refer to Coating Specification M8.

2.2.3 Design Criteria

Designers should be aware that cement mortar lining might be rapidly degraded by water containing:

(a) Low pH

(b) High sulphides e.g. H_2S in sewage applications

(c) Under-saturated calcium carbonate.

The maximum velocity for water in contact with CML should be 8 m/s for intermittent service and 4 m/s for optimal service life.

CML should be subject to reinstatement wherever it has been removed from pipework during fabrication or subsequent modification. Reinstatement depends on its size e.g. for DN 500 and below welded bands should be provided at welded pipe joints.

CML shall not interfere with the operation of valve discs that may protrude into the pipe bore.

2.3 Coatings

For information on pipework coatings refer to DS 95.

2.4 Dismantling Joints

2.4.1 Pump Dismantling Pipe Couplings and Restraints

Where a flanged elbow is provided adjacent to the discharge side of a pump, the arrangement shall be such as to enable safe removal of the elbow and thereby the removal of the pump.

For in-line pumps a restrained dismantling coupling shall be fitted to the discharge pipework, located between the pump and the non-return valve, to enable ease of removal of either item. Restrained dismantling joints are not covered by standard drawings and have little compressive load carrying capability. Previous project examples are available but they shall designed for the application considering the following:

(a) Couplings shall comprise a complete assembly of the body, fasteners, and one-piece rubber sealing sleeve with no loose parts. 'Teekay AXIFLEX' or "Strab" couplings have previously been used;

(b) Dismantling joints shall be longitudinally restrained with tie bolts and the pipework designed and supported to ensure that pipework loads on the pump discharge are well below manufacturers specified nozzle load limits;

(c) The restraining flanges should be braced with strengthening gussets at the bolts and be slotted to facilitate removal of the tie bolts;

(d) Dismantling pipe couplings shall not be subjected to lateral forces.

Pipe external surfaces under flexible joining couplings shall be coated in accordance with Coating Specification M4. For more information on coating requirements refer to DS 95.

Pipe spigots mating to couplings shall be prepared within the tolerances specified by the dismantling coupling manufacturer.

2.4.2 Pipework Dismantling Joints used in Pits

Dismantling joints or flanges should be provided for pipework appurtenances such as non-return valves, control valves and flowmeters located in pits in order to facilitate removal of these items for servicing.

A typical dismantling flange for this purpose would be the 'UNIFLANGE' or equivalent. Care should be taken to select UNIFLANGES strictly in accordance with the manufacturer's recommendation particularly with respect to the maximum pressure rating of large flange sizes. VICTAULIC COUPLINGS have also been used in combination with grooved pipe specials, covered in the following paragraphs.

2.4.3 Hard-Piped Pipework

When large butterfly and gate valves (e.g. DN 500 and greater) are installed in buried service, they are generally installed without dismantling joints or dismantling flanges. The flanges of the valve are mated up to pipework flanges, one of which is a welded slip-on flange to allow for installation. This type of installation is referred to as 'hard piping', and the pipework must be cut in order to subsequently remove the valve. This system has generally been adopted by the Corporation for many years now, primarily due to the cost of providing dismantling joints in these large sizes. Some pipework, particularly when higher pressures are involved, may require a tie-bolt arrangement or large thrust block to take up axial thrust if a dismantling joint was incorporated into the installation. This cost can be avoided by the use of hard piping.

2.4.4 Dismantling Hard-Piped Pipework

In order to remove a hard piped valve for maintenance, the pipe must be cut. To replace the valve, a welding band can be used to allow the pipework to be made up to the correct length. There are a couple of options for reinstatement of the cement mortar lining in MSCL pipe after such a procedure. If a manhole exists, the cement mortar lining can be reinstated by hand by entry into the pipe. For more information on the cement mortar lining requirement refer to Coating Specification M4. This would involve confined space entry and the associated procedures. If there is not a manhole, one could be retrofitted. Alternatively, a thicker than normal welding band may be used (e.g. 10 mm versus 6 mm) and a second concave welding band welded over it. Grout is then used to fill the resultant void between the two bands. The complexity and cost of such an operation may be greater than if a dismantling joint had been used. However, gate valves and butterfly valves for waterworks purposes are robust items and due to the long time before the valve is expected to be removed for maintenance or replacement, Net Present Value analysis tends to favour hard piping.

2.4.5 Grooved Jointing Systems (e.g. *Victaulic* Couplings)

The Corporation uses couplings with grooved joints for quick installation and/or removal of equipment. The couplings are primarily used on small pipework (DN300 and below), in applications such as packaged pressure booster stations and in treatment plants.

For larger applications (DN350 and above), the Corporation is trialing *Victaulic* couplings with their Advanced Groove System (AGS) to facilitate the removal of critical equipment in pits or above ground where straight sections of pipe make future removal difficult. The couplings will potentially lower maintenance time and costs compared to traditional hard-piped pipework, and lower capital costs and space requirements compared to dismantling joints.

2.4.5.1 Small Applications (DN50 to DN300) – Packaged booster stations, treatment plants, etc.

Grooved jointing systems may be used to join copper or stainless steel pipe subject to approval by the Corporation. Grooved jointing systems shall comply with AS 3688. In accordance with the grooved jointing systems, standard sizes approved by the Corporation are:

(a) Copper – DN 50 to DN 150;

(b) Stainless steel – DN 50 to DN 300.

2.4.5.2 Large Applications (DN350 and above) – Control valves, flowmeters, etc.

For larger applications Victaulic couplings with AGS may be used on critical equipment, such as non-return valves, pressure reducing valves and other control valves, subject to approval by the Corporation.

The connecting pipework shall be restrained to protect the joint from axial or bending loads caused by thermal expansion or pressure induced strain (e.g. by a puddle flange bolted to the pit wall or similar).

The *Victaulic flexible Style W77* coupling is preferred. The flexible coupling can provide a small tolerance for angular deflection and axial movement without reducing the maximum allowable axial load, bending moment and pressure rating of the coupling. The coupling housing shall be hot dipped galvanized or fusion bonded epoxy coated.

The coupling shall be supplied with two Victaulic flanged adapter nipples. The flanged adapter nipples shall be fusion bonded epoxy coated carbon steel. Stainless steel shall be used for the flanged adapter nipples in stainless steel pipe systems. The flanged adapter nipples shall be prefabricated in the following standard lengths:

- 300 mm for DN350 to DN600 pipe, and
- 400 mm for DN650 to DN1200 pipe.

Longer lengths may be specified to suit brownfield installations, or arrangements where supplying a longer spool would eliminate unnecessary flanges or fittings. The flanges shall be supplied to AS/NZS 4087 and in accordance with DS38-02; alternative flanges may be supplied subject to approval by the Corporation.

Note: Victaulic couplings cannot provide axial adjustment during the construction of pipe systems.

2.5 Flanged Connections

Flanged connections shall be installed in accordance with DS 38-02.

2.6 Materials of Construction

For general information and materials of construction requirements refer to the Materials section of DS 30-02 and the relevant pipe type contained in section 4 of this Standard.

2.7 Pipework

2.7.1 Water and Sewage Pump Stations

Design of water and sewage pump station manifolds, offtakes and related pipework shall comply with the requirements of contained in DS 32, DS 32-01 and draft DS 32-02 and the relevant parts of this Standard as appropriate.

2.7.2 Vacuum Sewage Pump Stations

Design of water, sewage and vacuum pipework for vacuum sewage pump stations shall comply with the requirements of Pipework in the Vacuum Sewage Pump Station section contained in DS 32 and the relevant parts of this Standard.

2.7.3 Compressed Air

Design of compressed air pipework systems shall comply with the Compressed Air section of DS 35 and the relevant parts of this Standard.

2.7.4 Process Pipework

Process pipework materials shall comply with the Pipework section of DS 33 and DS 34 and the relevant parts of this Standard.

2.7.5 Miscellaneous Pipework

Miscellaneous service pipework materials shall comply with the Pipework section of DS 33 and DS 34 for blower air, fire service, fuel oil, instrument air, plant air, drinking water, sample water, service water and the relevant parts of this Standard.

2.8 Pipework Supports

2.8.1 Pump Station Pipework Supports

Pipework within a pump station or valve pit shall be adequately supported by adjustable stands designed to accommodate all cantilever loads induced when pumps and valves are removed for service. Pipework supports exposed to water or wastewater environments shall be stainless steel. For normally dry conditions the support stands shall be fabricated from hot dip galvanised mild steel. Hot dip galvanising shall comply with the Australian Standard AS/NZS 4680. For more information refer to Coating Specifications H1 and H2.

2.8.2 Process Pipework and Ducting

(a) Process pipework shall be designed to ensure safe, convenient and unfettered access to pumps, items of equipment, valves and appurtenances;

(b) The design shall, where practicable, provide straight, unencumbered walkways through plant rooms and yards, avoiding the need to step-over pipework and safe height clearance;

(c) Process pipework shall be supported with the support spacing designed using the combined mass of pipe and contents, for load calculations. Vibrational excitation of resonant structures (e.g. steel landings) shall be considered and avoided in the positioning of supports;

(d) Large valves and other appurtenances shall be independently supported;

(e) Pipe supports shall be to the supplier's requirements in terms of support centres and unsupported spans for the material of the pipeline and its contents under all operating conditions;

(f) Positioning of supports shall take into account access to and potential removal of pumps, valves and fittings, such that the pipe (or ducting) is adequately supported with components removed;

(g) Pipework and ducting shall be supported using clamps, supports, hangers and brackets specifically designed for the duties, including consideration of corrosion resistance and dissimilar material issues;

(h) Pipes shall be installed and supported so that pump nozzle forces and moments are well within manufacturers specified limits;

(i) Continuous support shall be provided for small flexible pipelines;

(j) Supports shall take into account any force or movement brought about through pressurization, thermal expansion or due to inherent or externally imposed vibration;

(k) Pipework design shall be visually acceptable in terms of vertical lines being plumb, even spacing of parallel pipe runs and overall appearance;

(l) Where pipelines or supports are required to be painted or coated, this shall be completed before the supports are installed.

(m) Pipework shall not transmit vibration to critical ancillary equipment e.g. compressors, blowers etc.

2.9 Threaded Connections

2.9.1 General

Threaded end connections for pipework containing fluid should generally only be used for joining smaller sized pipework e.g. DN 65 and smaller. Threaded end connections can be used for larger pipe sizes e.g. up to DN 150 but would be subject to pressure limitations with the potential for leakage in these relatively large sizes. Where leakage is of concern, pipe end connections above DN 65 shall be flanged. Threaded components used in corrosive service shall be manufactured from a corrosion-resistant material.

Thread types and joint combinations may be taper-to-taper or taper-to-parallel.

Designers shall comply with the relevant requirements of Clause 3.24.3 of AS 4041 when designing threaded connections.

2.9.2 Fastening Threads

Fastening threads are used for applications where sealing against fluid pressure is not required, or sealing is achieved by use of a compression joint utilizing an O-ring or other seals against fastener sealing faces and not the thread e.g. a union fitting.

Fastening threads are designated as Series G in AS 1722.2.

2.9.3 Sealing Threads

Sealing pipe threads shall be used to provide a pressure-tight joint for pipework and appurtenances for conveying fluids at pressure with sealing being affected between the thread surfaces in contact. Sealing threads are available in the following series per AS ISO 7.1:

(a) Internal – Parallel, and designated as Rp e.g. Rp 1½

(b) Internal – Taper, and designated Rc (c - conical) e.g. Rc 1½

(c) External – Taper (always) and designated R e.g. R 1½

2.9.4 Incorrect use of Fastening Threads

Local plumbing industry practice in the past has seen the use of Series G internal fastening threads on some fittings, where an Rp threaded sealing joint should have been provided. A Series G fastening thread is not intended to be used for sealing purposes.

Manufacturers provide Series Rp sealing threads on some products such as copper alloy valves (as specified in AS 1628) and tapping bands. However many other fittings were supplied with Series G internally threaded connections, resulting in a joint combining an external sealing thread and an internal fastening thread. In order to seal the joint for pressure applications, liberal amounts of thread tape were required.

The problem has been confined to some plumbing products and appears to be due to incorrect interpretation of AS 3688 which does not actually specify where sealing threads or fastening threads should be used. Nor does it state that "internal sealing threads shall be Rp series" or show them on any drawings. It is implied however as AS 3688 does specify “sealing pipe threads shall comply with the relevant requirements of AS ISO 7.1”, which only refer to Rp and Rc as the internal thread options and not Series G which relates to AS 1722.2.

2.10 Rock Traps

Where flow in pipelines is likely to contain solids that could damage pipework components it shall be fitted with a rock trap e.g. Where applicable rock traps shall be fitted upstream of control valve complexes in order to trap debris (e.g. dislodged CML) and excessive sand.

The design should consist of enlarged pipe (to slow the flow) with screens, inspection facility and a flushing point. The flushing point should be designed scour out accumulated sand and small rocks without the need for pipe entry. Rock traps would need to be regularly opened for inspection.

Where applicable rock traps should also be placed upstream of new sections of pipe to protect against failure, which could be experienced where a section of poor CML allows small lumps of broken CML to tumble along the downstream main and eroded the CML, and steel along the bottom of the pipe.

Rock traps may need to be moved or duplicated when further stages extend the upstream end of the new pipe.

2.11 Welding

All welding shall be in accordance with the requirements WS-1.

2.12 Crimped Pipe and Fittings

2.12.1 General

Crimped pipe and fitting systems are proprietary pipe and fitting systems based on crimped O-ring seals as the primary joining method. They offer some advantages in terms of installation time and the avoidance of hot works during the installation process. Systems available in Australia include *Press-Fit*, *Vic-Press*, and *Tubepress* and *Viega Propress*.

The Water Corporation has investigated use of crimped piping systems (refer Report #9615461) and as a result catalogued and procured crimping equipment for the ***Viega Propress*** copper pipe crimping system. Crimping equipment is catalogued and copper fittings are stocked for ***Viega Propress*** in sizes from 20mm to 50mm.

Crimped pipe and fitting systems may be used for joining pipes and fittings smaller than DN150. Stainless steel 316L or copper press fit piping may be used for plant water and compressed air applications, where the pipe is accessible. The systems shall not be used for general conveyance piping (e.g. reticulation) or in buried or inaccessible locations. Consideration must be given to the advantages and limitations of crimped pipe systems as described in section 2.12.2 and 2.12.3.

Where crimped pipe and fitting systems are proposed they should be the subject of appropriate HAZOP, Constructability and Operability studies and explicitly accepted by the end user prior to incorporating in the design. A long term user commitment to the tooling and upskilling required is essential. Ancillary services in large pump stations and treatment plants are likely possible applications.

Different materials of O-rings are used for various applications and must be checked with the manufacturer to ensure fittings with the correct type of O-ring for the application is used.

2.12.2 Limitations

Crimped pipe and fitting systems are conducive to speedy and safe construction and avoid the need for hot works but have limitations in requiring proprietary tools and parts for both installation and on-going maintenance. They should only be used in above ground applications with accessibility for inspection and maintenance.

Press fit sizes DN125 and DN150 are limited to a working pressure of 1600kPa, and test pressure 2400kPa. These pressures can be achieved with regular pressing tools.

For sizes DN65 to DN100, working pressure up to 2500kPa is achievable. For pressures higher than 2400kPa, a special pressing tool is required.

2.12.3 Crimped pipe and fitting systems vs Welded pipe

The advantages and disadvantages of press fit systems vs welded metallic pipes are summarized in the table 2.2 below.

Table 2.2 – Crimped vs welded metal pipes

Advantages of Crimped system	Disadvantages of Crimped system
Avoids hot works Faster installation than welded pipe join Lower installation cost than welded piping The joints immediately reach their final mechanical stability i.e. no waiting for the joint to cool or adhesive to dry	Proprietary systems, not to any international standards Limited sizes available Proprietary tooling required for on-going maintenance and expansion Working pressure limited to 16bar for DN125-DN150 Working pressure limited to 25bar for DN65-DN100 Special tools required for higher pressures Risk of future supply continuance of the proprietary system The geometry of the fitting and compressed area can vary between manufacturers, may not be interchangeable Operator training required

NOTE: Information derived from The European Stainless Steel Development Association 'Euro Inox', Materials and Applications Series, Volume 19

3 SUMMARY OF PIPE TYPES

3.1 General Applications for Pipe Types

A general summary of pipe types (shown in alphabetical order) used by the Corporation and their related applications are shown in the following table for guide purposes. Details and requirements for each pipe type are covered in either Section 4 Metallic Pies or Section 5 Plastic Pipes as relevant.

Table 3.1 – Summary of Pipe Types and Applications

Material	Size Range DN	Typical Applications	Pressure or Flange Classification/Jointing/Comments
Acronitrile butadiene styrene (ABS)	DN 10 to 950[1]	Water and wastewater	PN 4.5 and PN 20[1]; Solvent welded, elastomeric ring seal and threaded joint
Carbon steel[2]	DN 15 to DN 300	Gas, oil and compressed air	Screwed BSP ≤ DN 50; Flanged ≥ DN 65.
Cast iron (CICL)	DN 80 to DN 1200 - (PN 14, 21); DN 80 to DN 600 - (PN 35)	Water and wastewater	Replaced by ductile iron; Subject to external graphitic corrosion and associated catastrophic longitudinal cracking in corrosive buried service conditions
Copper	DN 6 – DN 600	Hot and cold water; Gas; and Compressed air	PN 14, flanges to AS/NZS 4087 - (DN15 – 150); Table F and H to AS 2129 (derating applies); Brazed joints; Mechanical compression joints; Flanged joints.
Ductile iron[3] (DICL)	DN 300 to DN 750	Water and wastewater	PN 16 and 35 flanges to AS/NZS 4087; Elastomeric seal joint; Integral or screwed flange joint.
Galvanised mild steel (GMS)	DN 8 to DN 150	Non corrosive fluids; Protective conduits, Plant air (aeration)	Table E flanges to AS 2129; Screwed BSP ≤ DN 50; Flanged ≥ DN 65.
Glass reinforced plastic (GRP)	DN 50 to DN 4000[4]	Water, wastewater and drainage	Pressure - PN 6 to PN 32[4]; Non pressure – PN 1.0; Elastomeric seal ring joint.
Mild steel cement mortar lined (MSCL)	DN 100 to DN 1400	Water and wastewater	PN 14, 21, 35 flanges to AS/NZS 4087 or PN 25, and PN 50 flanges to EN 1092-1; Elastomeric seal ring joint; Various welded slip-in or butt joints; Welded flanged joints.
Polybutylene (PB)	DN 15 to DN 28	Hot water	PN 12; Mechanical compression joint.
Polyethylene (PE 100)	DN 100 to DN 800 (UP to DN800 flanges covered by DS38-02)	Water, wastewater; Treatment processes; and Compressed air	PN 12.5 and PN 16; Mechanical joint; or Butt-fusion joint; or Electro-fusion joint.
Polyvinyl chloride –	DN 100 to DN 575 – Series 1 solvent weld jointed	Water and wastewater	PN 6 to PN 18; Solvent welded joints and fittings

modified (PVC-M)	DN 100 to DN 600 – Series 2 rubber ring jointed	Water and wastewater	PN 6 to PN 16; Elastomeric seal ring joint.
Polyvinyl chloride – oriented (PVC-O)	DN 63 – DN 630 DN 100 - 750	Water and wastewater	PN 6.3 to PN 25
Polyvinyl chloride – unplasticised (PVC-U)	DN 10 to 575 – Series 1 solvent weld jointed	Water and waste water treatment fluids	PN 4.5 to PN 18; Solvent welded joints and fittings with screwed and flanged connections.
	DN 100 to 600 – Series 2 rubber ring jointed	Water and wastewater	PN 6 to PN 20; Elastomeric seal ring joint.
Stainless steel	DN 10 to 1500	Water and wastewater Process and special pipework, Compressed air	PN 16, 21, 35 flanges to AS/NZS 4087; Butt joint or socket welded; or Flanged; or Screwed.

NOTES:

1. Sizes and pressure classification ranges as shown in AS/NZS 3518 Tables 3.3 (A), (B), (C) however proprietary sizes and pressures available may not provide this coverage e.g. DN 15 to DN 300 and PN 6 to PN 10 maximum.
2. Carbon steel is not preferred by the Corporation for compressed air.
3. Ductile iron is more expensive than MSCL and therefore is not used by the Corporation.
4. Sizes and pressure classification ranges as shown in AS 3571.1 and AS 3571.2 however proprietary sizes and pressures available may not provide this coverage e.g. DN 150 to DN 2900 maximum.

4 METALLIC PIPES

4.1 Carbon Steel Pipe and Fittings

4.1.1 General

Carbon steel is a common pipe material used in process pipework for pressure applications in compatible fluids and environments. It is available in low, medium and high carbon content grades. Pipework is generally made from low carbon steel grades. Low carbon steel is more ductile and therefore easier to work than medium and high carbon steels however this is at the expense of hardness and tensile strength. Medium and high carbon steels have progressively higher tensile strengths and hardness than low carbon steels as a result of heat treatment.

Carbon steel is not preferred by the Corporation for compressed air.

4.1.2 Corrosion Resistance

Plain carbon steel pipe in slightly corrosive environments such as water service applications suffers from internal corrosion. Accordingly it should not be used for this type of service or any service with corrosion potential either internally or externally without appropriate barrier coatings.

4.1.3 Jointing

Carbon steel pipe and fittings should be seamless or electric resistance welded (ERW) with threaded joints in small sizes with weld neck or slip-on flanges for larger sizes as shown in the following tables.

Table 4.1 Carbon Steel Pipe Construction Details

Size	Wall Thickness	Construction	Ends
DN 15 – DN 100	Light	Seamless or ERW	≤ DN 50 – Threaded; ≥ DN 65 – Table E flanges to AS 2129.
DN 15 – DN 150	Medium		

4.1.4 Reference Standards

Carbon steel pipes and fittings shall comply with manufacturing, testing and inspection requirements as set out in the following table.

Table 4.2 – Carbon Steel Reference Standards

Item	Material/Designation	Standard
Carbon Steel Pipe	Materials, design, fabrication, testing and inspection	AS 4041
	Dimensions	AS 1074
Carbon Steel Fittings – Threaded, weld neck or slip-on	Thread	AS ISO 7.1
	Properties	AS 1448
Carbon Steel Flanges - Forged carbon steel	Properties	AS 1448
	Dimensions	AS 2129 Table E

4.2 Copper Pipes and Fittings

4.2.1 General

Copper pipe has good corrosion resistance in water but is relatively expensive compared with plastic alternatives. However compared with equivalent plastic pipe and fittings, copper:

- Has superior mechanical strength,
- Is not subject to UV degradation,
- Is not susceptible to hydrocarbon (insecticide solvents) or other toxic contamination in buried service.

4.2.2 Copper Pipe Types

Only Type A and Type B copper pipes shall be used for pressure applications.

4.2.2.1 Type A Copper Pipe

Type A copper pipe is thick wall and should be used for sanitary applications where gas attack may be prevalent; or water applications for buried service conditions where corrosive soil, or unstable ground conditions are likely e.g. under roadways, or to meet minimum pressure requirements for a particular pipe diameter (refer example below).

4.2.2.2 Type B Copper Pipe

Type B copper pipe is suitable for general waterworks applications in above and below ground applications.

4.2.2.3 Pressure Ratings

Pressure ratings for copper pipe is both size and temperature dependent and selection for pressure applications should be in accordance with Appendix B of AS 1432 e.g.:

For PN 14 (1400 kPa) cold water applications for temperatures ≤50ºC, copper tube selection would be limited to ≤ DN 100 for Type A and ≤ DN 80 for Type B.

4.2.3 Corrosion Resistance

Copper pipe can be subject to premature failure from pitting corrosion if contaminants such as sand are allowed to settle inside the bore, or use of excessive brazing flux, which may collect inside the pipe. Further information regarding copper pipe corrosion is contained in AS 4809.

Copper pipe is subject to corrosion fatigue and the effects of erosion-corrosion and the Designer shall ensure that pipework application shall be designed to avoid these conditions. For further information regarding corrosion-fatigue and erosion-corrosion refer to the relevant parts of the Corrosion section of DS 32-02. Copper alloy materials are subject to corrosion in several applications where H_2S gas is present and accordingly their use shall be avoided in these conditions.

4.2.4 Jointing

Joints shall only be used when necessary and shall be slipped silver brazing in accordance with the manufacturer's recommendations. The use of 'soft solders' to AS 1834.1 is generally not permissible on Corporation water services. Capillary joints with soft solder shall only be used in inaccessible locations. Brazing alloy used for copper/copper alloy capillary jointing shall comply with the silver brazing alloys referred to in DS 30-02 Materials in the section Silver Brazing.

Mechanical compression and flanged joints shall not be used in buried or concealed locations.

Fittings shall be 70/30 copper-zinc alloy brass. At pipe outlets, a male and female brass nipple should be brazed onto the main pipe with appropriate BSP thread to accommodate bibcock, stopcock, valves and fittings.

Pipe connections to fixtures shall be made by means of screwed connections and gunmetal unions. Hose cocks and risers shall be firmly fixed to walls or other supports.

4.2.5 Reference Standards

Copper pipes and fittings shall comply with manufacturing, testing and inspection requirements as set out in the following table.

Table 4.3 – Copper Pipe Reference Standards

Item	Material/Designation	Standard
Copper Pipe	Design, manufacture, testing and inspection:	AS 4041 AS 1432
Fittings	Capillary type; or Compression cone type	AS 3688
Solder	Silver solder	AS/NZS ISO 17672
Copper pipe and fittings	Installation and commissioning	AS 4809

4.3 DICL Pipe and Fittings

4.3.1 General

Ductile iron has a spheroidal graphite structure produced by the introduction of magnesium and heat treatment which provides good tensile characteristics, which are almost equivalent to steel. DI cement mortar lined pipe and fittings are used for above-ground and buried service in water supply and wastewater applications. However DICL pipe is not preferred for Corporation applications because the external coating does not provide corrosion protection and the external polyethylene (PE) sleeve is considered vulnerable to damage. DICL pipe is generally not cost effective compared with MSCL. Further information relating to DI pipe is available in DS 60.

4.3.2 Design Factors

For information relating to the performance of cement mortar lining Designers should refer to ‘Cement Mortar Lining (CML)’ in the Design Criteria section of this Standard.

Cavitation effects for high velocities should be checked for susceptible configurations such as direction changes or local sharp re-entrant pipework vertices.

4.3.3 Corrosion Resistance

DICL pipe is relatively resistant to corrosion however it can be subject to external electrolytic and graphitic corrosion in aggressive soil conditions. DI suffers graphitic corrosion at a similar rate to cast iron however it tends to manifest itself in saucer shaped depressions which may form holes and leak but doesn’t lead to catastrophic longitudinal cracking as for grey cast iron.

Above ground installations shall be coated in accordance with Coating Specification B1. If top colour coat is required then Coating Specification C2 shall be followed. For more information on coating requirements refer to DS 95.

DICL pipe for buried service is provided with an internal cement mortar lining and an external cold applied bituminous paint (designed to provide only minimal short-term corrosion protection). DI pipe for buried service requires external protection via a PE sleeve fitted during installation.

Correct installation of buried service DICL pipe is important to provide an integral corrosion-resistant system and accordingly should only be carried out by persons appropriately qualified and holding either a Statement of Attainment (for competency based training) or Recognized Prior Learning (RPL) certification. The PE sleeve however still presents a potential source of corrosion of the pipe if not fitted correctly or is damaged during installation where corrosive ground conditions exist.

DICL fittings for buried service shall be either coated internally and externally with a:

(a) cement mortar lining and bituminous coatings respectively, or

(b) polymeric coating to AS/NZS 4158.

4.3.4 Jointing

DICL pipe is available with flanged or socketed joints, the former being used for above ground installations and below ground for connection to valves. DICL may be joined via a Gibault® joint for cut-ins or terminations.

Socketed joints are used for below ground use. Where flanged fittings are used on socketed pipelines, thrust blocks shall be used for flanged tees, bends or blank ends if there is insufficient anchoring length of the flanged pipe in the ground to prevent separation of the socketed/flanged pipe transition joint. Flanges shall be primed and wrapped with System A as described in Coating Specification L1.

DICL pipe and fittings are compatible with Series 2 PVC-U pipe complying with AS/NZS 1477.

4.3.5 Reference Standards

DICL pipe and fittings shall comply with the following table.

Table 4.4 Reference Standards for DI Pipe and Fittings

Item	Material/Designation	Standard
Pipe and CML	Design, manufacture, testing and inspection	AS 4041
	Ductile iron/Class K9	AS/NZS 2280
Fittings (polymeric coated)	Ductile iron	AS/NZS 2280
	Fusion bonded epoxy	AS/NZS 4158
Joint rings	EPDM, NBR	AS 1646
Pipe sleeving	Polyethylene	AS 3680

4.4 GMS Pipe

4.4.1 General

Galvanised mild steel pipe and fittings (also referred to as tube) are used for general purposes in applications involving non-corrosive fluids or gases in sizes from DN 8 to DN 150, with screwed or flanged connections. GMS pipe has good mechanical strength.

4.4.2 Corrosion Resistance

GMS pipe shall not be used for drinking water applications because of its low corrosion resistance in this type of service, particularly with respect to screwed connections.

GMS pipe shall not be used for compressed air lines due to its susceptibility to corrosion from moisture-laden air and condensate.

4.4.3 Reference Standards

GMS pipe and fittings shall comply with the following table.

Table 4.5 – Reference Standards for GMS Pipe

Item	Material/Designation	Standard
Pipe and fittings	Manufacture, testing and inspection	AS 4041, AS 1074
	Hot dip galvanising	AS/NZS 4792

4.5 MSCL Pipe and MSCL Pipe Specials

4.5.1 General

MSCL pipe and fittings provide low to high pressure above or below ground service with welded or flanged joints.

This Section is mainly devoted to MSCL pipe specials that are used in mechanical works and further information relating to MSCL pipe and fittings is available in DS 60 and SPS 100.

4.5.2 Corrosion Resistance

4.5.2.1 DICL Pipe

Steel pipe has poor corrosion resistance unless it is lined internally, and coated, or wrapped externally and provided with cathodic protection when used in contact with corrosive soils.

MSCL pipe specials shall be provided with the following corrosion protection:

(a) A cement mortar lining (CML) internally with an inorganic zinc silicate external coating for above ground service, or

(b) A CML internally with a fusion bonded medium density polyethylene external coating, for above and below ground service i.e. for large pipe specials such as manifolds etc.

4.5.2.2 Coating of Pipe Specials

After welding and machining, pipe specials flanges shall be given a protective coating of silicone based water repellent.

External coating of pipe specials shall be in accordance with the ‘Painted Above Ground’ and ‘Painted Below Ground’ clauses in this section as required, except that pipe external surfaces under flexible joining couplings shall be epoxy coated in accordance with Coating Specification M4. For more information on coating requirements refer to DS 95.

4.5.2.3 Lining Restoration

Lining restoration shall comply with the Coating Specification M8.

4.5.2.4 Painted Above Ground Coating

The extent of coating damage shall be assessed for the above-ground pipework as outlined in Criteria for Assessment and Repair section in DS 95. If the coating damage is extensive i.e. if the rust percentage is 50% and greater, it may be more cost effective to completely recoat the structure.

Pipe specials and portions of pipe specials exposed to the atmosphere shall be cleaned and coated in accordance with Surface Preparation A1 and Coating Specification B1, if no coloured top coat is required. If a coloured top coat is required then Coating Specification C2 shall be followed.

If the coating damage is very minor, that is if the rust percentage is up to 20% (Refer: Measles Chart in DS 95), then mechanical wire brush or power tool cleaning is sufficient to clean the surface area. This is followed by the application of Coating Specification E1.

4.5.2.5 Wrapping Buried Pipe Specials

Buried pipe specials shall be wrapped with a petrolatum 4-step system in accordance with System B of Coating Specification L1.

4.5.3 CML Interference

Pipework specials with cement mortar lining adjacent to butterfly valves or non-return valves shall not interfere with the operation of the valve disc or flap.

4.5.4 Jointing

MSCL pipes and specials shall comply with the following table:

Table 4.6 – Joint Types for MSCL Applications

Pipe Size	Joint Type	Application
DN 100 to DN 250	Flanged; or Slip-in welded; or Plain end with welding bands.	Above and below ground for pump stations, and valve and flowmeter pipework as appropriate
DN 300 and larger	Flanged; or Rubber ring (RRJ)	

4.5.5 Reference Standards

Where relevant (depending on below or above ground service) MSCL pipes and fittings shall be manufactured in accordance with the following table.

Table 4.7 – MSCL Pipe and Specials Reference Standards

Item	Material/Designation	Standard
MSCL Pipe	Manufacture, testing and inspection; Cement mortar lining; Fusion bonded medium density polyethylene coating	Refer Note 1, SPS 100
MSCL Pipe Specials	Fabrication (in accordance with, pipework Class 2P); Cement mortar lining; Dimensions – for standard fittings	Refer Note 1, CML shall be in accordance with SPS 100
	Welding	Welding section of DS 30-02
Pipe specials external coating - above ground (Note 2)	Inorganic zinc silicate (IZS) (minimum dry film thickness of 80 microns)	AS/NZS 3750.15, Coating Specification: B1 or C2 – Refer Note 3
Pipe specials external coating - below ground	Where MSCL fusion bonded medium density PE coating pipe is used (e.g. manifolds)	Refer Note 4
MSCL Joints	Fabrication and coating	Refer Note 5
	Flanges	Refer Note 6

NOTES:

1. Refer DS 60 and DS 63 for pipeline standards and design.
2. Fusion bonded medium density PE coated pipe specials may be used for above ground service e.g. manifolds etc.
3. Coating Specification C2 should be used where a decorative coating is required
4. Restoration shall comply with 'Lining Restoration' clause in this section
5. MSCL joints shall comply with the 'Fabrication and Coating' clause in this section
6. Flanges shall comply with DS 38-02

4.6 Stainless Steel Pipe and Fittings

4.6.1 General

Stainless steel pipe combines corrosion resistance and high mechanical strength. It is used for transportation of corrosive fluids and gases, and for structural purposes in moist or, corrosive environments. Stainless steel pipe is relatively expensive.

In Corporation applications stainless steel pipe is normally restricted to water and wastewater, and treatment processes.

4.6.2 Corrosion Resistance

4.6.2.1 Use in Drinking and Non-potable Water

Stagnant conditions should be avoided when using stainless steel for transporting drinking water as they promote deposition of sediments and growth of bacterial slimes both of which can increase the risk of corrosion via crevice and microbial corrosion respectively.

Minimum velocity for clean water is 0.5 m/s (and up to a maximum of 30 m/s) and for raw water a minimum velocity of 1 m/s is preferred to provide transport of sediments.

High velocity and associated turbulence are actually beneficial in maintaining the corrosion resistant performance of stainless steel.

Crevice or pitting corrosion of grade 316 stainless steel is likely to occur when chloride levels exceed 1000 mg/L for the pH range of 6.5 to 8, particularly for flow velocities less than 0.6 m/s.

If other factors such as crevices and oxidising agents are present a more conservative value of 250 mg/L would be more appropriate. Aeration of water increases the likelihood of crevice corrosion so that totally de-aerated water generally causes the stainless steel to be resistant to corrosion.

4.6.2.2 Use in Seawater

Grade 316 stainless steel in seawater may be subject to crevice or pitting corrosion as mentioned above for high chloride water where flow velocity is less than 0.6 m/s. For information on seawater service the Designer should refer to the section on Materials for Seawater Service in DS 30-02.

4.6.3 Rating and Construction

(a) Most Corporation pressure containment applications would be covered by use of Schedule 40S stainless steel piping for temperatures ≤ 100 ºC (refer Note). Designers shall take into account any additional external stresses the pipe may be exposed to in addition to the AOP when selecting the appropriate wall thickness.

(b) Pipes and fittings used for water conveyance shall have a PREN ≥22.

(c) Stainless steel pipework and fittings shall be manufactured in accordance with the Stainless Steel Pipe and Fittings Reference Standards table below. Low carbon grades shall be used for applications where welding is required. Fittings are available in sizes from DN 6 to DN 100.

(d) Spiral welded tube may be used for sizes greater than 75 mm and all spiral welds shall be manufactured from the TIG process and fully passivated. Spiral welded stainless steel tube shall not be used for pump station manifolds or offtakes because of restraining difficulties with this relatively thin-walled and therefore flexible pipe system.

(e) Pipe supports shall be stainless steel for exposed environments subject to moisture. In dry environments hot-dip galvanised mild steel supports may be used.

(f) Insulation of joints shall be provided where galvanic corrosion of dissimilar metals such as mild steel or cast iron would otherwise be likely.

(g) Designers should comply with the sections on Corrosion and Materials contained in DS 30-02 for general information relating to corrosion and pickling and passivation of stainless steel products.

(h) Welding shall comply with WS-1.

NOTE: Whilst Schedule 10S stainless steel pipe may be rated for the pressures and temperatures it should not be used where it may be subject to distortion during fabrication.

4.6.4 Reference Standards

Stainless steel pipework and fittings should comply with the following table.

Table 4.8 – Stainless Steel Pipe and Fittings Reference Standards

Item	End Connection	Material	Standards	Grades
Pipe	Screwed or socket welded	Design	AS 4041	-
		Dimensions	ASME B36.19	-
		Properties	ASTM A312M	304, 316
		Properties	ASTM B729	UNS N08020
Fittings – Low Pressure	Screwed: Male – BSPT – R Series; Female – BSPP – RP Series	Casting	ASTM A351M	316
		Bar	ASTM A276M	-
		Pipe (nipples)	ASTM A312M	-
Fittings – High Pressure	Screwed – NPT	Wrought Forged	ASTM A403M ASTM A182M	316

5 PLASTIC PIPE

5.1 ABS Pipe and Fittings

5.1.1 General

ABS pipe like PVC-U is used in pressure applications. It has better mechanical strength than PVC-U but has lower chemical resistance. It is available in a range of pressure classes which may vary with increase in pipe diameter. ABS pipe and fittings colour is normally grey.

Solvent welded ABS pipe is available in a wide range of grades and hardness but essentially is only used as an alternative to PVC-U pipe where greater resistance to change in mechanical properties is required.

The minimum pressure classification of ABS pipe used on Corporation assets for pressure applications should be PN 10.

5.1.2 Corrosion Resistance

ABS is corrosion resistant.

5.1.3 Chemical Resistance and Pipe Class

ABS is capable of handling a wide range of chemicals including moderately strong mineral acids and also caustic solutions. For specific chemicals the designer should refer to the manufacturer's chemical resistance charts.

5.1.4 UV Resistance

Currently ABS pipe is imported and is only available from one supplier in Australia who claims it to be resistant to ultra violet degradation however these claims have yet to be substantiated. Until they are ABS pipework exposed to direct sunlight shall painted and stored in accordance with 'UV Embrittlement' in the PVC-U section of this Standard.

5.1.5 Pressure and Temperature Relationships

ABS pipe and fittings have a progressively reduced pressure capability with increasing fluid temperature above 20 ºC. Accordingly a thermal derating factor shall be applied to the maximum allowable operating pressure for ABS pipe and fittings where fluid temperatures exceed 20 ºC in accordance with the manufacturer's recommendations.

5.1.6 Structural Integrity

Refer to the Structural Integrity clause for PVC-U pipe of this Standard for factors that should be considered.

5.1.7 Cyclic Loading

The Corporation has encountered premature failure of ABS pipe and fittings due to the effect of stress regression or cyclic loading. Fatigue failures have occurred at both ends of the spectrum in terms of number of cycles and magnitude of stress or pressure fluctuation. Accordingly fatigue failures have occurred at a large number of cycles versus small pressure fluctuations as well as for a small number of cycles versus large pressure fluctuations. At this stage there is no design information relating ABS pipe fatigue failure to number of cycles versus stress amplitude.

Designers should:

(a) Avoid the use of ABS pipe and fittings when designing systems which have cyclic loading such as multiple pump starts and stops and multiple valve openings and closures.

(b) Consider a check on fatigue life at the design stage where cyclic loads are anticipated, based on PVC-U pipe as detailed in WSA 03.

5.1.8 Jointing

5.1.8.1 Solvent Weld

ABS pipe and fittings are primarily designed for solvent cement welded joints. However other jointing systems, which utilise 'O' rings, or flanges and threaded jointing, are also used.

5.1.8.2 Flanges

The use of flanged jointing for brittle material such as ABS, PVC-M, PVC-O, and PVC-U is not preferred by the Corporation. In the event that ABS flanges are used their mating faces shall be flat faced utilising a full face gasket (refer Note). In addition the flanges shall be fitted with galvanized mild steel or stainless steel backing flanges with pre-drilled holes conforming with AS/NZS 4087.

NOTE: Flat face flanges are required in order that bolting couples are not produced as would otherwise occur if raised flanges faces or narrow face gaskets were used, as rotation during tightening may cause cracking.

5.1.9 Reference Standards

ABS pipes and fittings shall comply with manufacturing, testing and inspection requirements as set out in the following table.

Table 5.1 – ABS Pipe and Fittings Reference Standards

Item	Material/Designation	Standard
ABS Pipe and fittings	Compounds	AS/NZS 3518
Jointing	Solvent cement and priming fluids	AS 3879
Installation	Pipe systems	AS/NZS 3690

5.2 GRP Pipe

5.2.1 General

GRP pipe is centrifugally cast from fiberglass reinforced plastic utilizing unsaturated polyester resin. The pipe is strong, light and is used in water supply, wastewater and drainage applications, for pressure and non-pressure service.

The Corporation generally requires external diameter series e.g. in accordance with Appendix ZZ of AS 3571.1 and AS 3571.2.

Design of GRP pipework shall comply with the manufacturer's requirements.

5.2.2 Corrosion Resistance

GRP is inherently corrosion resistant and UV resistant.

5.2.3 UV Resistance

GRP is inherently UV resistant.

5.2.4 Jointing

GRP pipe joints are elastomeric ring style.

5.2.5 Reference Standards

GRP pipes shall comply with the materials, dimensions and mechanical and physical requirements contained in AS 3571.1 for wastewater and drainage applications and AS 3571.2 for water supply.

5.3 PB Pipe and Fittings

5.3.1 General

Polybutylene pipe is used widely in domestic plumbing and recycled water applications. PB pipe is suitable for both cold and hot water services particularly for long pipeline runs in indirect sunlight applications. PB pipe is available in a pressure class of PN 16, applicable for a temperature of 20 ºC and for outside diameters from DN 15 to DN 28.

5.3.2 Practices to Avoid

PB pipe shall not be used for:

(a) Drinking water in contaminated ground or where hydrocarbons are potentially present as tainting of the water could occur,

(b) Use in direct sunlight unless sleeved,

(c) Solvent welding.

5.3.3 Corrosion Resistance

PB pipe is corrosion resistant.

5.3.4 Chemical Resistance

PB pipe is resistant to most acids and alkalis and some solvents. The designer should consult the manufacturer for performance of PB pipe and fittings for particular chemicals and temperatures.

5.3.5 UV Resistance

PB pipe is not UV resistant.

5.3.6 Pressure and Temperature Relationship

PB pipe and fittings have a progressively reduced pressure capability with increasing fluid temperature above 20 ºC. Accordingly a thermal derating factor shall be applied to the maximum allowable operating pressure for PB pipe and fittings where fluid temperatures exceed 20 ºC in accordance with the manufacturer's recommendations.

5.3.7 Jointing

PB pipe jointing system utilizes mechanical jointing fittings.

5.3.8 Reference Standards

PB pipe and mechanical fittings design, manufacture, testing and inspection shall comply with AS 4041 and AS/NZS 2642.

Table 5.2 – PB Pipe and Fittings Reference Standards

Item	Material/Designation	Standard
Pipe	Design, manufacturing, testing and inspection	AS 4041 AS/NZS 2642.1
	Hot and cold water applications	AS/NZS 2642.2
Jointing fittings	Mechanical jointing fittings	AS/NZS 2642.3

5.4 PE Pipe and Fittings

5.4.1 General

Polyethylene pipe is suitable for general purpose applications and characteristically is relatively flexible, exhibits high impact strength and abrasion resistance and is non-toxic. However it is subject to a high coefficient of thermal expansion and may impart tainting of drinking water in the presence of hydrocarbon based products which may leach through the pipe wall.

This section of the Standard relates to Series 1 pipe for general purposes in accordance with AS/NZS 4130 which is designed for use in conveyance of fluids under pressure e.g. water, wastewater and air. Series 2 and Series 3 types relate to gas conveyance pipes which are not relevant to this Standard.

PE pipe is available in two compound classifications e.g. PE 80B and PE 100. The PE 100 pipe compound has a higher 50 year design strength (10 MPa) than PE 80B material (8 MPa) and therefore requires a thinner wall thickness to achieve the same performance (refer Note).

AS/NZS 4130 covers PE pipe pressure classes up to PN 25 and diameters up to DN 2000 for Series 1 pipes.

NOTE: The Corporation specifies PE 100 pipe and fittings for pressure applications essentially because of availability of product, which is market driven matter rather than any concerns with the PE 80B pipe.

PE pipe and fittings shall comply with the requirements contained in SPS 125.

Note that PE pipe is flammable, which may be a consideration in some outdoor aboveground installations in close proximity to combustible material (e.g. grass fires, bush fires).

5.4.2 Corrosion Resistance

PE pipe is corrosion resistant.

5.4.3 Chemical Resistance

PE pipe is resistant to a wide range of chemicals such as non-oxidising strong acids, strong bases and salts. It is affected by some solvents and is attacked by strong oxidizing chemicals. The designer should consult the pipe manufacturer for performance of PE pipe and fittings for particular chemicals and temperatures.

5.4.4 UV Resistance

PE pipe stabilized against UV degradation (containing carbon black) is suitable for use in direct sunlight.

5.4.5 Pressure and Temperature Relationship

PE pipe and fittings have a progressively reduced pressure capability with increasing fluid temperature above 20 ºC. Accordingly a thermal derating factor shall be applied to the maximum allowable operating

pressure for PE pipe and fittings where fluid temperatures exceed 20 ºC in accordance with the manufacturer's recommendations.

5.4.6 Cyclic Loading

PE pipe has comparatively good cyclic loading capability. Calculations shall be made where pressure fluctuations occur.

5.4.7 PE Pipe Selection Considerations

PE pipework for pressure applications shall be selected in accordance with the requirements of SPS125 and DS60 with flanged connections to DS38-02. The designer shall consider the merits and drawbacks of PE pipework, compared against alternate materials, prior to recommending its use. The following considerations, together with others relevant to the location and application, shall be made:

- Cost
- Performance, including fatigue and temperature de-rating at service temperature
- Corrosion resistance
- Pipe restraint / support
- Availability of suitably rated pressure pipe and fittings
- Impact of transients
- Risk and consequence of failure
- Reparability: - the availability, cost, practicality, timeliness and adequacy of repair capabilities for the proposed location
- Regional preference

5.4.8 Jointing

PE pipe joints shall be of either the mechanical compression or electro-fusion types.

5.4.9 Reference Standards

Design, manufacture, testing and installation shall comply with the following table.

Table 5.3 – PE Pipe Reference Standards

Item	Material/Designation	Standard
PE Pipe	Manufacture, testing and inspection, PE compound properties	AS/NZS 4130 AS/NZS 4131
PE/PP Pipe fittings	Mechanical Joints and fittings; Electro-fusion fittings.	AS/NZS 4129
PE/PP Pipeline construction	Above and below ground, pressure and non-pressure	AS/NZS 2033 AS/NZS 2566

5.5 PVC-M Pipe and Fittings

5.5.1 General

Modified PVC (PVC-M) is corrosion free, rigid and non-heat weldable and is suitable for general-purpose usage e.g. inside, outside and buried service. PVC-M is a high strength PVC material, which has superior qualities over unplasticized PVC (PVC-U) with respect to higher impact resistance and

ductility, and increased hydraulic capacity (because of reduced wall thickness and therefore larger internal diameter). PVC-M pipe is designed to be compatible with existing AS/NZS 1477 systems.

Special conditions apply to the use of pressures less than PN 12 for vacuum applications and some soil conditions and accordingly the manufacturer's recommendations should be followed in these instances. The thinner wall section of PVC-M (and PVC-O) may cause problems with higher rates of longitudinal expansion compared with PVC-U in terms of support and use of correct tapping bands e.g. full circle type.

PVC-M pressure pipe used for buried service water and wastewater applications shall comply with the requirements contained in SPS 116.

5.5.2 Corrosion Resistance

PVC-M is corrosion resistant.

5.5.3 Chemical Resistance

PVC-M is equivalent to PVC-U in most instances but its use for long-term contact with some concentrated chemicals or at higher temperatures should be avoided without consultation with the manufacturer and approval of the Corporation.

5.5.4 UV Resistance

PVC-M is subject to UV degradation so that similar requirements apply as for PVC-U when exposed to sunlight. For further information refer to UV Degradation in the PVC-U section of this Standard.

5.5.5 Pressure and Temperature Relationships

PVC-M (including PVC-O and PVC-U) pipe and fittings have a progressively reduced pressure capability with increasing fluid temperature above 20 ºC. Accordingly a thermal derating factor shall be applied to the maximum allowable operating pressure for PVC-M pipe and fittings where fluid temperatures exceed 20 ºC in accordance with the manufacturer's recommendations.

5.5.6 Cyclic Loading

The Corporation has encountered premature failure of PVC-U pipes, valves and fittings due to the effect of stress regression or cyclic loading. Failures have occurred at both ends of the spectrum in terms of number of cycles and magnitude of stress or pressure fluctuation. Accordingly failures have occurred at a large number of cycles versus small pressure fluctuations as well as for a small number of cycles versus large pressure fluctuations.

Designers should avoid the use of PVC-M pipe when designing systems which have high cyclic loading such as multiple pump starts and stops and multiple valve openings and closures.

Cyclic loading will have an effect on safety factor and should be allowed for in the design. Designers should ensure pipe selection takes account of cyclic fatigue and any temperature de-rating and establish fatigue de-rating of the pipe based upon a 100 year cyclic loading.

For further information on cyclic loading factors refer to Cyclic Loading in the PVC-U section of this Standard.

5.5.7 Jointing

5.5.7.1 Solvent Weld and Elastomeric Rings

PVC-M pressure pipes are available in nominal 6.0 m lengths with jointing systems as follows:

(a) Series 1: Metric pipe series in nominal sizes DN 100 to DN 575 for pressures PN 6 to PN 18 for solvent cement joining. Solvent cement fittings are available in all diameters up to DN 150.

(b) Series 2: Ductile iron outside diameter (CIOD) series in nominal sizes DN 100 to DN 600 for pressures PN 6 to PN 16. Pipe is supplied with spigot and socket ends for elastomeric ring jointing.

Pipe is compatible with AS/NZS 1477 Series 2 dimension socketed (rubber ring) fittings for ductile iron, in diameters DN 100 upwards.

5.5.7.2 Flanges

PVC-M pipe and fittings are primarily designed for solvent cement welded or elastomeric ring joint systems in accordance with the above. However flanged and threaded jointing systems are also used for Series 1 PVC-M pipes to accommodate some appurtenances.

The use of flanges for brittle material such as PVC-M, and PVC-U is not preferred by the Corporation. In the event that it is unavoidable PVC-M flange mating faces shall be flat-faced utilising a full face gasket (refer Note). In addition the flanges shall be fitted with galvanized mild steel or stainless steel backing flanges with pre-drilled holes conforming with AS/NZS 4087.

NOTE: Flat face flanges are required in order that bolting couples are not produced as would otherwise occur if raised flanges faces or narrow face gaskets were used, as rotation during tightening may cause cracking.

5.5.8 Reference Standards

PVC-M pipe reference standards are referred to in the following table.

Table 5.4 - PVC-M Pipe Reference Standards

Item	Material/Designation	Standard
PVC-M Pipe – Series 1 for above and below ground service	Manufacturing, materials, testing and inspection	AS 4041, AS/NZS 4765
	Solvent welded joints and solvent welded cements	AS 3879
PVC-M Pipe – Series 2 for below ground service	Manufacture, testing and inspection; Joint rings.	Refer to DS 63 for sizes $\leq$ DN 250; Refer to DS 60 – Pipelines for sizes $\geq$ DN 300.
	Pipelaying design	AS/NZS 2566
Pipeline construction	Pressure pipelines	AS/NZS 2032, AS/NZS 2566

5.6 PVC-O Pipe

5.6.1 General

Oriented PVC pipe is corrosion free, rigid and non-heat weldable and is an approved product for wastewater pressure applications. It may be suitable for general-purpose pressure applications (e.g. inside, outside and buried service) or where constructability aspects warrant the use of rubber ring pipe (e.g. when multiple services must be crossed). PVC-O is a high strength PVC material, which has superior qualities over PVC-U. The molecules in PVC-O have been specifically oriented during manufacture by longitudinal and circumferential expansion, which has the effect of increased yield strength allowing higher operating pressures and mitigation against radial crack propagation. As a result the wall thicknesses are thinner than equivalent rated PVC-U pipes. Temperature derating, chemical resistance, cyclic loading and UV embrittlement factors also apply to PVC-O pipe although it has a higher cyclic loading tolerance than PVC-U and PVC-M.

5.6.2 Chemical Resistance

PVC-O pipe is less resistant to chemicals than PVC-M and therefore shall not be used in chemical environments or for chemical process pipework.

5.6.3 Cyclic Loading

PVC-O is susceptible to cyclic loading. For further information on cyclic loading refer to Cyclic Loading in the PVC-U section of this Standard.

5.6.4 Jointing

PVC-O pipe is not suitable for solvent welding and is only available in rubber ring jointing.

5.6.5 Referenced Standards

PVC-O pipe is referenced in AS/NZS 4441 and shall comply with the requirements of SPS 117.

5.7 PVC-U Pipe and Fittings

5.7.1 General

Unplasticised PVC (PVC-U) pipe and fittings are corrosion free, rigid and non-heat weldable and are suitable for general-purpose usage e.g. inside, outside and for buried service.

PVC-U pressure pipe used for buried service water and wastewater applications shall comply with the requirements contained in SPS 115.

For water and wastewater applications using PVC-U pipework, PN18 pipe is acceptable.

For all chemical treatment and sampling applications, Schedule 80 system of PVC-U shall be adopted as a standard piping system. This must include the use of the entire system, including pipe and fittings, and manufacturer recommended primer and gap filling cement compatible with the service the piping is used in. Selection of pipe system, primer and solvent cement shall also conform to the following sub-sections.

5.7.1.1 Chemical Service PVC-U Pipe

Where rigid PVC-U pipe is specified for chemical service then the pipe and fittings shall be Schedule 80 PVC to ASTM D1784. The designer shall determine and specify the maximum design pressure and temperature for each section of pipe in the proposed works and shall confirm the suitability of the pipe, fittings and specified jointing system for use at the design conditions; noting that each of these system components have maximum allowable operating pressure that vary depending on line diameter, chemical service, chemical concentration, temperature, and other factors. Designers shall refer to the piping system manufacturer design guides and DS 78.

5.7.1.2 Chemical Service PVC-U Pipe Cleaner and Solvent Cement

Tangit Cleaner and Tangit DTX solvent cement shall be used in all instances for the chemicals listed in Table 5.5.

Table 5.5 – Critical Chemical Service

Medium	Concentration of %
Sulphuric acid	> 70% H_2SO_4
Hydrochloric acid	> 25% HCl
Nitric acid	> 20% HNO_3

Sodium hypochlorite (calcium hypochlorite)	> 6% NaOCl active chlorine
Hydrogen peroxide	> 5% H_2O_2
Hydrofluoric acid	Any HF concentration

5.7.1.3 Other Chemicals

For all other chemicals (i.e. not listed in Table 5.5), *Tangit cleaner* and *Tangit PVC-U* solvent cement are preferred. *Tangit All Pressure* is equivalent to Tangit PVC-U and is therefore also acceptable. Other PVC-U solvent cement systems may be accepted where recommended by the Schedule 80 PVC-U piping system manufacturer for the specific chemical service and at the design pressure and design temperature specified by the designer.

5.7.2 Practices to Avoid

PVC-U pipework shall not be used for:

(a) Compressed air because of likelihood of degradation due to heat and cyclic loading;

(b) Positive displacement dose or other pumps because of the high cyclic loading characteristics (refer Cyclic Loading below);

(c) Drinking water in contaminated ground or where hydrocarbons are potentially present as tainting of the water could occur

(d) Attachment directly to vibrating machinery as it could be subject to premature failure.

(e) Long term storage and installation in direct sunlight unless it has been covered or painted.

NOTE: PVC pipe notch sensitivity tests are conducted at 20 ºC as is the rated pressure. Higher temperatures degrade these performances e.g. pressure rating is reduced by 2% for every 1 ºC temperature rise above 20 ºC.

5.7.3 Corrosion Resistance

PVC-U is corrosion resistant.

5.7.4 Chemical Resistance

PVC-U pipe is resistant to a wide range of chemicals including strong acids and bases. It should not be used with most solvents and hydrocarbons. The designer should consult the pipe manufacturer for performance of PVC-U pipe and fittings for particular chemicals and fluid temperatures.

For chemical dosing and sampling applications, PVC-U pressure pipework used shall be Schedule 80, manufactured in accordance with ASTM D1785. A Schedule 80 piping system has greater wall thickness offering significant additional mechanical strength and higher pressure rating. A Schedule 80 piping system also has additional clearance in the fitting to pipe fitment to allow the use of gap filling cement, offering a sound solvent weld with greater mechanical strength.

NOTES:

a. The gap filling cement recommended by schedule 80 pipe system suppliers contain no additional fillers and is only PVC-U dissolved in solvent i.e. once the solvent evaporates from the joint, only PVC-U remains.

b. Some PVC solvents contain silica that is attacked by chemicals; Sodium Hypochlorite and Fluosilicic Acid (FSA) in particular dissolves the silica over time leading to pipe joint failure.

Joints utilising PVC-U flanges are not preferred (refer to the ‘Flanges’ Clause in the ‘Jointing’ section below.

Lists of chemicals and process fluids used in water and wastewater treatment are contained in the Pipework sections of DS 33 and DS 34 respectively.

5.7.5 UV Degradation

PVC-U pipe is particularly susceptible to UV degradation. Research by Uni-Bell PVC Pipe Association showed that exposure of PVC to UV over a two year period resulted in discoloration or 'sunburn' of the pipe surface. The sole characteristic adversely impacted by UV exposure was impact strength; however, the average impact strength still exceeded the value required for new pipe. There was no effect on the tensile strength or elasticity of the PVC.

In order to minimise the effects of UV exposure and degradation over long periods, white non UV stable PVC pipe installations shall be coated according to Coating Specification K1. Grey UV stable Schedule 80 piping system does not require painting. PVC-U pipes and fittings shall be stored so that they are not exposed to direct or indirect sunlight.

There is anecdotal evidence that in addition to UV degradation, thermal degradation of PVC-U pipe occurs. For example, painting the PVC-U pipe a dark colour may result in premature degradation of PVC-U pipe in outdoor installations. This should be considered when selecting paint colour or prompt consideration of other protection strategies.

5.7.6 Pressure and Temperature Relationships

PVC-U (including PVC-M and PVC-O) pipe and fittings have a progressively reduced pressure capability with increasing fluid temperature above 20 ºC. Accordingly a thermal de-rating factor shall be applied to the maximum allowable operating pressure for PVC-U pipe and fittings where fluid temperatures exceed 20 ºC in accordance with the manufacturer's recommendations.

5.7.7 Structural Integrity

The following factors relating to structural integrity of PVC-U pipe shall be considered:

(a) PVC-U pipe and valves shall not be used for external above-ground potable and recycled water services, for sizes DN 32 and below. Pipe in these sizes shall be copper with copper-alloy or stainless steel valves.

NOTE: PVC-U pipe in these sizes is unsuitable because it requires significant temperature derating, is vulnerable to physical damage and requires constant painting to avoid UV degradation.

(b) Polyethylene pipe should be used in preference to ABS and PVC-U where applicable, however thermal expansion and pipework support issues (if above ground) may require special consideration.

(c) PVC-U pipe shall not be used in underground galleries.

(d) Plastic pipework may be connected directly to metal pipework however it shall be downstream of a metal isolating valve.

(e) PVC and ABS pipe containing hazardous chemicals outside bund areas, which are vulnerable to external damage or potential failure, shall be installed in a containment pipe.

5.7.8 Cyclic Loading

The Corporation has encountered premature failure of PVC-U pipe and fittings due to the effect of stress regression or cyclic loading. Failures have occurred at both ends of the spectrum in terms of number of cycles and magnitude of stress or pressure fluctuation. Failures have occurred at a large number of cycles versus small pressure fluctuations as well as for a small number of cycles versus large pressure fluctuations.

Designers should:

(a) Avoid the use of PVC-U pipe and fittings when designing systems which have cyclic loading such as multiple pump starts and stops and multiple valve openings and closures.

(b) Undertake a check at the design stage on fatigue life where cyclic loads are anticipated based on PVC-U in accordance with the manufacturer's recommendations.

(c) Establish fatigue de-rating of the pipe based upon a 100 year cyclic loading

(d) Ensure pipe selection takes account of cyclic fatigue and any temperature de-rating.

The following table shows the recommended fatigue cycle factors for PVC-U, PVC-M and PVC-O.

Table 5.6 - PVC Pipe Fatigue Cyclic Factors

Total Cycles	Approx. No Cycles/day for 100y life	Fatigue Cycle Factors, *f*		
		PVC-U	PVC-M	PVC-O
26400	1	1	1	1
100000	3	1	0.67	0.75
200000	5.5	0.81	0.54	0.66
500000	14	0.62	0.41	0.56
1000000	27	0.5	0.33	0.49
2500000	82	0.38	0.25	0.41
5000000	137	0.38	0.25	0.41
10000000	274	0.38	0.25	0.41

Using the factors provided in the table, the maximum cyclic pressure range (MCPR) for a given class of pipe can be calculated from the following formula:

MCPR = (PN/10) x *f*

5.7.9 Jointing

5.7.9.1 Solvent Weld and Elastomeric Rings

PVC-U pressure pipes are available in nominal 6.0 m lengths with jointing systems as follows:

(a) Series 1: Metric pipe series in nominal sizes DN 100 to DN 575 for pressures PN 6 to PN 18 for solvent cement joining.

Solvent cement fittings are available in all diameters up to DN 150.

(b) Series 2: Cast iron outside diameter (CIOD) series in nominal sizes DN 100 to DN 600 for pressures PN 6 to PN 16. Pipe is supplied with spigot and socket ends for elastomeric ring jointing.

Pipe is compatible with AS/NZS 1477 Series 2 dimension socketed (rubber ring) fittings for ductile iron, in diameters DN 100 upwards.

5.7.9.2 Flanges

PVC-U pipe and fittings are primarily designed for solvent cement welded or elastomeric ring joint systems in accordance with the above. However flanged and threaded jointing systems are also used for Series 1 PVC-M pipes to accommodate some appurtenances.

The use of flanges for brittle material such as PVC-M, and PVC-U is not preferred by the Corporation. In the event that it is unavoidable, PVC-U flange mating faces shall be flat-faced utilising a full face

gasket (refer Note). In addition the flanges shall be fitted with galvanized mild steel or stainless steel backing flanges with pre-drilled holes conforming with AS/NZS 4087.

NOTE: Flat face flanges are required in order that bolting couples are not produced as would otherwise occur if raised flanges faces or narrow face gaskets were used, as rotation during tightening may cause cracking.

5.7.10 Reference Standards

Where relevant (depending on service) PVC-U pipes and fittings shall be manufactured in accordance with the following table:

Table 5.7 – PVC-U Pipe Reference Standards

Item	Material/Designation	Standard
PVC-U Pipe – Series 1 for above and below ground service	Manufacturer, materials, testing and inspection	AS 4041, AS/NZS 1477
	Solvent welded joints and solvent welded cements	AS 3879
PVC-U Pipe – Series 2 for below ground service	Manufacture, testing and inspection	Refer to DS 63 for sizes < DN 250
	Joint rings	Refer to DS 60 for sizes ≥ DN 300
	Pipelaying design	AS/NZS 2566
Pipeline construction	Pressure pipelines	AS/NZS 2032

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