FLOWTITE™ GRP Pipe and Fittings

Engineering Design and Installation Guide

iPLEX Pipelines

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Section 1

Introduction

1.0 Introduction

Iplex Pipelines Australia Pty Ltd is a major Australian manufacturer and supplier of plastic pipes and fittings suitable for civil, plumbing, irrigation industrial and mining applications. As a leader in plastic pipe technology, Iplex Pipelines has continued to develop and introduce new and innovative products offering solutions for the demanding service and environmental solutions of today. Iplex Pipelines has been a leader in GRP pipeline technology for the water and sewerage industry in Australia and New Zealand since 1985.

1.1 FLOWTITE™ GRP Pipe Systems

FLOWTITE™ is a glass reinforced polymer pipe suitable for pressure and non pressure applications. It is produced on a continuously winding and advancing mandrel, ensuring consistent high quality pipes. FLOWTITE™ pipes are recognised for their strength, flexibility and corrosion resistance making them suitable for a range of applications including water, sewerage and drainage.

FLOWTITE™ GRP pipes were first produced in Norway in 1971. The process has been refined over the intervening period to become the leading "State- of-the-Art" technology in GRP pipe manufacture. The technology is now being used worldwide on all continents with more than forty four winding machines located in twenty licensed pipe factories.

Manufacture

FLOWTITE™ GRP pipe is distributed by Iplex Pipelines and maufactured by RPC Pipe Systems at their purpose built facility in Lonsdale, South Australia. FLOWTITE™ pipes can be manufactured in a number of standard diameters ranging from DN300 up to DN3000.

FLOWTITE™ pipe is manufactured using the continuous advancing mandrel process. This process allows the use of continuous glass fibre reinforcements in the circumferential direction. For a pressure pipe or buried conduit the principle stress is in the circumferential direction, incorporating continuous reinforcement in this direction yields a higher performing product at lower cost.

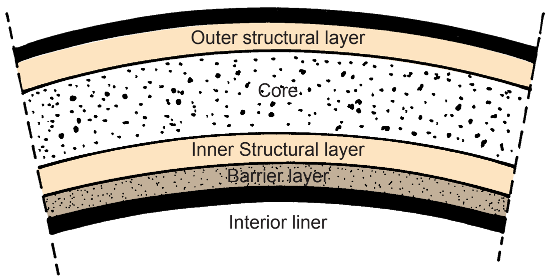


Figure 1.1 – Typical cross section of FLOWTITE™ Pipe wall

Using the technology developed by FLOWTITE™, a very dense laminate is created that maximizes the contribution from the three basic raw materials, namely glass fibre, silica sand aggregate and thermosetting resin.

Both continuous glass fibre rovings and chopped rovings are incorporated for high hoop strength and axial reinforcement. A silica sand aggregate is placed near the neutral axis in the core to provide increased stiffness. Thermosetting resin, delivered through a dual resin delivery system gives the equipment the capability of applying a special inner resin liner for severe corrosive applications while utilizing a less costly resin for the structural and outer portion of the laminate.

Figure 1.2 – The FLOWTITE ™ winding process showing the raw materials laying-up on the mandrel

The raw materials are placed on the continuously advancing mandrel in specific locations to ensure optimum strength with minimum weight. The materials are applied to produce a series of layers which give both pressure resistance as well as pipe stiffness.

Figure 1.1 shows the typical wall construction of a FLOWTITE™ pipe Table1.1 explains the layers' construction and purpose. Note that all layers contain thermosetting resin.

Table 1.1 FLOWTITE™ pipe layers

Layer	Construction	Purpose
Interior liner	"C" glass tissue	Protection
Barrier layer	Chopped glass fibres	Protection
Inner structural layer	Continuous glass fibres and chopped glass fibres	High modulus structural reinforcement
Core	Silica sand aggregate and chopped glass fibres	Solid separating core
Outer structural layer	Continuous glass fibres and chopped glass fibres	High modulus structural reinforcement
Exterior surface	Chopped glass and "C" glass tissue or polyester veil	Protection

Once the materials have been applied the laminate is cured completely using a number of strictly controlled mechanisms (Figure 1.3). The cured laminate is cut to length as required. Standard lengths are 12 metre, 6 metre and 3 metre. Intermediate lengths can also be manufactured at 1 metre increments. Longer lengths are possible but cannot be pressure tested.

Figure 1.3 – FLOWTITE™ pipes being cured with infra red heat

Figure 1.4 – Finished pipe ready for inspection

All pipes are quality inspected after manufacture and the pipe spigots are chamfered and calibrated where necessary for fitment of couplings. Each pressure pipe is pressure tested to twice its nominal pressure class to verify performance.

Couplings are cut from specially made “coupling pipes” of an appropriate diameter to allow for internal grinding of grooves for the rubber seals and central register. Couplings are also proof tested at 2 x PN pressure on a hydrostatic testing machine.

1.2 Applications for FLOWTITE™ :

FLOWTITE™ pipes and fittings are suitable for both pressure and non-pressure applications and have been used successfully for:

- Water supply transmission and distribution mains
- Gravity and rising main sewers
- Irrigation
- Mining
- Trenchless applications i.e. slip lining
- Drainage

Further references and case studies can be found on the Iplex website www.iplex.com.au.

1.3 Advantages of FLOWTITE™

Features	Benefits
FLOWTITE™ is immune to galvanic corrosion. Pipes and fittings are suitable for use in acidic and saline soils or soils of low resistivity.	FLOWTITE™ provides a longer service life in aggressive waters and soils containing chlorides, carbon dioxide, acids, hydrogen sulphide and sulphates.
FLOWTITE™ pipe dimensions are compatible with Australian Standard sizes as detailed in AS/NZS 3571.	FLOWTITE™ is interchangeable with ductile iron pipes, Series 2 - PVC- U, PVC-M and PVC-O pipes, and most existing AC pipeline installations.
FLOWTITE™ pipes are not affected by dynamic stresses.	FLOWTITE™ does not require rerating for cyclic loading.
FLOWTITE™ is electrically non conductive.	Unaffected by stray (earth) or induced currents. Cathodic protection systems do not need to be considered for either FLOWTITE™ pipes or surrounding structures.
The FLOWTITE™ GRP pipe coupling with REKA rubber ring seals is a proven pipe joint system with almost eighty-years of proven performance and reliability.	Allows all pipe lengths to be utilised. It has a low jointing effort with practical angular deflection for minor or major changes in pipe alignment (or in areas prone to mine subsidence). The same couplings can be used on cut pipes and fittings.
An extensive range of standard FLOWTITE™ GRP fittings is available together with custom-made fittings to suit individual requirements.	Allows for standard and special layout configurations. Multiple fittings can also be manufactured as single structures.
FLOWTITE™ pipes are manufactured with a reinforced resin liner and external scuff layer.	Increased resistance to UV degradation. Increased protection during handling and installation.
The smooth and large internal bore of FLOWTITE™ pipe provides excellent hydraulic performance.	Low friction losses, greater flow capacity and lower pump operating costs.
FLOWTITE™ pipes provide low water hammer surge celerity compared with other pipe materials.	Assists the designer with water hammer pressure reduction measures.
FLOWTITE™ pipes are approximately ¼ the mass of ductile iron pipes and 1/10th the mass of concrete pipes of the same sizes.	Provides benefits in transport, handling and installation.
Longer pipe lengths.	Reduces the number of pipe joints on site and increases installation efficiency.

Figure 1.5 – DN1000 PN16 FLOWTITE™ pressure pipes and GRP fittings for a 63km recycled water supply line for the Lowood to Caboonbah pipe section, Western Corridor Queensland

Section 2

Material Properties

2.0 Material Properties

2.1 Physical characteristics

The wall construction of FLOWTITE™ pipes can vary according to the pipe class and stiffness, therefore only indicative material parameter values have been given below. For more specific information contact Iplex Pipelines' Technical Services.

Property	Value	Unit
Density	1800 - 2100	kg/m^3
Thermal coefficient of expansion (Axial)	24 – 30 x 10^{-6}	m/m.K
Thermal conductivity	0.14 – 0.22	W/m.K
Tensile strength (Circumferential Hoop)	125 – 500	MPa
Tensile strength (Longitudinal Axial)	25 – 60	MPa
Elastic modulus (Circumferential Tensile) Elastic modulus (Circumferential Flexural)	10,000 – 31,000 13,000 – 31,000	MPa
Elastic modulus (Longitudinal Tensile and Flexural)	6,000 – 12,500	MPa
Circumferential bending creep ratio (50 years)	0.6	
Circumferential tensile strain (Ultimate) - Initial - Long Term (50 years)	 1.52% 0.65%	
Circumferential bending strain - Initial - Long Term (50 years)	 2.3% 1.3%	
Poisson's Ratio	0.22 – 0.29	
Combustibility characteristics (AS 1530.3 – 1989) - Ignitability index (0 – 20) - Spread of flame index (0 – 10) - Heat evolved index (0 – 10) - Smoke development index (0 – 10)	 10 0 2 6	

Embodied energy

The embodied energy of FLOWTITE™ GRP pipes is generally lower than that of equivalent non-polymer pipe materials. For detailed information, contact Iplex Pipelines' Technical Services.

Ring stiffness

The stiffness of a pipe indicates the ability of the pipe to resist external soil, hydrostatic and traffic loads together with negative internal pressures.

It is a measure of the pipes resistance to ring deflection. It is determined by testing and is the value obtained by dividing the force per unit length of specimen by the resulting deflection at 3 percent deflection.

$$S = \frac{Ff}{Ld_v} \qquad \text{.........Equation 2.1}$$

Where

S = stiffness (N/m/m)

F = force (N)

L = length of test specimen (m)

d_v = deflection (m)

D_m = mean diameter (m)

f = a deflection coefficient including a correction factor for ovality of the deformed specimen obtained as follows:-

$$f = 10^{-5} \times (1860 + 2500\, d_v/D_m) \qquad \text{.......Equation 2.2}$$

According to the Australian and ISO Standards, stiffness is expressed as follows:

$$S = \frac{EI}{D_m^3} \quad \text{.............................} \textit{Equation 2.3}$$

Where

S = the pipe stiffness as determined by testing in N/m/m

E = the apparent modulus of elasticity in Pa.

D_m = mean diameter (m)

I = the second moment of area per unit length of the pipe wall section in m^4 per m and is expressed as:

$I = t^3/12$ where t = wall thickness in m.

The initial stiffness is determined using a specific test method and cannot be obtained through calculations using nominal values of E and t as FLOWTITE™ is a GRP composite.

There are other common terms used internationally describing pipe stiffness.

For example according to German DIN Standards and the ATV Code, the ring stiffness is defined as:

$$SR = \frac{EI}{R_m^3} \quad \text{.............................} \textit{Equation 2.4}$$

Where R_m = mean radius (m).

This stiffness value is 8 times greater than that given by the Australian and ISO Standards, so that in order to avoid mistakes E and SR are expressed as N/mm^2 (MPa) when using this formula.

According to American ASTM Standards the ring stiffness measured at 5% deflection, is expressed as:

$$\frac{F}{d_v} \text{ (pounds per square inch) } \text{.................} \textit{Equation 2.5}$$

Where F = load per unit length (pounds per inch)
d_v = vertical pipe deflection (inches)

GRP pipes are classified by the nominal stiffness value determined from the standard initial stiffness test.

Table 2.1 Nominal stiffness / Comparison of units

Nominal stiffness	Unit	SN5000	SN10000
S_P (ISO and Aust.)	N/m/m	5000	10000
S_R (DIN ATV)	N/mm^2	0.04	0.08
$\frac{F}{d_v}$ (ASTM)	psi	40	80

Abrasion resistance

FLOWTITE™ pipes are manufactured with an internal layer of reinforced resin providing resistance to abrasion.

The potential for bore abrasion wear can be determined using the Darmstadt method. The test used was developed at the "Institute of Hydraulics and Hydrology" of Darmstadt, Germany and the procedure involves axially rocking a half section of pipe through 22 degrees, so that a calibrated load of abrasive slurry slides back and forth along the invert of the pipe.

When tested, a FLOWTITE™ pipe specimen showed a wear rate of 0.34mm per 100,000 cycles. (Figure 2.1)

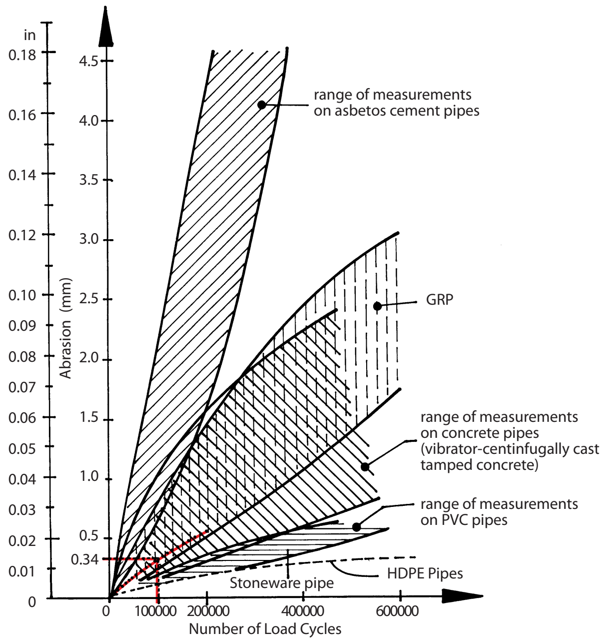


Figure 2.1 – Abrasion resistance of FLOWTITE™ GRP pipe (in red) versus other pipe materials

Ultraviolet solar radiation resistance

FLOWTITE™ pipes have a non-structural external layer of reinforced resin to provide weathering resistance when stored or installed above ground. This external layer protects the structural layers from UV radiation, which may discolor over time. If this is not acceptable, pipes may be coated with an acrylic (water based) paint.

Weather resistance

Standard FLOWTITE™ pipes can be permanently stored in the open without any detrimental effects on the structure of the pipe from UV radiation however, some superficial roughening and discoloration of the external and internal surfaces may occur which is acceptable. For periods over 6 months in open areas it is recommended that the rubber rings should be stored indoors.

Potable water approvals

FLOWTITE™ pipes and fittings meet the requirements of AS/NZS 4020. Australian/New Zealand Standard Testing of products for use in contact with drinking water.

FLOWTITE™ pipe has also been tested and approved for the conveyance of potable water by the following world leading authorities and testing institutes:

- NSF (Standard No. 61) – United States
- DVGW – Germany
- Lyonnaise des Eaux – France
- Water Byelaws Scheme (WBS) – United Kingdom
- Russia (Cert. No. 0770¨0 03515I04521A8)
- Oficina Técnia De Estudios Y Controles – Spain
- Pánstwowy Zaklad Higieny (National Institute of Hygiene) – Poland
- OVGW – Austria
- NBN.S. 29001 – Belgium

Figure 2.2 – DN1000 PN16 SN10000 FLOWTITE™ pressure pipes with special long length 'angled' GRP bends designed for 'curvi linear alignment and installed at Wivenhoe Dam in South East Queensland

2.2 Chemical properties

Maximum service conditions

Standard FLOWTITE™ pipes are intended for use with water, sewage and controlled industrial wastes at temperatures of up to 35°C in the pH range 3 to 9. For temperature and chemical conditions in excess of these values Iplex Pipelines' engineers should be consulted for advice on rerating and chemical suitability.

With the exception of chlorinated or aromatic solvents, FLOWTITE™ pipes have a high resistance to chemical attack. Furthermore, special resin systems can also be used to improve chemical resistance at elevated temperatures. In the case of some solvents, the use of a vinyl ester resin system may be recommended.

Performance in exceptional chemical environments

FLOWTITE™ pipes selected for use in severe environments, such as the processing industry, especially at elevated temperatures, may require special resin systems such as vinyl esters. Because of the range of factors involved, the final determination of the suitability of FLOWTITE™ for a given environment becomes the sole responsibility of the specifier.

The following chemical resistance table (Table 2.2) is based on information supplied by resin manufacturers as a general guide. It is not intended to imply approval for any given application, as neither the resin suppliers nor Iplex Pipelines has any control over the conditions of usage or the means of identifying all environmental conditions that may affect the selected pipes and fittings.

Using this guide

All materials listed in "green" can be used with our current standard pipe resin systems. All materials listed in "blue" are in addition to the "green" materials that can be used in pipes that use a vinyl ester resin liner. All materials listed in "red" are not recommended and may not work in any type of FLOWTITE™ pipe system.

* Current EPDM type gasket cannot be used. Other types of gasket materials e.g. Viton™ may be suitable or consult Iplex Pipelines

** No FLOWTITE™ Technology recommendation. Consult your local gasket supplier for compatibility.

Table 2.2 Chemical resistance guidelines

Chemical	Standard resin	Vinyl ester resin	Not recommend
Acetic Acid <20%**		X	
Adipic Acid**		X	
Alum (Aluminium Potassium Sulphate) (45° C)	X		
Aluminium Chloride, Aqueous (40° C)	X		
Ammonia, Aqueous, <20%		X	
Ammonium Chloride, Aqueous (40°C)	X		
Ammonium Fluoride			X
Ammonium Nitrate, Aqueous (40°C)	X		
Ammonium Phosphate-Monobasic, Aqueous (40°C)	X		
Ammonium Sulphate, Aqueous (40°C)	X		
Aniline Hydrochloride		X	
Antimony Trichloride (40°C)**			X
Barium Carbonate**		X	
Barium Chloride (40°C)		X	
Barium Sulphate (40°C)		X	
Beet Sugar Liquor		X	
Benzene Sulfonic Acid (10%)*		X	
Benzoic Acid*		X	
Black Liquor (Paper)		X	
Bleach			X
Borax (40°C)	X		
Boric Acid		X	
Bromine, Aqueous 5%*		X	
Butyric Acid, <25% (40° C)**		X	
Calcium Bisulfite*		X	
Calcium Carbonate		X	
Calcium Chlorate, Aqueous (40°C)**	X		
Calcium Chloride (Saturated) (40°C)	X		
Calcium Hydroxide, 100%		X	
Calcium Hypochlorite		X	
Calcium Nitrate (40° C)	X		
Calcium Sulphate NL AOC (40°C)	X		
Cane Sugar Liquors		X	
Carbon Dioxide, Aqueous (40°C)	X		
Carbon Tetrachloride			X
Casein	X		
Caustic Potash (KOH) (40°C)		X	
Chlorine, Dry Gas*		X	
Chlorine, Water*		X	
Chlorine Wet Gas**		X	
Chlorocetic Acid			X
Citric Acid, Aqueous		X	
Copper Acetate, Aqueous (40°C)	X		
Copper Chloride, Aqueous (40°C)	X		
Copper Cyanide (30°C)		X	
Copper Nitrate, Aqueous (40°C)	X		
Copper Sulphate, Aqueous (40°C)	X		
Crude Oil (Sour) (30°C)*	X		
Crude Oil (Sweet) (30°C)*	X		
Crude Oil, Salt Water (25°C)*		X	
Cyclohexane (40°C)*		X	
Cyclohexanol (30°C)*		X	
Dibutyl Sebacate (25°C)	X		
Dibutylphthalate (25°C)	X		

Table 2.2 Chemical resistance guidelines - Continued...

Chemical	Standard resin	Vinyl ester resin	Not recommend
Diesel Fuel(25°C)*	X		
Dioctyl Phthalate (40°C)**	X		
Ethylene Glycol (40°C)	X		
Ferric Chloride, Aqueous (40°C)	X		
Ferric Nitrate, Aqueous (30°C)	X		
Ferric Sulphate, Aqueous (40°)	X		
Ferrous Chloride (30°C)	X		
Ferrous Nitrate, Aqueous (30°C)**	X		
Ferrous Sulphate, Aqueous (40°C)	X		
Formaldehyde			X
Fuel Oil (25°C)*	X		
Gas, Natural, Methane			X
Gasoline, Ethyl*		X	
Glycerine		X	
Green Liquor, Paper		X	
Hexane (30°C)*	X		
Hydro bromic Acid			X
Hydrochloric Acid, up to 15% (25°C)	X		
Hydrofluoric Acid			X
Hydrogen Sulphide, Dry		X	
Kerosene*		X	
Lactic Acid, 10% (30°C)	X		
Lactic Acid, 80% (25°C)	X		
Lauric Acid (40°C)	X		
Lauryl Chloride**	X		
Lauryl Sulphate**	X		
Lead Acetate, Aqueous (25°C)	X		
Lead Nitrate, Aqueous (25°C)	X		
Lead Sulphate**	X		
Linseed Oil*	X		
Lithium Bromide, Aqueous (40°C)**	X		
Lithium Chloride, Aqueous (40°C)**	X		
Magnesium Bicarbonate, Aqueous (30°C)**	X		
Magnesium Carbonate (40°C)**		X	
Magnesium Chloride, Aqueous (40°C)	X		
Magnesium Nitrate, Aqueous (40°C)	X		
Magnesium Sulphate (40°C)	X		
Manganese Chloride, Aqueous (40°C)**	X		
Manganese Sulphate, Aqueous (40°C)**	X		
Mercuric Chloride, Aqueous (40°C)	X		
Mercurous Chloride, Aqueous (40°C)**	X		
Mineral Oils*	X		
n-Heptane (25°C)*	X		
Naphthalene (30°C)*	X		
Naphtha*		X	
Nickel Chloride, Aqueous (40°C)	X		
Nickel Nitrate, Aqueous (40°C)	X		
Nickel Sulphate, Aqueous (40°C)	X		
Nitric Acid			X
Oleic Acid (40°C)	X		
Oxalic Acid, Aqueous		X	
Ozone Gas			X
Paraffin (30°C)*	X		
Pentane (30°C)*	X		

Table 2.2 Chemical resistance guidelines - Continued...

Chemical	Standard resin	Vinyl ester resin	Not recommend
Perchloric Acid (25°C)		X	
Petroleum, Refined & Sour*		X	
Phosphoric Acid		X	
Phosphoric Acid (30°C)	X		
Phthalic Acid (30°C)		X	
Potassium Permanganate, 25%**		X	
Potassium Bicarbonate**		X	
Potassium Bromide, Aqueous (40°C)	X		
Potassium Chloride, Aqueous (40°C)	X		
Potassium Dichromate, Aqueous (40°C)	X		
Potassium Ferrocyanide (40°C)**	X		
Potassium Ferrocyanide, Aqueous (40°C)**	X		
Potassium Nitrate, Aqueous (40°C)	X		
Potassium Sulphate (40°C)	X		
Propylene Glycol (30°C)	X		
Sea Water (40°C)	X		
Sewage (50°C)	X		
Silicone Oil (40°C)	X		
Silver Nitrate, Aqueous (40°C)	X		
Sodium Bromide, Aqueous (40°C)**	X		
Sodium Chloride, Aqueous (40°C)	X		
Sodium Dichromate (25°C)	X		
Sodium Dihydrogen Phosphate (40°C)	X		
Sodium Ferrocyanide (40°C)**	X		
Sodium Hydroxide 10%		X	
Sodium Mono-phosphate		X	
Sodium Nitrate, Aqueous (40°C)	X		
Sodium Nitrite, Aqueous(40°C)**	X		
Sodium Silicate		X	
Sodium Sulphate, Aqueous (40°C)	X		
Sodium Sulphide		X	
Sodium Tetraborate (30°C)**	X		
Stannic Chloride, Aqueous (40°C)*	X		
Stannous Chloride, Aqueous (40°C)	X		
Stearic Acid (40°C)**	X		
Sulphur			X
Sulphuric Acid, <25% (25°C)*	X		
Tannic Acid, Aqueous (35°C)	X		
Tartaric Acid (30°C)	X		
Toluene Sulfonic Acid**		X	
Tributyl Phosphate (40°C)		X	
Triethanolamine (40°C)		X	
Triethylamine (40°C)		X	
Turpentine*		X	
Urea, Aqueous (30°C)**	X		
Vinegar (25°C)	X		
Water, Distilled (40°C)	X		
Water, Sea (40°C)	X		
Water Tap (40°C)	X		
Zink Chloride, Aqueous (40°C)	X		
Zinc Nitrate, Aqueous (40°C)**	X		
Zinc Sulphate, Aqueous (40°C)	X		
Zinc Sulphite, Aqueous (40°C)**	X		

Figure 2.3 – DN750 PN16 FLOWTITE™ water supply line for the City of Wyong NSW

Section 3

Product Specifications

3.0 Product Specifications

3.1 Standards for manufacture of GRP pipes and fittings

Standards developed internationally apply to glass reinforced polyester (GRP) pipes, sometimes referred to as fibreglass or fibre reinforced polyester (FRP), when used for infrastructure, including the conveyance of potable water, irrigation water, sewage and industrial waste. Common to all modern pipe product standards is the fact that they are performance-based documents. That is, the required performance and testing of the pipe is specified rather than prescriptive requirements on the manufacturing process.

FLOWTITE™ pipes have been appraised by the Water Services Association of Australia (WSAA). Refer to Product Appraisal 04/06 "FLOWTITE™ GRP Pipe Systems for Fibrelogic Pipe Systems Pty. Ltd".

The following list includes standards commonly used for the manufacture and testing of GRP pipes and fittings.

ISO Standards

The International Standards Organization (ISO) has published a suite of GRP product standards and corresponding test methods. FLOWTITE™ Technology in Europe participated in the development of these standards; thereby ensuring performance requirements will result in reliable products. The ISO Standards for GRP pipes and fittings manufacture relevant to infrastructure works include:

ISO 10639 "Plastics piping systems for pressure and non-pressure water supply -Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin"

ISO 10467 "Plastics piping systems for pressure and non-pressure drainage and sewerage - Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin"

Australian Standards

Australian practice is to use ISO based standards for GRP pipes and fittings and the following Australian Standards have been revised to meet the latest ISO Standards.

FLOWTITE™ is manufactured to comply with:

- Australian Standard AS 3571.1 "Plastic piping systems – Glass reinforced thermo setting plastics (GRP) systems based on unsaturated polyester (UP) resin – Pressure and non pressure drainage and sewerage" (ISO 10467:2004 Mod)

- Australian Standard AS 3571.2 "Plastic piping systems – Glass reinforced thermo setting plastics (GRP) systems based on unsaturated polyester (UP) resin – Pressure and non pressure water supply" (ISO 10639:2004 Mod)

- Australian Standard AS 3572 "Plastics – Glass Filament Reinforced Plastics (GRP) – Methods of Test".

United States of America, Standards

FLOWTITE™ pipes manufactured in Australia are designed to meet United States Standards in addition to the ISO and AS Standards.

ASTM

Currently, there are several ASTM Product Standards in use that apply to a variety of GRP pipe applications. All product standards apply to pipes with diameter ranges of 200mm to 3600mm and require flexible joints to withstand hydrostatic testing in configurations (per ASTM D4161) that simulate exaggerated in-use conditions. These standards include various qualification and quality control tests.

- ASTM D3262 "Standard Specification for "Fibre glass" (Glass-Fibre-Reinforced Thermosetting - Resin) Sewer Pipe"

- ASTM D3517 "Standard Specification for "Fibre glass" (Glass-Fibre-Reinforced Thermosetting - Resin) Pressure Pipe"

- ASTM D3754 "Standard Specification for "Fibre glass" (Glass-Fibre-Reinforced Thermosetting - Resin) Sewer and Industrial Pressure Pipe"

AWWA

ANSI/AWWA C950 'AWWA Standard for Fibreglass Pressure Pipe' is one of the most comprehensive product standards in existence for GRP pipe. This standard for pressure water applications has extensive requirements for pipe and joints, concentrating on quality assurance and prototype qualification testing. Like ASTM standards, this is a product performance standard. FLOWTITE™ pipe is designed to meet the performance requirements of this standard. AWWA has recently issued a new "Fibreglass Pipe Design" manual M-45, which includes chapters on the design of GRP pipelines for buried and aboveground installations.

- AWWA C950 "Fibreglass Pressure Pipe"
- AWWA M-45 "Fibreglass Pipe Design Manual"

Other Standards

Standardisation organisations such as BSI and DIN have also published performance specifications for GRP pipes to which FLOWTITE™ complies where nominated.

- DIN 16868 "Glass Fibre-Reinforced Polyester Resin Pipes"
- BS 5480 "Pipes and Fittings for Water and Sewage"

Associated fittings

Fittings used with FLOWTITE™ pipes may be either of GRP or metallic materials. The following documents may be relevant:-

- AS 3571.1 2009: "Plastics piping systems - Glass-reinforced thermoplastics (GRP) systems based on unsaturated polyester (UP) resin - Pressure and non-pressure drainage and sewerage" (ISO 10467:2004, MOD)

- AS 3571.2 2009: "Plastics piping systems - Glass-reinforced thermoplastics (GRP) systems based on unsaturated polyester (UP) resin - Pressure and non-pressure water supply" (ISO 10639:2004, MOD)

- ISO 10467 "Plastics piping systems for pressure and non-pressure drainage and sewerage – Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin"

- ISO 10639 "Plastics piping systems for pressure and non-pressure water supply – Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin"
- AS 1281 "The Cement Mortar Lining of Steel Pipes and Fittings"
- AS 1579 "Arc-welded steel pipes and fittings for water and wastewater"
- AS 2129 – "Flanges for pipes, valves and fittings"
- AS/NZS 2280 "Ductile iron pressure pipes and fittings"
- AS/NZS 4087 "Metallic flanges for waterworks purposes"
- AS/NZS 4331.1 (ISO 7005) "Metallic flanges - Steel flanges"

Note: Flange thicknesses for GRP will (depending on the design) normally be greater than metal flanged thicknesses.

For water supply, sewerage rising-mains, and other pressure applications, GRP pressure fittings, standard ductile iron fittings, valves and hydrants are all suitable for use with FLOWTITE™ pipe. Steel fittings may also be used for diameters of DN900 or larger.

The outside diameters of FLOWTITE™ GRP pipes are compatible with Australian Standard PVC-U, PVC-M and PVC-O Series 2 sizes, ductile iron and some AC pipes and fittings of the same nominal diameter.

3.2 FLOWTITE™ GRP fittings

FLOWTITE™ GRP pressure fittings are manufactured in Classes PN6, PN10, PN16, PN20, PN25 and PN32 for use with FLOWTITE™ pipes of the corresponding class. These fittings are fabricated from FLOWTITE™ pipes using wrapped GRP laminate. FLOWTITE™ GRP fittings are normally supplied with spigot ends suitable for use with FLOWTITE™ couplings. Flanged fittings are also available and are generally fabricated with either a GRP full-faced or stub flange and metal backing ring depending on the design. For higher operating pressures stub flanges with steel backing plates may be the preferred option.

"Non-pressure" (i.e. PN1) GRP fittings are also fabricated from FLOWTITE™ pipes and are normally supplied with spigot ends suitable for use with FLOWTITE™ couplings. Sewer branch connections can be made by using specially fabricated GRP saddle fittings with branch off takes. The saddles are attached to the side of the pipe with an epoxy adhesive applied in-situ. Branch off takes include an adaptor coupling with a rubber ring or solvent weld socket for joining to PVC DWV pipe.

3.3 Ductile iron fittings

Ductile iron fittings with socket joints can be used on selected FLOWTITE™ pipes of the same nominal size. Conventional socketed fittings complying with AS/NZS 2280 – "Ductile Iron Pressure Pipes and Fittings" in sizes DN100 to DN750 are suitable. A complete range of bends, tees, reducers and flange-spigot pieces is available with Griptite™ rubber ring sockets in sizes DN100 to DN750. Other joint designs may also be acceptable. Iplex Pipelines should be contacted to confirm the suitability of any particular range of fittings.

These fittings may be protected from corrosion using various alternatives.

- Polymeric coated
- Cement lining and polyethylene wrap

3.4 Steel fittings

Steel (and stainless steel) fittings fabricated from steel plate can be used with FLOWTITE™ pressure pipes. Normally, steel fittings are protected from corrosion externally by ultra high build epoxy and internally by cement lining. Fittings must be manufactured with specially sized spigots to match FLOWTITE™ pipe outside diameters, including tolerances so that the joint can be made with standard FLOWTITE™ GRP couplings.

Relevant standards are

- AS 1594 "Hot-rolled steel flat products"
- AS 3678 "Hot-rolled structural steel plates, floor plates and slabs"
- AS 1579 "Arc welded steel pipes and fittings for water and waste water"
- AS 1281 "Cement mortar lining of steel pipes and fittings"
- AS 4321 "Fusion bonded medium density polyethylene coatings and linings for pipes and fittings"
- AS 2312 "Guide to protection of iron and steel from atmospheric corrosion"

Figure 3.1 – Examples of polymeric coated ductile iron fittings with Griptite® seals suitable for use with FLOWTITE™

Figure 3.2 – DN1000 spigot epoxy coated steel fitting joined to a PN16 SN10000 FLOWTITE™ water main using a FLOWTITE™GRP coupling

Figure 3.3 – DN1200 x 600 Flanged Access and Air Valve tee assembly with spigot inserted into DN1200 PN25 FLOWTITE™ coupling

Figure 3.4 – DN1200 steel flange spigot connector with thrust flange, prior to coating and lining in the workshop

Note: the spigot has been machined to FLOWTITE™ PN25 dimensions and tolerances.

3.5 Test requirements for pipes

A common element shared by all standards is the need for a pipe manufacturer to demonstrate compliance with the standards' minimum performance requirements. In the case of GRP pipe, these minimum performance requirements fall into both short-term and long-term requirements.

The short-term tests are conducted at manufacturing sites as part of daily quality control, while the latter have been conducted at FLOWTITE™ Technology's laboratory or by a certified third party. Results from quality control tests are part of a FLOWTITE™ factory's records and are retained by the factory, while the type tests are carried out and archived by FLOWTITE™ Technology, which is the international parent organisation.

FLOWTITE™ Purchase Acceptance Standards (PAS) are common to the worldwide organisation and each factory maintains Technical Data Sheets and test reports for the raw material supplied.

FLOWTITE™ pipes comply with the requirements of ISO 10467 and ISO 10639. These Standards are essentially the same except that the sewer pipes must comply with the strain corrosion type test and water supply pipes with the requirements of AS/NZS 4020 for potable (drinking quality) water. All FLOWTITE™ pipes currently manufactured in Australia meet both standards.

Raw materials are delivered with vendor certification demonstrating their compliance with FLOWTITE™ quality requirements. In addition, all raw materials are sample tested prior to their use. These tests ensure that the pipe materials comply with the stated specifications.

Resins

FLOWTITE™ pipes are normally manufactured using orthophthalic polyester resins. However where unusual environmental conditions exist, isophthalic polyester or vinyl ester can be specified.

Aggregate and fillers

The quartz sand used in FLOWTITE™ pipes is required to meet the specific grading curve particle sizing of the FLOWTITE™ Purchase Acceptance Standard.

Elastomeric seals

The elastomeric sealing rings comply with the requirements of EN 681-1: 1996 Type WA and WC and AS 1646. Unless otherwise requested EPDM rings will be supplied. However in special circumstances other polymer rings may be supplied (Table 3.1).

Table 3.1 Elastomers for FLOWTITE™ seals

Polymer	Abbreviation
Ethylene Propylene-Diene*	EPDM
Nitrile-Butadiene	NBR
Styrene-Butadiene	SBR

* *The standard polymer supplied. Other types are rarely needed and can only be obtained as a special order.*

3.6 Production testing

Every pipe is subjected to the following control checks:

- Outside diameter
- Wall thickness
- Pipe length
- Visual inspection of all surfaces
- Hydrostatic leak tightness test (for PN6 or higher)

On a sampling basis, the following control checks are performed:

- Pipe stiffness
- Deflection without liner cracking or structural failure
- Axial and circumferential tensile load capacity
- Barcol hardness
- Composition

3.7 Joint testing

Three methods of jointing FLOWTITE™ pipes have been tested i.e. both flexible and rigid joints, with or without end load resisting capability to meet the requirements of Clause 7 of ISO 10467 and ISO 10639. The following test reports are available:

- Flexible non-end-load-bearing joints – test report T-93-102
- Wrapped non-end-load-bearing joints – test report T-2004-127
- Bolted non-end-load-bearing joints – test report T-2004-129

Outside diameters

FLOWTITE™ pipes are externally controlled in accordance with Table 3.1 External Diameter Series of AS/NZS 3571. Normal tolerances are given in Table 3.2

Figure 3.5 – Pipe stiffness test

Table 3.2 Tolerances on spigot outside diameters for PN <20

DN	Minimum OD (mm)	Maximum OD (mm)
300	344	345
375	425	426
450	506	507
525	586	587
600	666	667
675	746	747
750	825	826
900	922	923
1000	1024	1025
1100	1126	1127
1200	1228	1229
1300	1330	1331
1400	1432	1433
1500	1534	1535
1600	1636	1637
1700	1738	1739
1800	1840	1841
1900	1942	1943
2000	2044	2045
2100	2146	2147
2200	2248	2249
2300	2350	2351
2400	2452	2453
2500	2554	2555
2600	2656	2657
2700	2758	2759
2800	2860	2861
2900	2962	2963
3000	3064	3065

Pipe lengths

The actual length of each pipe is equal to the nominal length with a tolerance of ± 25 mm. The effective (i.e. laying) length is equal to the pipe length plus 10mm (an allowance for the centre register in the coupling).

Surface quality

The surface of the pipe shall be relatively smooth and free of exposed fibre or sharp projections. Refer to Appendix B of AS 3571 for guidance with respect to surface defects.

Barcol hardness

When tested in general accordance with ASTM Standard D2583 the surface Barcol hardness of the pipe shall be greater than 35.

Specific ring stiffness

A test specimen from each batch is tested in accordance with ISO 7685 and the calculated initial stiffness shall be not less than the nominal branded stiffness.

A 300mm long test piece is taken once per 24 hours of pipe manufactured in a single batch. A diametral load is applied with the pipe bearing top and bottom on flat plates. The load to achieve a 3% deflection is recorded and used to calculate the initial stiffness.

Specific ring deflection

When tested in accordance with ISO 10466, a test specimen from each production batch of pipes must satisfy the requirements of Table 3.3 at the nominated deflections. The stiffness test specimen is also used for this test.

Table 3.3 Minimum test deflections

Nominal stiffness SN	5000 N/m/m	10000 N/m/m
No visible damage to inside layer at % deflection of: -	12	9
No structural damage at % deflection of: -	20	15

Initial specific longitudinal tensile test

When an axially oriented test specimen cut from each pipe batch is tested in accordance with ISO 8513, the longitudinal tensile strength indicated for the pipe shall not be less than the value given in Table 3.4. The mean elongation at rupture shall not be less than 0.25%.

Table 3.4 Minimum axial tensile strengths (N/m/m) of external circumference

DN	PN1*	PN6	PN10	PN16	PN20	PN25	PN32
300	110	173	181	206	230	253	289
375	133	192	210	245	268	305	354
450	137	203	224	267	288	331	384
525	138	213	239	284	311	356	417
600	146	233	263	314	347	402	471
675	157	258	292	353	389	453	536
750	169	284	324	389	433	504	599
900	182	309	352	427	476	558	664
1000	194	333	381	464	518	607	726
1200	219	383	440	538	603	711	854
1400	245	434	498	612	688	815	981
1600	270	485	555	687	-	-	-
1800	296	537	614	761	-	-	-
2000	321	587	672	837	-	-	-
2200	347	637	730	911	-	-	-
2400	372	687	789	985	-	-	-
3000	449	838	962	1208	-	-	-

Note: Tensile strengths in table 3.4 above are shown for SN2500 and comply with AS 3571. FLOWTITE™ axial strengths will be greater for higher stiffness pipes.

Apparent initial circumferential tensile strength

When a circumferentially oriented test specimen cut from each pipe batch is tested in accordance with ISO 8521, the tensile strength it indicates for the pipe shall not be less than the value given in Table 3.5. These values may be calculated from the equation:

$$P_o = 0.02 x \sigma_{cu} / d_m$$

Where

σ_{cu} = circumferential strength (N/m/m) determined from ISO 8521

P_o = initial failure test pressure (MPa) determined by regression testing

d_m = mean diameter (m)

Long term type testing

In addition to daily quality control testing, ISO 10467 and ISO 10639 require periodic type testing to determine long term properties such as hydrostatic failure pressures, stiffness creep (or relaxation), and strain corrosion. These tests have a duration up to 10,000 hours to enable extrapolation to establish design values. That is, using the methods of ISO 10928, the physical parameters required can be determined for the specified nominal 50-year design period.

Table 3.5 Initial (average) circumferential tensile strength (N/m/m)

DN	PN6	PN10	PN16	PN20	PN25	PN32
300	1001	1111	1614	1913	2251	2755
375	1061	1411	2027	2508	2922	3602
450	1092	1560	2358	2715	3238	3980
525	1125	1702	2483	3005	3573	4396
600	1223	1909	2852	3474	4148	5096
675	1405	2120	3290	3991	4806	5933
750	1587	2407	3763	4560	5482	6743
900	1761	2709	4167	5077	6114	7589
1000	1927	3018	4614	5646	6790	8372
1200	2290	3583	5491	6733	8088	10010
1400	2654	4139	6367	7766	9413	11648
1600	3036	4712	7253	-	-	-
1800	3389	5292	8112	-	-	-
2000	3760	5889	9015	-	-	-
2200	4124	6454	9900	-	-	-
2400	4488	7059	10759	-	-	-
3000	5580	8760	13389	-	-	-

A statistically significant number of test specimens, are prepared and loaded to various degrees so as to obtain a series of ultimate load (or strain) values spread over the duration of the test period. A "log time" – "log load" regression line of best fit is established using the method of least squares. The 95% lower confidence limit line can then be constructed based on the 50-year minimum value. In the case of the hydrostatic design this information is needed to set values for the short-term quality control tests.

Rigorous joint type tests, which include the combined effect of, draw and shear loading at normal and maximum angular deflections are also requirements of the Standards.

Long term pressure testing

FLOWTITE™ pressure pipe is designed on a strain basis to fulfill the requirements of ISO 10467, ISO 10639, AWWA C950, ASTM D3517 and ASTM D3754. The 50-year strain value for FLOWTITE pipe as determined in report T-95-101R, $\varepsilon 50$, is 0.65%. Current product designs comply with this value. For example on particular pipe specimens strain measurements were made and then using regression analysis the long-term strain of 0.0065 at 23.2bar pressure was determined. That is the 50-year burst pressure, p_{50}, equaled 2.32MPa. The analysis also provided the corresponding initial value, p_0, of 6.37MPa.

The minimum design pressure can be computed from equation 24 in ISO 10467 and ISO 10639

i.e.: $p_{0,d} = C \times 0.1 \times PN / R_{R,p} \times \eta_{t,PN,97,5\%LCL} / (1 - Y \times 0.01 \times 1.96)$

The Standards require that the average of the last 20 initial failure pressures during production, $p_{0,\,mean}$ to be greater than this value for the product in question.

With $C = p_0/p_6$ and $R_{R,p} = p_{50}/p_6$ this equation becomes:

$$p_{0,d} = p_0/p_{50} \times 0.1 \times PN \times \eta_{t,PN,97,5\%LCL} / (1 - Y \times 0.01 \times 1.96)$$

The coefficient of variation 'Y', for the FLOWTITE™ process has been measured over a period of time and found to be generally within the range of 2.5% to 8%. Assuming a conservative value of 9% the expression for $p_{0,d}$ becomes:

$$p_{0,d} = 63.7/23.2 \times 0.1 \times PN \times \eta_{t,PN,97,5\%LCL} \times 1.21 = 3.32 \times PN \times \eta_{t,PN,97,5\%LCL}$$

Using the values for safety factors in Table 16 of ISO 10467 and ISO 10639 the values for $p_{0,d}$ are shown in the following Table 3.6:

Table 3.6 Minimum long-term factors of safety

	PN6	PN10	PN16	PN20	PN25	PN32
$\eta_{t,PN,97,5\%LCL}$ applied to the long term 97.5% LCL	1.6	1.55	1.45	1.38	1.3	1.3
$\eta_{t,PN,mean}$ applied to the long term mean	2.0	1.9	1.83	1.8	1.6	1.6
$p_{0,d}$ MPa	3.19	5.15	7.70	9.16	10.8	13.8

Cyclical internal hydrostatic pressure testing

In accordance with Clause 5.3 of ISO 10467 and ISO 10639 the resistance of FLOWTITE™ pressure pipes to cyclic internal pressure has been verified through testing to ISO. The results are recorded in TÜV test report TÜV MP4/3338-90 and Veroc test report 13-T86. In both cases pipes were subjected to one million cycles between 0.75 x PN and 1.25 PN without showing any sign of failure.

Resistance to strain corrosion

The strain corrosion resistance of FLOWTITE™ pipes has been measured to a value of 0.66% (see test report T-99-107). Using the equation in Clause 10.6 of ISO 10952 this value can be converted to deflections and compared with the requirements. By using the thickest of the pipes in each stiffness class the following deflections are obtained:

Nominal stiffness SN	5000 N/m/m	10000 N/m/m
Deflection %	11.3	9.0

Figure 3.6 – Strain corrosion testing of FLOWTITE™ GRP pipe samples

Section 4

Product Range

4.0 Product Range

4.1 Description and classification

FLOWTITE™ pipes are currently manufactured in Australia in the nominal size range DN300 to DN3000.

FLOWTITE™ pipes in sizes DN300 to DN750 are manufactured with the same outside diameters as ductile iron pipe for the same nominal diameter. As a result the internal diameters are approximately 10% larger than the same comparable nominal size. Additional Australian FLOWTITE™ sizes not found in the ductile iron range DN100 to DN750 are DN525 and DN675.

Nominal pressure classes (PN)

Pressure pipes are classified according to nominal pressure and nominal stiffness; non-pressure pipes by nominal stiffness only.

Nominal stiffness (SN)

The standard nominal stiffness classes available are SN5000 and SN10000.

Other pipe pressure or stiffness classes apart from those listed may be manufactured on request (For example SN20000).

Branding and marking

All pressure pipes are branded to indicate the nominal diameter, pressure class and stiffness.

Couplings for non-pressure pipes are branded to indicate the nominal diameter. Because couplings are common in the non pressure and pressure range up to Class 6 they will generally be branded Class 6, for example “DN900 PN6”.

Table 4.1 - Pipe spigot ends - dimensional details

DN	Witness mark P (mm)	Calibration length CL (mm)	Chamfer length N (mm)
300	130	160-165	9-12
375	130	160-170	10-16
450-525	130	165-170	10-20
600 to 2500	160	170-175	15-20
2600 to 3000	175	170-175	15-20

All dimensions are nominal.

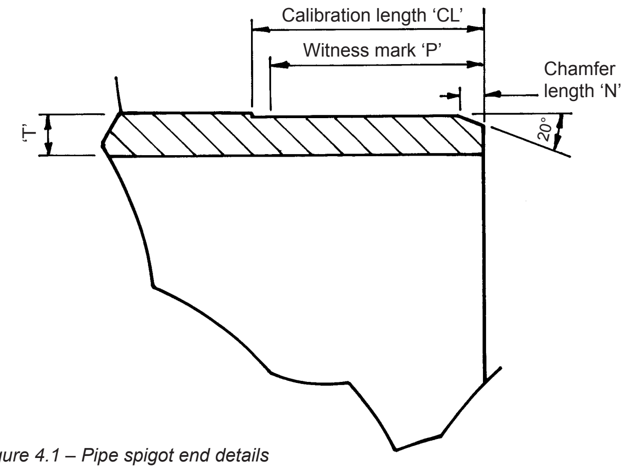


Figure 4.1 – Pipe spigot end details

Table 4.2

Nominal pressure rating PN	PN1	PN6	PN10	PN16	PN20	PN25	PN32
Working pressure (MPa)	0.1	0.6	1.0	1.6	2.0	2.5	3.2
Working pressure (Bar)	1	6	10	16	20	25	32
Working head (Metres)	10	61	102	163	204	255	326
Maximum nominal diameter for specific PN	3000	3000	3000	3000	3000	2400	1800

Table 4.3 FLOWTITE™ GRP pipe details - SN5000 (excluding pipe coupling)

DN	Spigot OD (mm)	Nominal pipe stiffness SN5000																	
		PN1			PN6			PN10			PN16			PN20			PN25		
		t (mm)	ID (mm)	Mass (kg/m)	t (mm)	ID (mm)	Mass (kg/m)	t (mm)	ID (mm)	Mass (kg/m)	t (mm)	ID (mm)	Mass (kg/m)	t (mm)	ID (mm)	Mass (kg/m)	t (mm)	ID (mm)	Mass (kg/m)
375	426	7	412	18	7	412	18	7	413	17	6	414	16	6	414	16	6	414	15
450	507	8	490	27	8	490	27	8	491	25	7	492	23	7	493	22	7	493	21
525	587	10	568	36	10	568	36	9	569	33	8	570	30	8	571	29	8	571	28
600	667	11	646	46	11	646	46	10	647	42	9	648	38	9	649	37	9	649	36
675	747	12	723	57	12	723	57	11	725	53	10	726	48	10	727	46	10	727	45
750	826	13	800	70	13	800	70	12	802	64	11	803	58	11	804	56	11	804	55
900	923	15	894	87	15	894	87	14	896	81	13	898	72	12	898	70	12	899	68
1000	1025	16	993	106	16	993	106	15	995	99	14	997	89	14	998	86	13	998	83
1100*	1127	18	1092	128	18	1092	128	16	1094	119	15	1097	107	15	1098	103	15	1099	100
1200	1229	19	1191	152	19	1191	152	18	1193	142	16	1196	126	16	1197	122	16	1197	119
1300*	1331	21	1290	179	21	1290	179	19	1293	166	18	1296	148	17	1298	143	17	1298	139
1400	1433	22	1389	207	22	1389	207	21	1392	192	19	1395	171	19	1396	165	18	1396	160
1500*	1535	24	1488	238	24	1488	238	22	1491	220	20	1495	196	20	1497	189	20	1497	184
1600	1637	25	1587	270	25	1587	270	24	1590	250	21	1594	222	21	1596	214	21	1597	208
1700*	1739	27	1686	305	27	1686	305	25	1690	282	23	1694	251	22	1696	241	22	1697	235
1800	1841	28	1785	341	28	1785	341	26	1788	316	24	1793	280	23	1796	270	23	1796	262
1900*	1943	30	1885	379	30	1885	379	28	1888	351	25	1893	312	25	1895	300	24	1896	293
2000	2045	31	1983	419	31	1983	419	29	1987	389	27	1992	345	26	1995	332	26	1995	323
2100*	2147	33	2083	462	33	2083	462	31	2087	428	28	2092	380	27	2094	366	27	2095	351
2200	2249	34.3	2180	507	34.3	2180	507	32	2185	469	29	2192	417	28	2194	401	28	2195	377
2300*	2351	35.7	2281	553	35.7	2281	553	33	2285	513	30	2291	455	30	2294	438	29	2294	405
2400	2453	37	2379	602	37	2378	602	35	2383	558	32	2391	495	31	2393	476	31	2394	434
2500*	2555	39	2479	654	39	2479	654	36	2484	605	33	2490	536	32	2493	516	-	-	-
2600*	2657	40	2578	706	40	2578	706	38	2583	654	34	2590	580	33	2592	552	-	-	-
3000	3065	46	2974	938	46	2974	938	-	-	-	-	-	-	-	-	-	-	-	-

Note:
1. All dimensions and masses are nominal only. Pipe masses exclude the coupling
2. Sizes nominated * are subject to availability. Contact Iplex Pipelines for further information.

Table 4.4 FLOWTITE™ GRP pipe details - SN10000 (excluding pipe coupling)

DN	Spigot OD (mm)	Nominal pipe stiffness SN10000																				
		PN1			PN6			PN10			PN16			PN20			PN25			PN32		
		t (mm)	ID (mm)	Mass (kg/m)	t (mm)	ID (mm)	Mass (kg/m)	t (mm)	ID (mm)	Mass (kg/m)	t (mm)	ID (mm)	Mass (kg/m)	t (mm)	ID (mm)	Mass (kg/m)	t (mm)	ID (mm)	Mass (kg/m)	t (mm)	ID (mm)	Mass (kg/m)
300	345	8	328	16	8	328	16	8	328	16	8	328	16	6	332	13	6	332	13	6	333	13
375	426	8	409	22	8	409	22	8	409	22	8	410	21	8	411	20	8	411	19	8	411	19
450	507	10	487	32	10	487	32	10	487	32	9	489	29	9.	489	28	9	489	27	9	490	26
525	587	12	564	43	12	564	43	12	564	43	11	566	39	10	567	37	10	567	36	10	567	35
600	667	13	641	56	13	641	56	13	641	56	12	643	50	12	644	48	11	644	46	11	645	45
675	747	15	718	71	15	718	71	15	718	71	13	721	63	13	721	60	13	722	58	12	722	56
750	826	16	794	87	16	794	87	16	794	87	15	797	76	14	798	73	14	799	70	14	799	68
900	923	18	887	107	18	887	107	18	887	107	16	891	95	16	892	91	15	893	87	15	893	84
1000	1025	20	985	133	20	985	133	20	985	133	18	989	117	17	991	111	17	991	107	17	992	104
1100*	1127	22	1084	161	22	1084	161	22	1084	161	20	1088	141	19	1091	134	18	1091	129	18	1092	125
1200	1229	24	1181	191	24	1181	191	24	1181	191	21	1187	167	20	1188	159	20	1189	153	20	1190	148
1300*	1331	26	1280	223	26	1280	223	26	1280	223	23	1286	195	22	1288	186	22	1289	179	21	1290	173
1400	1433	28	1378	259	28	1378	259	28	1378	259	25	1384	226	24	1386	215	23	1387	207	23	1388	200
1500*	1535	29	1477	296	29	1477	296	29	1477	296	26	1483	259	25	1486	247	25	1487	237	24	1488	229
1600	1637	31	1574	337	31	1574	337	31	1574	337	28	1581	294	27	1585	280	26	1586	269	26	1587	260
1700*	1739	33	1674	379	33	1674	379	33	1674	379	30	1681	332	29	1684	316	28	1685	303	27	1686	291
1800	1841	35	1771	425	35	1771	425	35	1771	425	31	1778	372	30	1783	353	29	1784	340	29	1785	319
1900*	1943	37	1870	473	37	1870	473	37	1870	473	33	1878	413	32	1882	393	31	1883	378	-	-	-
2000	2045	39	1967	523	39	1967	523	39	1967	523	35	1976	458	33	1981	435	33	1982	419	-	-	-
2100*	2148	41	2067	576	41	2067	576	41	2067	576	36	2076	380	35	2079	366	34	2081	351	-	-	-
2200	2249	43	2164	632	43	2164	632	43	2164	632	38	2174	552	37	2178	525	36	2180	500	-	-	-
2300*	2351	45	2264	690	45	2264	690	45	2264	690	40	2273	604	38	2277	573	37	2279	540	-	-	-
2400	2453	47	2360	750	47	2360	750	47	2360	750	41	2372	657	40	2376	624	39	2378	580	-	-	-
2500*	2555	48	2460	814	48	2460	814	48	2460	814	43	2471	712	41	2475	678	-	-	-	-	-	-
2600*	2657	50	2559	881	50	2559	881	50	2559	881	45	2569	769	43	2574	731	-	-	-	-	-	-
3000	3065	58	2949	1170	58	2949	1170	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note:

1. *All dimensions and masses are nominal only. Pipe masses exclude the coupling*
2. *Sizes nominated * are subject to availability. Contact Iplex Pipelines for further information.*

Table 4.5 Coupling details

DN	Coupling length (mm)	Coupling dimensions & mass													
		PN1		PN6		PN10		PN16		PN20		PN25		PN32	
		OD +5/-0 (mm)	Mass (kg)	OD +5/-0 (mm)	Mass (kg)	OD +5/-0 (mm)	Mass (kg)	OD +5/-0 (mm)	Mass (kg)	OD +5/-0 (mm)	Mass (kg)	OD +5/-0 (mm)	Mass (kg)	OD +5/-0 (mm)	Mass (kg)
300	270	388	12	388	12	389	12	390	12	391	12	392	13	399	15
375	270	469	14	469	14	470	15	471	15	472	15	473	16	480	18
450	270	550	17	550	17	551	17	553	18	554	18	555	19	563	22
525	270	630	19	630	19	631	20	633	21	634	21	636	22	644	26
600	330	716	31	716	31	718	32	721	35	724	36	727	38	733	43
675	330	796	34	796	34	798	36	802	39	804	40	807	43	816	50
750	330	875	38	875	38	879	41	882	43	884	44	888	48	898	57
900	330	973	43	973	43	977	47	980	50	983	52	989	57	1005	73
1000	330	1076	48	1076	48	1080	54	1084	57	1087	59	1100	73	1116	91
1100*	330	1178	54	1178	54	1184	60	1188	64	1192	69	1208	87	1224	107
1200	330	1281	59	1281	59	1287	67	1291	72	1300	82	1315	101	1331	122
1300*	330	1383	65	1383	65	1389	73	1395	79	1406	95	1421	115	1334	137
1400	330	1486	71	1486	71	1492	79	1500	90	1512	107	1526	128	1542	151
1500*	330	1588	76	1588	76	1595	86	1605	101	1617	119	1631	141	1646	165
1600	330	1691	82	1691	82	1698	93	1710	113	1722	131	1736	154	1750	179
1700*	330	1793	88	1793	88	1800	100	1814	124	1826	143	1839	167	1853	192
1800	330	1896	93	1896	93	1903	107	1918	134	1930	155	1943	179	1957	206
1900*	330	1998	99	1998	99	2007	116	2022	146	2033	166	2046	191	-	-
2000	330	2100	105	2100	105	2110	125	2126	156	2137	178	2149	203	-	-
2100*	330	2203	111	2203	111	2214	135	2229	167	2240	189	2252	215	-	-
2200	330	2305	117	2305	117	2317	144	2333	178	2344	201	2355	227	-	-
2300*	330	2408	123	2408	123	2420	153	2436	188	2446	213	2457	239	-	-
2400	330	2510	130	2510	130	2523	163	2539	199	2549	224	2560	250	-	-
2500*	330	2612	136	2612	136	2626	172	2642	210	2652	235	-	-	-	-
2600*	360	2730	201	2730	201	2741	232	2755	268	2768	305	-	-	-	-
3000	360	3141	240	3141	240	3152	275	-	-	-	-	-	-	-	-

Note:

1. All dimensions and masses are nominal only.
2. Sizes nominated * are subject to availability. Contact Iplex Pipelines for further information.

GRP fittings

A range of Flowtite™ GRP fittings is available for pressure and non-pressure applications. The dimensions shown in the following tables are provided as a guide only and may change without notice. If dimensions are critical, contact Iplex Pipelines.

FLOWTITE™ GRP fittings are manufactured in PN1, PN6, PN10, PN16, PN20, PN25 and PN32 for use with FLOWTITE™ pipe of the corresponding class in all available diameters.

The fittings are manufactured in accordance with AS 3571.1 "Plastic piping systems – Glass reinforced thermo setting plastics (GRP) systems based on unsaturated polyester (UP) resin – Pressure and non pressure drainage and sewerage (ISO 10467:2004 Mod) and AS 3571.2 "Plastics piping systems – Glass reinforced thermoplastics (GRP) systems based on unsaturated polyester (UP) resin - Pressure and non-pressure water supply" (ISO 10639:2004, MOD).

FLOWTITE™ fittings are normally supplied with spigots machined to suit FLOWTITE™ couplings. Spigot dimensions are in accordance with Table 4.3 and Table 4.4.

FLOWTITE™ GRP pipes in sizes DN300 to DN750 are also compatible with series 2 ductile iron fittings and valves.

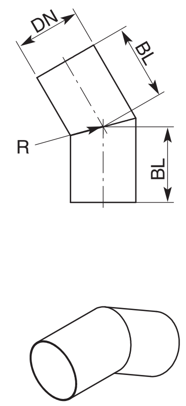
Some products are not shown but may be available on request to suit specific project requirements.

Figure 4.2 – Flanged off-takes for air valves and scours (Note stub flanges and backing plates, which are the preferred option)

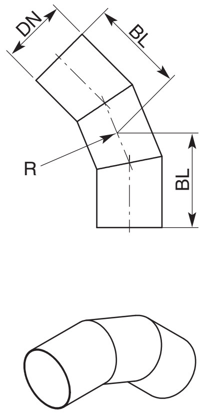
Figure 4.2a – Flange to spigot connectors drilled to specification

Figure 4.2b – FLOWTITE™ pressure bends with couplings ready for despatch

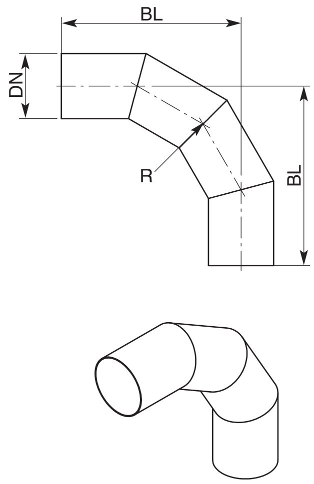
Bends:



11.25°, 22.5° & 30° Bends



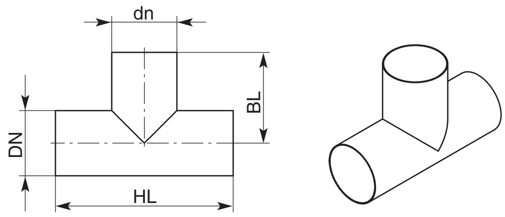
45° & 60° Bends



90° Bend

DN	Radius R (mm)	Lay length BL (mm)					
		11.25°	22.5°	30°	45°	60°	90°
300	450	400	400	400	500	550	750
375	600	450	450	450	600	650	900
450	675	450	500	500	600	700	1000
525	750	450	500	500	650	750	1050
600	900	400	400	450	600	700	1100
675	1050	400	450	450	650	800	1200
750	1200	450	450	500	700	850	1350
900	1350	450	500	550	800	950	1500
1000	1500	450	500	550	850	1000	1650
1200	1800	500	600	600	950	1200	1950
1400	2100	600	650	700	1100	1350	2250
1600	2400	650	750	800	1250	1550	2550
1800	2700	700	800	850	1350	1700	2850
2000	3000	700	800	900	1450	1800	3100
2200	3300	700	800	900	1550	1950	3350
2400	3600	700	800	1000	1550	2100	3600

Tees:



DN	dn	PN1		PN6		PN10		PN16		PN20		PN25		PN32	
		HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)
300	300	940	480	1020	520	1060	540	1120	560	1160	580	1180	600	1260	640
375	300	940	520	1040	560	1100	600	1140	620	1180	640	1220	660	1320	700
	375	1020	520	1180	580	1220	620	1280	640	1320	660	1360	680	1440	720
450	300	960	560	1040	600	1100	640	1140	660	1180	680	1240	700	1340	760
	375	1040	560	1180	640	1240	660	1300	680	1340	720	1400	740	1500	800
	450	1140	580	1320	660	1380	700	1440	740	1500	760	1540	780	1640	820
525	300	960	600	1040	640	1100	680	1160	700	1200	720	1260	760	1380	820
	375	1040	600	1200	680	1260	700	1320	740	1360	760	1420	780	1560	860
	450	1140	620	1340	720	1400	740	1460	780	1520	800	1580	840	1720	900
	525	1260	640	1460	740	1520	780	1600	800	1660	840	1720	860	1840	920
600	300	1020	640	1120	680	1160	720	1220	740	1260	760	1320	800	1480	880
	375	1120	640	1260	720	1320	740	1380	780	1440	800	1500	840	1660	920
	450	1220	660	1400	760	1460	780	1540	820	1600	860	1680	900	1820	960
	525	1320	680	1520	780	1580	820	1680	860	1740	880	1820	920	1960	1000
	600	1420	720	1660	840	1720	880	1820	920	1900	960	1960	1000	2080	1060
675	300	1040	680	1120	720	1160	760	1240	780	1280	820	1340	840	1500	940
	375	1120	680	1260	760	1320	780	1380	820	1440	840	1500	880	1680	980
	450	1220	700	1400	800	1480	820	1540	860	1620	900	1680	940	1860	1020
	525	1320	720	1540	820	1600	860	1680	900	1760	940	1840	980	2020	1060
	600	1420	760	1680	880	1740	920	1840	980	1920	1000	2000	1060	2140	1120
	675	1540	780	1800	900	1880	960	2000	1000	2060	1040	2140	1080	2280	1140
750	300	1040	720	1120	760	1160	800	1240	820	1280	860	1360	880	1540	980
	375	1120	720	1260	800	1320	820	1400	860	1460	900	1520	920	1720	1020
	450	1220	740	1400	840	1480	860	1560	920	1620	940	1700	980	1900	1080
	525	1320	760	1540	860	1620	900	1700	940	1780	980	1860	1020	2040	1120
	600	1440	800	1680	920	1760	960	1860	1020	1940	1060	2020	1100	2200	1180
	675	1540	820	1820	960	1900	1000	2000	1060	2100	1100	2180	1140	2360	1220
	750	1640	840	1940	980	2040	1020	2160	1080	2240	1120	2320	1160	2480	1240
900	300	1060	780	1120	820	1180	840	1240	880	1300	900	1400	960	1580	1040
	375	1140	780	1260	840	1320	880	1400	920	1460	940	1540	1000	1760	1100
	450	1220	780	1400	880	1480	920	1560	960	1640	1000	1720	1040	1920	1140
	525	1340	800	1560	920	1620	960	1720	1000	1800	1040	1880	1080	2100	1180
	600	1440	860	1700	980	1780	1020	1880	1080	1940	1100	2060	1160	2260	1260
	675	1560	880	1840	1000	1920	1060	2020	1100	2120	1140	2220	1200	2420	1300
	750	1660	880	1960	1040	2060	1080	2180	1140	2260	1180	2380	1240	2540	1340
	900	1780	900	2120	1060	2220	1120	2360	1180	2460	1240	2540	1280	-	-
1000	300	1050	850	1150	900	1200	900	1250	950	1350	1000	1450	1000	1600	1150
	375	1150	850	1300	900	1350	950	1450	1000	1500	1000	1600	1050	1800	1200
	450	1250	850	1450	950	1500	1000	1600	1050	1650	1050	1750	1100	2000	1250
	525	1350	850	1550	1000	1650	1000	1750	1050	1800	1100	1900	1150	2150	1300
	600	1500	950	1700	1050	1800	1100	1900	1150	2000	1200	2100	1250	2300	1350
	675	1600	950	1850	1100	1950	1100	2050	1200	2150	1200	2250	1250	2500	1400
	750	1700	950	2000	1100	2100	1150	2200	1200	2300	1250	2400	1300	2650	1450
	900	1800	950	2150	1150	2250	1200	2400	1250	2500	1300	2600	1350	-	-
	1000	1950	1000	2300	1150	2450	1250	2550	1300	2700	1350	2750	1400	-	-

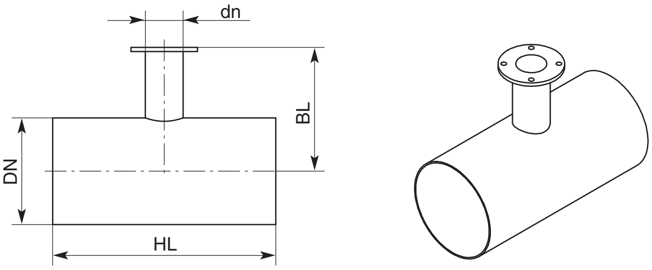
Tees - Continued...

DN	dn	PN1		PN6		PN10		PN16		PN20		PN25		PN32	
		HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)
1200	300	1100	950	1150	1000	1200	1000	1300	1050	1350	1100	1500	1150	1700	1250
	375	1150	950	1300	1000	1350	1050	1450	1100	1500	1150	1650	1200	1900	1300
	450	1250	950	1450	1050	1500	1100	1600	1150	1700	1200	1800	1250	2050	1350
	525	1400	1000	1600	1100	1650	1100	1750	1150	1850	1200	1950	1250	2250	1400
	600	1500	1050	1700	1150	1800	1200	1900	1250	2000	1300	2100	1350	2400	1500
	675	1600	1050	1850	1200	1950	1250	2100	1300	2150	1350	2300	1400	2600	1550
	750	1700	1050	2000	1200	2100	1250	2250	1300	2350	1350	2450	1450	2750	1600
	900	1850	1100	2150	1250	2300	1300	2400	1350	2550	1400	2650	1500	-	-
	1000	2000	1100	2350	1300	2450	1350	2600	1400	2700	1450	2850	1550	-	-
	1200	2250	1150	2700	1350	2800	1400	3000	1500	3100	1550	3250	1650	-	-
1400	300	1150	1050	1200	1100	1250	1100	1350	1150	1400	1200	1550	1300	1800	1400
	375	1200	1050	1300	1100	1400	1150	1500	1200	1550	1250	1700	1300	1950	1450
	450	1300	1050	1450	1150	1550	1200	1650	1250	1700	1300	1850	1350	2150	1500
	525	1400	1100	1600	1200	1650	1200	1800	1300	1850	1350	2000	1400	2300	1550
	600	1500	1150	1700	1250	1800	1300	1950	1350	2050	1400	2150	1450	2500	1650
	675	1600	1150	1850	1300	1950	1350	2100	1400	2200	1450	2350	1500	2650	1650
	750	1750	1150	2000	1300	2100	1350	2250	1450	2350	1500	2500	1550	2850	1750
	900	1850	1200	2150	1350	2300	1400	2450	1500	2550	1550	2700	1600	-	-
	1000	2000	1200	2350	1400	2500	1450	2650	1550	2750	1600	2900	1650	-	-
	1200	2250	1250	2700	1450	2850	1550	3000	1600	3150	1700	3300	1750	-	-
	1400	2550	1300	3050	1550	3200	1600	3400	1700	3550	1800	3700	1850	-	-
1600	300	1150	1150	1200	1200	1250	1250	1350	1300	-	-	-	-	-	-
	375	1250	1150	1300	1200	1400	1250	1500	1300	-	-	-	-	-	-
	450	1350	1150	1450	1250	1550	1300	1650	1350	-	-	-	-	-	-
	525	1400	1200	1600	1300	1700	1350	1800	1400	-	-	-	-	-	-
	600	1500	1250	1700	1350	1850	1400	1950	1450	-	-	-	-	-	-
	675	1650	1250	1900	1400	1950	1450	2100	1500	-	-	-	-	-	-
	750	1750	1250	2000	1400	2150	1450	2250	1550	-	-	-	-	-	-
	900	1850	1300	2200	1450	2300	1500	2450	1600	-	-	-	-	-	-
	1000	2000	1300	2350	1500	2500	1550	2650	1650	-	-	-	-	-	-
	1200	2300	1350	2700	1550	2900	1650	3050	1750	-	-	-	-	-	-
	1400	2550	1400	3050	1650	3250	1750	3450	1850	-	-	-	-	-	-
	1600	2800	1400	3400	1700	3600	1800	3800	1950	-	-	-	-	-	-
1800	300	1200	1250	1200	1300	1250	1350	1400	1400	-	-	-	-	-	-
	375	1300	1250	1350	1350	1400	1350	1550	1450	-	-	-	-	-	-
	450	1350	1300	1500	1350	1550	1400	1650	1450	-	-	-	-	-	-
	525	1450	1300	1600	1400	1700	1450	1800	1500	-	-	-	-	-	-
	600	1550	1350	1750	1450	1850	1500	2000	1600	-	-	-	-	-	-
	675	1650	1350	1900	1500	2000	1550	2150	1600	-	-	-	-	-	-
	750	1750	1350	2050	1500	2150	1550	2300	1650	-	-	-	-	-	-
	900	1850	1400	2200	1550	2300	1600	2500	1700	-	-	-	-	-	-
	1000	2050	1400	2350	1600	2500	1650	2700	1750	-	-	-	-	-	-
	1200	2300	1450	2750	1650	2900	1750	3100	1850	-	-	-	-	-	-
	1400	2600	1500	3100	1750	3250	1850	3500	1950	-	-	-	-	-	-
	1600	2850	1550	3450	1850	3600	1950	3850	2050	-	-	-	-	-	-
	1800	3100	1550	3750	1900	3950	2000	4250	2150	-	-	-	-	-	-
2000	300	1300	1400	1300	1400	1300	1500	1400	1500	-	-	-	-	-	-
	375	1400	1400	1400	1500	1500	1500	1600	1600	-	-	-	-	-	-
	450	1400	1400	1500	1500	1600	1500	1700	1600	-	-	-	-	-	-
	525	1500	1400	1600	1500	1700	1600	1900	1600	-	-	-	-	-	-
	600	1600	1500	1800	1600	1900	1600	2000	1700	-	-	-	-	-	-
	675	1700	1500	1900	1600	2000	1700	2200	1700	-	-	-	-	-	-
	750	1800	1500	2100	1600	2200	1700	2300	1800	-	-	-	-	-	-
	900	1900	1500	2200	1700	2400	1700	2500	1800	-	-	-	-	-	-
	1000	2100	1500	2400	1700	2500	1800	2700	1900	-	-	-	-	-	-
	1200	2300	1600	2800	1800	2900	1900	3100	2000	-	-	-	-	-	-
	1400	2600	1600	3100	1900	3300	2000	3500	2100	-	-	-	-	-	-

Tees - Continued...

DN	dn	PN1		PN6		PN10		PN16		PN20		PN25		PN32	
		HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)
2000	1600	2900	1700	3500	2000	3700	2100	3900	2200	-	-	-	-	-	-
	1800	3200	1700	3800	2000	4000	2100	4300	2300	-	-	-	-	-	-
	2000	3400	1700	4200	2100	4400	2200	4700	2400	-	-	-	-	-	-
2200	300	1300	1500	1300	1500	1400	1600	-	-	-	-	-	-	-	-
	375	1400	1500	1400	1600	1500	1600	-	-	-	-	-	-	-	-
	450	1500	1500	1500	1600	1600	1600	-	-	-	-	-	-	-	-
	525	1600	1500	1700	1600	1800	1700	-	-	-	-	-	-	-	-
	600	1600	1600	1800	1700	1900	1700	-	-	-	-	-	-	-	-
	675	1700	1600	1900	1700	2000	1800	-	-	-	-	-	-	-	-
	750	1800	1600	2100	1700	2200	1800	-	-	-	-	-	-	-	-
	900	1900	1600	2200	1800	2400	1900	-	-	-	-	-	-	-	-
	1000	2100	1600	2400	1800	2600	1900	-	-	-	-	-	-	-	-
	1200	2400	1700	2800	1900	2900	2000	-	-	-	-	-	-	-	-
	1400	2600	1700	3100	2000	3300	2100	-	-	-	-	-	-	-	-
	1600	2900	1800	3500	2100	3700	2200	-	-	-	-	-	-	-	-
	1800	3200	1800	3900	2200	4100	2300	-	-	-	-	-	-	-	-
	2000	3400	1800	4200	2200	4400	2300	-	-	-	-	-	-	-	-
	2200	3700	1900	4500	2300	4800	2400	-	-	-	-	-	-	-	-
2400	300	1400	1600	1400	1700	1400	1700	-	-	-	-	-	-	-	-
	375	1400	1600	1400	1700	1500	1700	-	-	-	-	-	-	-	-
	450	1500	1600	1600	1700	1600	1700	-	-	-	-	-	-	-	-
	525	1600	1600	1700	1700	1800	1800	-	-	-	-	-	-	-	-
	600	1700	1700	1800	1800	1900	1800	-	-	-	-	-	-	-	-
	675	1800	1700	1900	1800	2100	1900	-	-	-	-	-	-	-	-
	750	1900	1700	2100	1800	2200	1900	-	-	-	-	-	-	-	-
	900	2000	1700	2200	1900	2400	2000	-	-	-	-	-	-	-	-
	1000	2100	1800	2400	1900	2600	2000	-	-	-	-	-	-	-	-
	1200	2400	1800	2800	2000	2900	2100	-	-	-	-	-	-	-	-
	1400	2600	1800	3100	2100	3300	2200	-	-	-	-	-	-	-	-
	1600	2900	1900	3500	2200	3700	2300	-	-	-	-	-	-	-	-
	1800	3200	1900	3900	2300	4100	2400	-	-	-	-	-	-	-	-
	2000	3500	2000	4200	2300	4500	2500	-	-	-	-	-	-	-	-
	2200	3700	2000	4600	2400	4800	2500	-	-	-	-	-	-	-	-
	2400	4000	2000	4900	2500	5100	2600	-	-	-	-	-	-	-	-

Air valve tees:

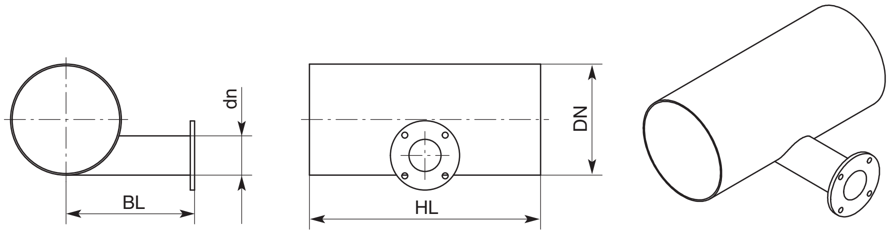


DN	dn	PN1		PN6		PN10		PN16		PN20		PN25		PN32	
		HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)
300	80	700	400	700	400	700	400	720	400	740	420	760	420	800	440
	100	720	400	720	400	720	400	760	400	780	420	800	420	840	460
375	80	700	440	700	440	700	440	740	440	740	460	780	460	820	500
	100	720	440	720	440	740	440	760	440	780	460	820	480	860	500
450	80	700	480	700	480	720	480	740	500	780	500	800	520	840	540
	100	740	480	740	480	740	480	780	500	800	500	820	520	880	540
	150	780	480	780	480	800	480	840	500	880	520	920	540	1000	580
525	80	700	520	700	520	720	520	760	540	780	540	820	560	880	600
	100	740	520	740	520	760	520	780	540	820	560	860	580	920	600
	150	780	520	780	520	800	520	860	540	880	560	920	580	1020	640
600	80	760	560	760	560	800	560	820	580	860	600	880	620	960	640
	100	800	560	800	560	820	560	860	580	900	600	920	620	1000	660
	150	840	560	840	560	880	560	920	580	960	600	1000	620	1120	700
	200	900	560	920	580	960	600	1000	620	1040	640	1100	660	1220	740
675	80	780	600	780	600	800	600	840	620	860	640	900	660	1000	700
	100	800	600	800	600	820	600	880	620	900	640	940	660	1040	720
	150	860	600	860	600	880	620	940	640	980	660	1020	680	1160	760
	200	920	600	920	620	960	640	1000	660	1060	680	1120	720	1260	780
750	100	800	640	800	640	820	640	880	660	920	700	960	720	1060	760
	150	860	640	860	640	880	660	940	680	980	700	1060	740	1180	800
	200	920	640	920	660	960	680	1020	700	1060	720	1140	760	1300	840
	250	980	660	1020	680	1060	700	1120	720	1160	760	1260	800	1420	880
900	100	800	680	820	680	840	700	900	720	920	740	980	780	1100	840
	150	860	680	880	680	900	700	960	720	1000	760	1080	800	1220	860
	200	940	700	940	700	960	720	1040	760	1080	780	1180	840	1340	920
	250	980	700	1020	720	1080	760	1140	780	1180	800	1280	860	1440	940
1000	100	850	750	850	750	900	750	900	800	950	800	1050	850	1150	950
	150	900	750	900	750	950	750	1000	800	1050	850	1150	900	1300	950
	200	950	750	950	750	1000	800	1050	800	1100	850	1250	900	1400	1000
	250	1000	750	1050	800	1100	800	1150	850	1200	900	1350	950	1500	1000
1200	100	850	850	850	850	900	850	950	900	1000	950	1100	1000	1250	1050
	150	900	850	900	850	950	900	1000	900	1100	950	1200	1000	1350	1100
	200	950	900	950	900	1000	900	1100	950	1150	1000	1300	1050	1500	1150
	250	1050	900	1050	900	1100	900	1200	950	1250	1000	1400	1050	1600	1150
1400	100	900	950	900	950	900	1000	1000	1000	1050	1050	1200	1150	1350	1200
	150	950	950	950	950	950	1000	1050	1000	1150	1100	1300	1150	1450	1250
	200	1000	1000	1000	1000	1050	1000	1150	1050	1250	1100	1350	1200	1550	1300
	250	1050	1000	1050	1000	1100	1050	1200	1050	1300	1150	1450	1200	1700	1300
1600	100	950	1050	950	1050	950	1100	1050	1150	-	-	-	-	-	-
	150	1000	1050	1000	1100	1050	1100	1100	1150	-	-	-	-	-	-
	200	1050	1100	1050	1100	1100	1100	1150	1200	-	-	-	-	-	-
	250	1100	1100	1100	1100	1150	1150	1250	1200	-	-	-	-	-	-

Air valve tees - Continued...

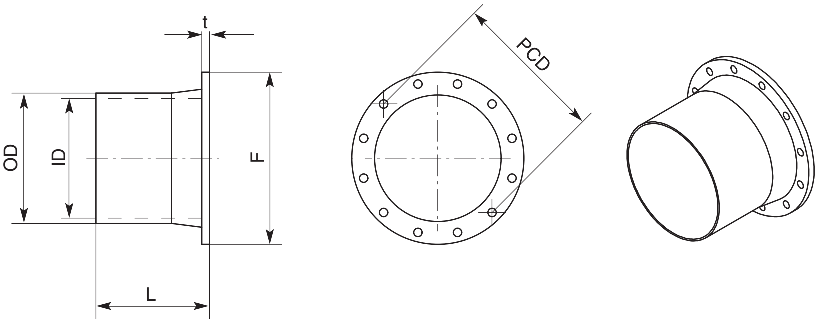
DN	dn	PN1		PN6		PN10		PN16		PN20		PN25		PN32	
		HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)
1800	100	1000	1200	1000	1200	1000	1200	1100	1250	-	-	-	-	-	-
	150	1050	1200	1050	1200	1050	1200	1150	1250	-	-	-	-	-	-
	200	1100	1200	1100	1200	1100	1200	1250	1300	-	-	-	-	-	-
	250	1150	1200	1150	1200	1200	1250	1300	1300	-	-	-	-	-	-
2000	100	1000	1300	1000	1300	1100	1300	1200	1400	-	-	-	-	-	-
	150	1100	1300	1100	1300	1100	1300	1200	1400	-	-	-	-	-	-
	200	1200	1300	1200	1300	1200	1400	1300	1400	-	-	-	-	-	-
	250	1200	1300	1200	1300	1300	1400	1400	1500	-	-	-	-	-	-
2200	100	1100	1400	1100	1400	1100	1400	-	-	-	-	-	-	-	-
	150	1100	1400	1100	1400	1200	1400	-	-	-	-	-	-	-	-
	200	1200	1400	1200	1400	1200	1500	-	-	-	-	-	-	-	-
	250	1300	1400	1300	1500	1300	1500	-	-	-	-	-	-	-	-
2400	100	1100	1500	1100	1500	1200	1600	-	-	-	-	-	-	-	-
	150	1200	1500	1200	1500	1200	1600	-	-	-	-	-	-	-	-
	200	1200	1500	1200	1500	1300	1600	-	-	-	-	-	-	-	-
	250	1300	1500	1300	1600	1300	1600	-	-	-	-	-	-	-	-

Scour tees:



DN	dn	PN1		PN6		PN10		PN16		PN20		PN25	
		HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)	HL (mm)	BL (mm)
300	100	720	380	720	380	740	380	780	400	800	420	820	420
375	100	720	400	720	400	760	420	780	420	800	440	840	480
450	100	740	440	740	440	760	440	780	460	820	480	860	520
	150	780	440	780	440	820	480	860	500	900	520	960	560
525	100	740	460	740	460	760	460	800	480	820	500	860	540
	150	780	480	800	480	840	500	880	540	900	560	980	600
600	100	800	480	800	480	820	500	860	520	900	540	920	580
	150	840	520	860	520	900	540	940	580	980	600	1040	640
	200	900	540	940	560	960	580	1020	620	1080	660	1180	700
675	100	800	500	800	500	820	520	880	540	900	580	940	600
	150	860	540	860	540	900	560	940	600	1000	640	1060	680
	200	920	580	940	600	980	620	1040	660	1080	680	1220	760
750	100	800	520	800	520	820	540	880	580	900	600	940	640
	150	860	560	860	560	900	580	940	620	1000	660	1080	700
	200	920	600	940	620	980	640	1040	700	1120	740	1220	780
	250	980	640	1020	660	1080	680	1140	720	1220	780	1360	840
900	100	800	560	800	560	840	560	880	600	920	620	960	660
	150	880	600	880	600	900	620	960	660	1000	700	1080	740
	200	940	640	940	660	1000	680	1060	720	1140	780	1240	840
	250	1000	660	1040	700	1080	720	1160	780	1240	820	1380	900
1000	100	850	600	850	600	850	600	900	650	950	650	1000	700
	150	900	650	900	650	950	650	1000	700	1000	750	1100	800
	200	950	700	950	700	1000	700	1100	800	1150	850	1250	900
	250	1000	700	1050	750	1100	800	1200	850	1300	900	1400	950
1200	100	850	650	850	650	850	650	900	700	950	750	1000	800
	150	900	700	900	700	950	700	1000	800	1050	800	1150	850
	200	950	750	950	750	1000	800	1100	850	1200	900	1300	1000
	250	1050	800	1050	800	1100	850	1200	900	1300	950	1450	1050
1400	100	900	700	900	700	900	700	950	750	1000	800	1050	850
	150	950	750	950	750	950	750	1000	850	1050	850	1200	950
	200	1000	800	1000	800	1050	850	1100	900	1200	1000	1350	1050
	250	1050	850	1100	900	1150	900	1200	1000	1350	1050	1500	1150
1600	100	950	750	950	750	950	750	1000	800	-	-	-	-
	150	1000	800	1000	800	1000	850	1050	900	-	-	-	-
	200	1050	850	1050	850	1100	900	1150	1000	-	-	-	-
	250	1100	900	1100	950	1150	950	1250	1050	-	-	-	-
1800	100	1000	800	1000	800	1000	800	1000	850	-	-	-	-
	150	1050	850	1050	850	1050	850	1100	950	-	-	-	-
	200	1100	950	1100	950	1100	950	1200	1050	-	-	-	-
	250	1150	1000	1150	1000	1200	1000	1250	1100	-	-	-	-
2000	100	1000	900	1000	900	1000	900	1100	900	-	-	-	-
	150	1100	900	1100	900	1100	900	1200	1000	-	-	-	-
	200	1200	1000	1200	1000	1200	1000	1200	1100	-	-	-	-
	250	1200	1100	1200	1100	1200	1100	1300	1200	-	-	-	-
2200	100	1100	900	1100	900	1100	900	-	-	-	-	-	-
	150	1100	1000	1100	1000	1200	1000	-	-	-	-	-	-
	200	1200	1100	1200	1100	1200	1100	-	-	-	-	-	-
	250	1300	1100	1300	1100	1300	1200	-	-	-	-	-	-
2400	100	1100	1000	1100	1000	1100	1000	-	-	-	-	-	-
	150	1200	1000	1200	1000	1200	1000	-	-	-	-	-	-
	200	1200	1100	1200	1100	1300	1100	-	-	-	-	-	-
	250	1300	1200	1300	1200	1300	1200	-	-	-	-	-	-

Flange spigot connectors:



DN	PN	Stiffness (N/m.m)	OD (mm)	ID (mm)	Standard reference	F (mm)	PCD (mm)	Number of holes	Diameter of holes (mm)	Fastener size	t (mm)	L (mm)
300	6	10000	344	330.4	AS/NZS 4087 PN16	455	406	12	22	M20	20	400
375	6	10000	425	408.4	AS/NZS 4087 PN16	550	495	12	26	M24	22	450
450	6	10000	506	486.2	AS/NZS 4087 PN16	640	584	12	26	M24	25	450
525	6	10000	586	563.2	AS/NZS 4087 PN16	825	756	16	30	M27	41	450
600	6	10000	666	640.1	AS/NZS 4087 PN16	825	756	16	30	M27	32	500
675	6	10000	746	717.0	AS/NZS 4087 PN16	910	845	20	30	M27	36	550
750	6	10000	825	793.1	AS/NZS 4087 PN16	995	927	20	33	M30	38	550
900	6	10000	922	886.8	AS/NZS 4087 PN16	1175	1092	24	36	M33	53	600
1000	6	10000	1024	984.9	AS/NZS 4087 PN16	1255	1175	24	36	M33	52	650
1200	6	10000	1228	1181.5	AS/NZS 4087 PN16	1490	1410	32	36	M33	63	750
300	10	10000	344	330.4	AS/NZS 4087 PN16	455	406	12	22	M20	25	400
375	10	10000	425	408.4	AS/NZS 4087 PN16	550	495	12	26	M24	29	450
450	10	10000	506	486.2	AS/NZS 4087 PN16	640	584	12	26	M24	33	450
525	10	10000	586	563.2	AS/NZS 4087 PN16	825	756	16	30	M27	53	450
600	10	10000	666	640.1	AS/NZS 4087 PN16	825	756	16	30	M27	41	500
675	10	10000	746	717.1	AS/NZS 4087 PN16	910	845	20	30	M27	46	550
750	10	10000	825	793.1	AS/NZS 4087 PN16	995	927	20	33	M30	49	550
900	10	10000	922	886.8	AS/NZS 4087 PN16	1175	1092	24	36	M33	68	600
1000	10	10000	1024	984.9	AS/NZS 4087 PN16	1255	1175	24	36	M33	67	650
1200	10	10000	1228	1181.5	AS/NZS 4087 PN16	1490	1410	32	36	M33	81	750
300	16	10000	344	330.9	AS/NZS 4087 PN16	455	406	12	22	M20	31	400
375	16	10000	425	409.2	AS/NZS 4087 PN16	550	495	12	26	M24	36	450
450	16	10000	506	487.7	AS/NZS 4087 PN16	640	584	12	26	M24	41	450
525	16	10000	586	565.0	AS/NZS 4087 PN16	825	756	16	30	M27	67	450
600	16	10000	666	642.4	AS/NZS 4087 PN16	825	756	16	30	M27	51	500
675	16	10000	746	719.8	AS/NZS 4087 PN16	910	845	20	30	M27	58	550
750	16	10000	825	796.3	AS/NZS 4087 PN16	995	927	20	33	M30	62	550
900	16	10000	922	890.2	AS/NZS 4087 PN16	1175	1092	24	36	M33	85	600
1000	16	10000	1024	988.9	AS/NZS 4087 PN16	1255	1175	24	36	M33	83	650
1200	16	10000	1228	1186.4	AS/NZS 4087 PN16	1490	1410	32	36	M33	102	750
300	20	10000	345	332.2	AS/NZS 4087 PN 21	495	438	16	26	M24	46	400
375	20	10000	426	410.6	AS/NZS 4087 PN 21	580	521	16	30	M27	50	450
450	20	10000	507	489.0	AS/NZS 4087 PN 21	675	610	20	33	M30	59	450
525	20	10000	587	566.6	AS/NZS 4087 PN 21	855	781	24	36	M33	89	450
600	20	10000	667	644.1	AS/NZS 4087 PN 21	855	781	24	36	M33	71	500
675	20	10000	747	721.7	AS/NZS 4087 PN 21	935	857	24	36	M33	72	550
750	20	10000	826	798.3	AS/NZS 4087 PN 21	1015	940	28	36	M33	78	550
900	20	10000	923	892.3	AS/NZS 4087 PN 21	1185	1105	32	39	M36	106	600
1000	20	10000	1025	991.2	AS/NZS 4087 PN 21	1275	1194	36	39	M36	109	650
1200	20	10000	1229	1189.0	AS/NZS 4087 PN 21	1530	1441	40	42	M39	133	750

Flange spigot connectors - Continued...

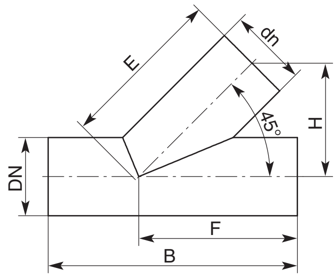
DN	PN	Stiffness (N/m.m)	OD (mm)	ID (mm)	Standard reference	F (mm)	PCD (mm)	Number of holes	Diameter of holes (mm)	Fastener size	t (mm)	L (mm)
300	6	10000	344	330.4	AS 2129 TABLE D	455	406	12	22	M20	20	400
375	6	10000	425	408.4	AS 2129 TABLE D	580	521	12	26	M24	26	450
450	6	10000	506	486.2	AS 2129 TABLE D	640	584	12	26	M24	25	450
525	6	10000	586	563.2	AS 2129 TABLE D	760	699	16	30	M27	34	450
600	6	10000	666	640.1	AS 2129 TABLE D	825	756	16	30	M27	32	500
675	6	10000	746	717.0	AS 2129 TABLE D	910	845	20	30	M27	36	550
750	6	10000	825	793.1	AS 2129 TABLE D	995	927	20	33	M30	38	550
900	6	10000	922	886.8	AS 2129 TABLE D	1175	1092	24	36	M33	53	600
1000	6	10000	1024	984.9	AS 2129 TABLE D	1255	1175	24	36	M33	52	650
1200	6	10000	1228	1181.5	AS 2129 TABLE D	1490	1410	32	36	M33	63	750
1400	6	10000	1432	1378.1	AS 2129 TABLE D	1700	1615	36	36	M33	68	800
1600	6	10000	1636	1574.7	AS 2129 TABLE D	1910	1825	40	39	M36	75	850
1800	6	10000	1840	1771.4	AS 2129 TABLE D	2110	2019	44	42	M39	79	950
2000	6	10000	2044	1968.2	AS 2129 TABLE D	2345	2250	44	42	M39	87	1000
2200	6	10000	2248	2164.8	AS 2129 TABLE D	2560	2460	44	48	M45	94	1050
2400	6	10000	2452	2361.6	AS 2129 TABLE D	2775	2673	52	48	M45	102	1100
3000	6	10000	3064	2951.5	AS 2129 TABLE D	3430	3315	60	55	M52	124	1200
300	10	10000	344	330.4	AS 2129 TABLE E	460	406	12	26	M24	25	400
375	10	10000	425	408.4	AS 2129 TABLE E	580	521	12	26	M24	34	450
450	10	10000	506	486.2	AS 2129 TABLE E	640	584	16	26	M24	34	450
525	10	10000	586	563.2	AS 2129 TABLE E	825	756	16	33	M30	54	450
600	10	10000	666	640.1	AS 2129 TABLE E	825	756	16	33	M30	41	500
675	10	10000	746	717.1	AS 2129 TABLE E	910	845	20	33	M30	47	550
750	10	10000	825	793.1	AS 2129 TABLE E	1000	927	20	36	M33	50	550
900	10	10000	922	886.8	AS 2129 TABLE E	1175	1092	24	36	M33	68	600
1000	10	10000	1024	984.9	AS 2129 TABLE E	1255	1175	24	39	M36	67	650
1200	10	10000	1228	1181.5	AS 2129 TABLE E	1490	1410	32	39	M36	83	750
300	16	10000	344	330.9	AS 2129 TABLE F	495	438	16	26	M24	41	400
375	16	10000	425	409.2	AS 2129 TABLE F	615	552	20	30	M27	54	450
450	16	10000	506	487.7	AS 2129 TABLE F	675	610	20	33	M30	53	450
525	16	10000	586	565.0	AS 2129 TABLE F	855	781	24	36	M33	80	450
600	16	10000	666	642.4	AS 2129 TABLE F	855	781	24	36	M33	64	500
675	16	10000	746	719.8	AS 2129 TABLE F	935	857	24	36	M33	65	550
750	16	10000	825	796.3	AS 2129 TABLE F	1015	940	28	36	M33	71	550
900	16	10000	922	890.2	AS 2129 TABLE F	1185	1105	32	39	M36	95	600
1000	16	10000	1024	988.9	AS 2129 TABLE F	1275	1194	36	39	M36	98	650
1200	16	10000	1228	1186.4	AS 2129 TABLE F	1530	1441	40	42	M39	120	750
300	6	10000	344	330.4	AS/NZS 4331 PN6	445	395	12	22	M20	20	400
375	6	10000	425	408.4	AS/NZS 4331 PN6	545	495	22	16	M20	24	450
450	6	10000	506	486.2	AS/NZS 4331 PN6	600	550	16	22	M20	20	450
525	6	10000	586	563.2	AS/NZS 4331 PN6	760	705	20	26	M24	35	450
600	6	10000	666	645	AS/NZS 4331 PN6	760	705	20	26	M24	23	500
675	6	10000	746	717.0	AS/NZS 4331 PN6	865	810	24	26	M24	30	550
750	6	10000	825	793.1	AS/NZS 4331 PN6	980	920	24	29.5	M27	38	550
900	6	10000	922	886.8	AS/NZS 4331 PN6	1080	1020	24	29.5	M27	40	600
1000	6	10000	1024	984.9	AS/NZS 4331 PN6	1180	1120	28	29.5	M27	42	650
1200	6	10000	1228	1181.5	AS/NZS 4331 PN6	1405	1340	32	32.5	M30	50	750
1400	6	10000	1432	1378.1	AS/NZS 4331 PN6	1630	1560	36	35.5	M33	58	800
1600	6	10000	1636	1574.7	AS/NZS 4331 PN6	1830	1760	40	35.5	M33	62	850
1800	6	10000	1840	1771.4	AS/NZS 4331 PN6	2045	1970	44	39	M36	68	950
2000	6	10000	2044	1968.2	AS/NZS 4331 PN6	2265	2180	48	42	M39	75	1000
2200	6	10000	2248	2164.8	AS/NZS 4331 PN6	2475	2390	52	42	M39	80	1050
2400	6	10000	2452	2361.6	AS/NZS 4331 PN6	2685	2600	56	42	M39	86	1100
3000	6	10000	3064	2951.5	AS/NZS 4331 PN6	3315	3220	68	48	M45	103	1200

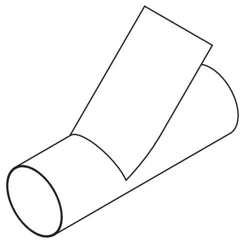
Flange spigot connectors - Continued...

DN	PN	Stiffness (N/m.m)	OD (mm)	ID (mm)	Standard reference	F (mm)	PCD (mm)	Number of holes	Diameter of holes (mm)	Fastener size	t (mm)	L (mm)
300	10	10000	344	330.4	AS/NZS 4331 PN10	450	400	12	22	M20	23	400
375	10	10000	425	408.4	AS/NZS 4331 PN10	570	515	16	26	M24	34	450
450	10	10000	506	486.2	AS/NZS 4331 PN10	620	565	20	26	M24	31	450
525	10	10000	586	563.2	AS/NZS 4331 PN10	785	725	20	29.5	M27	50	450
600	10	10000	666	646	AS/NZS 4331 PN10	785	725	20	29.5	M27	35	500
675	10	10000	746	717.1	AS/NZS 4331 PN10	900	840	24	29.5	M27	46	550
750	10	10000	825	793.1	AS/NZS 4331 PN10	1015	950	24	32.5	M30	56	550
900	10	10000	922	886.8	AS/NZS 4331 PN10	1115	1050	28	32.5	M30	60	600
1000	10	10000	1024	984.9	AS/NZS 4331 PN10	1230	1160	28	35.5	M33	65	650
1200	10	10000	1228	1181.5	AS/NZS 4331 PN10	1455	1380	32	39	M36	76	750
1400	10	10000	1432	1378.1	AS/NZS 4331 PN10	1675	1590	36	42	M39	85	800
1600	10	10000	1636	1574.7	AS/NZS 4331 PN10	1915	1820	40	48	M45	100	850
1800	10	10000	1840	1771.4	AS/NZS 4331 PN10	2115	2020	44	48	M45	105	950
2000	10	10000	2044	1968.2	AS/NZS 4331 PN10	2325	2230	48	48	M45	113	1000
2200	10	10000	2248	2164.8	AS/NZS 4331 PN10	2550	2440	52	55	M52	125	1050
2400	10	10000	2452	2361.6	AS/NZS 4331 PN10	2760	2650	56	55	M52	133	1100
300	16	10000	344	330.9	AS/NZS 4331 PN16	465	410	12	26	M24	33	400
375	16	10000	425	409.2	AS/NZS 4331 PN16	585	525	16	29.5	M27	46	450
450	16	10000	506	487.7	AS/NZS 4331 PN16	645	585	20	29.5	M27	45	450
525	16	10000	586	565.0	AS/NZS 4331 PN16	840	770	20	35.5	M33	74	450
600	16	10000	666	642.4	AS/NZS 4331 PN16	840	770	20	35.5	M33	58	500
675	16	10000	746	719.8	AS/NZS 4331 PN16	910	840	24	35.5	M33	60	550
750	16	10000	825	796.3	AS/NZS 4331 PN16	1025	950	24	39	M36	72	550
900	16	10000	922	890.2	AS/NZS 4331 PN16	1125	1050	28	39	M36	78	600
1000	16	10000	1024	988.9	AS/NZS 4331 PN16	1255	1170	28	42	M39	87	650
1200	16	10000	1228	1186.4	AS/NZS 4331 PN16	1485	1390	32	48	M45	103	750
1400	16	10000	1432	1383.9	AS/NZS 4331 PN16	1685	1590	36	48	M45	110	800
1600	16	10000	1636	1581.4	AS/NZS 4331 PN16	1930	1820	40	55	M52	130	850
1800	16	10000	1840	1778.9	AS/NZS 4331 PN16	2130	2020	44	55	M52	137	950

Non pressure (PN1) slope junctions:

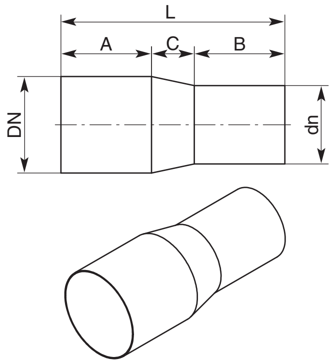
DN	dn	B (mm)	H (mm)	F (mm)	E (mm)	Mass (kg)
300	300	1100	710	700	500	30
375	300	1100	780	750	550	37
	375	1300	850	850	600	48
450	300	1100	850	800	600	48
	375	1300	920	900	650	62
	450	1400	920	950	650	74
525	300	1100	850	800	600	61
	375	1300	920	900	650	77
	450	1400	990	950	700	91
	525	1500	990	1000	700	108
600	300	1100	920	850	650	77
	375	1300	990	950	700	95
	450	1400	990	1000	700	112
	525	1500	1060	1050	750	130
	600	1600	1130	1100	800	153
675	300	1100	990	900	700	94
	375	1300	1060	1000	750	116
	450	1400	1060	1050	750	134
	525	1500	1130	1100	800	155
	600	1700	1200	1200	850	188
	675	1900	1270	1300	900	225
750	300	1100	1060	950	750	113
	375	1300	1130	1050	800	138
	450	1400	1130	1100	800	158
	525	1500	1200	1150	850	182
	600	1700	1270	1250	900	218
	675	1900	1340	1350	950	259
	750	2100	1410	1450	1000	304

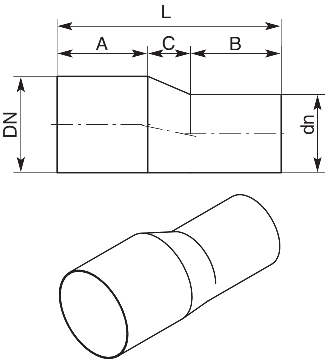




Reducers:

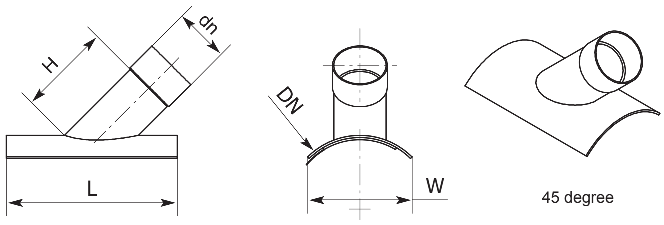
DN	dn	A (mm)	B (mm)	C (mm)	L (mm)
375	300	400	400	188	988
450	300	400	400	375	1175
450	375	400	400	188	988
525	300	400	400	563	1363
525	375	400	400	375	1175
525	450	400	400	188	988
600	300	400	400	750	1550
600	375	400	400	563	1363
600	450	400	400	375	1175
600	525	400	400	188	988
675	375	400	400	750	1550
675	450	400	400	563	1363
675	525	400	400	375	1175
675	600	400	400	188	988
750	375	400	400	938	1738
750	450	400	400	750	1550
750	525	400	400	563	1363
750	600	400	400	375	1175
900	525	400	400	938	1738
900	600	400	400	750	1550
900	675	400	400	563	1363
900	750	400	400	375	1175
1000	600	400	400	1000	1800
1000	675	400	400	813	1613
1000	750	400	400	625	1425
1000	900	400	400	250	1050
1200	675	500	500	1313	2313
1200	750	500	500	1125	2125
1200	900	500	500	750	1750
1200	1000	500	500	500	1500
1400	750	500	500	1625	2625
1400	900	500	500	1250	2250
1400	1000	500	500	1000	2000
1400	1200	500	500	500	1500
1600	900	600	600	1750	2950
1600	1000	600	600	1500	2700
1600	1200	600	600	1000	2200
1600	1400	600	600	500	1700
1800	1000	600	600	2000	3200
1800	1200	600	600	1500	2700
1800	1400	600	600	1000	2200
1800	1600	600	600	500	1700
2000	1200	600	600	2000	3200
2000	1400	600	600	1500	2700
2000	1600	600	600	1000	2200
2000	1800	600	600	500	1700
2200	1400	600	600	2000	3200
2200	1600	600	600	1500	2700
2200	1800	600	600	1000	2200
2200	2000	600	600	500	1700
2400	1600	600	600	2000	3200
2400	1800	600	600	1500	2700
2400	2000	600	600	1000	2200
2400	2200	600	600	500	1700



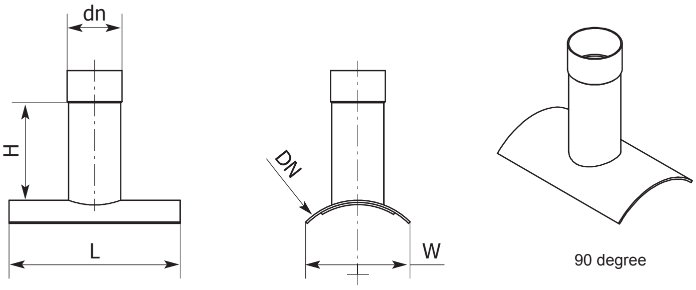


Saddle junctions (non pressure):

DN	dn	H (mm)	45 degree L (mm)	45 degree W (mm)	90 degree L (mm)	90 degree W (mm)
300	100	400	400	260	260	260
300	150	400	450	315	310	315
375	100	400	400	260	260	260
375	150	400	450	315	310	315
375	225	400	570	410	400	410
375	300	400	670	490	470	490
450	100	400	400	260	260	260
450	150	400	450	315	310	315
450	225	400	570	410	400	410
450	300	400	670	490	470	490
525	100	400	400	260	260	260
525	150	400	450	315	310	315
525	225	400	570	410	400	410
525	300	400	670	490	470	490
600	100	400	400	260	260	260
600	150	400	450	315	310	315
600	225	400	570	410	400	410
600	300	400	670	490	470	490
675	100	400	400	260	260	260
675	150	400	450	315	310	315
675	225	400	570	410	400	410
675	300	400	670	490	470	490
750	100	400	400	260	260	260
750	150	400	450	315	310	315
750	225	400	570	410	400	410
750	300	400	670	490	470	490
900	100	400	400	260	260	260
900	150	400	450	315	310	315
900	225	400	570	410	400	410
900	300	400	670	490	470	490
1000	100	400	400	260	260	260
1000	150	400	450	315	310	315
1000	225	400	570	410	400	410
1000	300	400	670	490	470	490
1200	100	400	400	260	260	260
1200	150	400	450	315	310	315
1200	225	400	570	410	400	410
1200	300	400	670	490	470	490
1400	100	400	400	260	260	260
1400	150	400	450	315	310	315
1400	225	400	570	410	400	410
1400	300	400	670	490	470	490
1600	100	400	400	260	260	260
1600	150	400	450	315	310	315
1600	225	400	570	410	400	410
1600	300	400	670	490	470	490
1800	100	400	400	260	260	260
1800	150	400	450	315	310	315
1800	225	400	570	410	400	410
1800	300	400	670	490	470	490
2000	100	400	400	260	260	260
2000	150	400	450	315	310	315
2000	225	400	570	410	400	410
2000	300	400	670	490	470	490
2200	100	400	400	260	260	260
2200	150	400	450	315	310	315
2200	225	400	570	410	400	410
2200	300	400	670	490	470	490
2400	100	400	400	260	260	260
2400	150	400	450	315	310	315
2400	225	400	570	410	400	410
2400	300	400	670	490	470	490
3000	100	400	400	260	260	260
3000	150	400	450	315	310	315
3000	225	400	570	410	400	410
3000	300	400	670	490	470	490



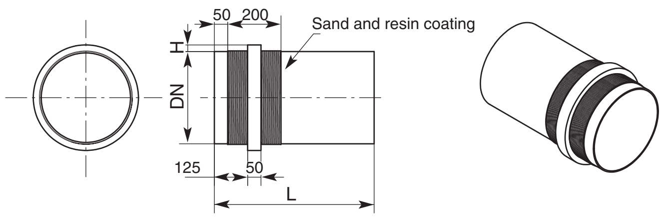
45 degree



90 degree

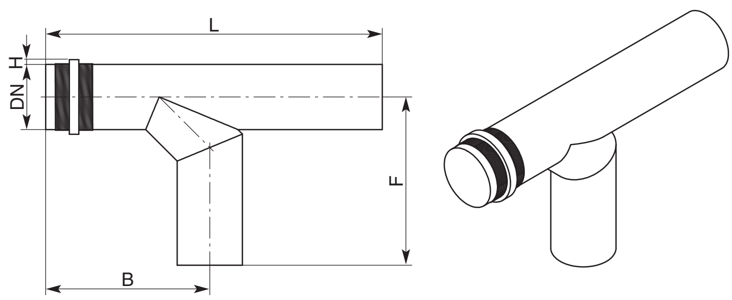
Manhole connectors (non pressure):

DN	OD (mm)	L (mm)	H (mm)
300	395	600	25
375	486	600	30
450	567	600	30
525	647	600	30
600	747	600	40
675	827	750	40
750	906	750	40
900	1013	750	45
1000	1115	1000	45
1200	1319	1000	45
1400	1523	1000	45
1600	1737	1000	50
1800	1941	1200	50
2000	2155	1200	55
2200	2359	1200	55
2400	2563	1200	55



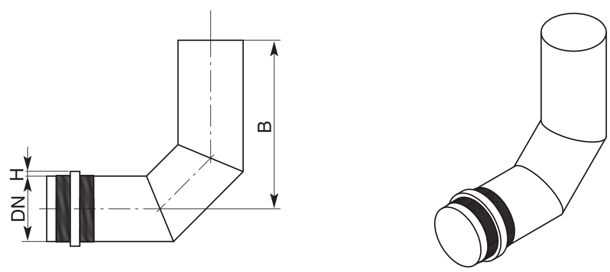
Manhole drop junction (non pressure):

DN	L (mm)	B (mm)	F (mm)	H (mm)
300	1780	890	890	25
375	1939	969	969	30
450	1877	939	939	30
525	2233	1117	1117	30
600	2380	1190	1190	40
675	2784	1392	1392	40
750	3000	1500	1500	40



Manhole drop bends (non pressure):

DN	B (mm)	H (mm)
300	890	25
375	969	30
450	939	30
525	1117	30
600	1190	40
675	1392	40
750	1500	40



Closed couplings (non pressure):

DN	OD (mm)	L (mm)
300	402	277
375	483	277
450	564	277
525	644	277
600	732	338
675	812	338
750	893	339
900	993	340
1000	1098	341
1200	1307	343
1400	1516	345
1600	1725	347
1800	1934	349
2000	2144	352
2200	2353	354
2400	2562	356
3000	3208	392

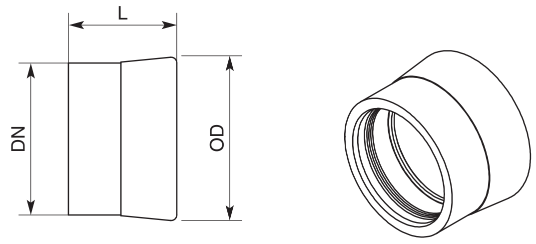


Figure 4.3 – DN750 PN16 FLOWTITE™ Pipe being installed for a critical water supply line for Wyong City Council NSW

Section 5

Hydraulic Design

5.0 Hydraulic Design

5.1 Flow and pressure capacity calculations

To assist the designer in selecting the appropriate pipe diameter, flow calculation software is available from Iplex Pipelines website at www.iplex.com.au. Alternatively, the flow resistance charts in this section may be used. These tools enable the designer to determine the relationship between friction losses, flow rate and velocity for all available diameters and classes in the FLOWTITE™ range.

FLOWTITE™ pipelines provide exceptionally good hydraulic performance when new, as they fall in the "smooth" polymer pipe category. However, these may in some instances be affected by various adverse service factors including:

- Growth of slime (varies with age of the pipeline and available nutrient in the water)
- Siltation or settlement of suspended particulate matter
- Fittings types and configurations

Iplex software allows for variation in temperature, viscosity and pipe roughness as required for any given application. In addition three flow resistance charts have been provided, Figures 5.1, 5.2 and 5.3. The flow charts are based on the following parameters:-

- Operating temperature of 20°C which corresponds to a kinematic viscosity of water $\upsilon = 1.01 \times 10^{-6}\ m^2/s$
- Equivalent roughness k = 0.02mm and 0.06mm ± 0.015mm

An approximate allowance for the effect of variation in water temperature on the chart values can be made by increasing the chart value of the head loss by 1% for each 3°C below 20°C and by decreasing it by 1% for each 3°C in excess of 20°C of pressure rating.

The value of roughness adopted for the charts was determined experimentally from a FLOWTITE™ transmission main in Norway that had been in service for many years. While the "experimental error" for roughness 'k' at ± 87% was quite large, the effect of this on flow calculations is only of the order of ± 7%. By way of comparison the ranges of roughness for new polymer based pipes when assumed to be clean, straight and concentrically joined given in AS 2200 "Design Charts for Water Supply and Sewerage" is between 0.003 to 0.015mm.

The notation used for the equations in this section follows:

C = Hazen Williams roughness co-effcient
D = internal diameter (m)
F = Darcy friction co-efficient
g = acceleration due to gravity (m/sec^2)
H_L = friction head loss (m)
H = Total (pumping) head
i = annual interest rate
j = annual interest rate including inflation
k = equivalent hydraulic roughness (m)
m = assumed inflation rate
n = Manning "n"
N = planned life of system (years)
Q = flow or discharge (L/s)
Q_p = most probable peak flow (L/s)
Q_f = flow or discharge - pipe flowing full (L/s)
R = hydraulic mean radius i.e. flow area/perimeter (m)
R_p = hydraulic mean radius for partly full pipe (m)
R_f = hydraulic mean radius for full pipe i.e. d/4 (m)
S = hydraulic gradient (m/m)
V = mean velocity (m/sec)
V_p = mean velocity in part full pipe (m/s)
V_f = mean velocity - pipe flowing full (m/s)
T = duration of pump operation (hours/year)
Y = depth of flow above pipe invert (m)
ρ = fluid density (kg/m^3)
ν = kinematic viscosity (m^2/sec)
2θ = angle (radians) subtended at pipe centre by water surface in invert
τ = average boundary shear stress (Pa)

The design software and flow charts are based on calculations using the Colebrook White Transition Equation (Equation 5.1). For pipes flowing full this equation takes into account liquid viscosity and pipe roughness and is recognized as being one of the most accurate in general use but requires iterative solutions.

The Colebrook-White transition equation is as follows:-

$$V = -2\sqrt{2gDS}\log\left(\frac{k}{3.7D} + \frac{2.51\nu}{d\sqrt{2gDS}}\right) \text{ (m/s)} \quad \text{.......Equation 5.1}$$

The smooth bore, the size of the internal diameter and the anticipated pipeline service should be taken into account by designers when comparing FLOWTITE™ with other pipe systems. Different applications may require a variation of the values of roughness coefficients chosen to conform to accepted practice. In the case of sewerage, it may be considered necessary to allow for slime development. Generally smooth pipe materials have a Colebrook White 'k' value equal to less than one fifth of the value used for the rougher materials such as cement lined concrete and vitrified clay pipes used for the same purpose.

Empirical formulae, exponential in form, have been in engineering use for many years. Being relatively easy to use they are still favoured by some engineers.

For water supply applications, Hazen Williams' equation is frequently used i.e.

$$V = 0.354\, C\, D^{0.63}\, S^{0.54} \quad \text{(m/s)} \quad \text{........Equation 5.2}$$

and

$$Q = 278\, C\, D^{2.63}\, S^{0.54} \quad \text{(L/s)} \quad \text{.......Equation 5.2a}$$

Using the Norwegian experimental data the derived value of Hazen-Williams Coefficient "C" for FLOWTITE™ is between 152 and 155.

The Manning Equation is the most common for non-pressure gravity flow.

$$V = \frac{1}{n} R^{2/3} . S^{1/2} \quad \text{(m/s)} \quad \text{...........Equation 5.3}$$

and

$$Q = \frac{4000}{n} \pi \left(\frac{D}{4}\right)^{8/3} S^{1/2} \quad \text{(L/s)} \quad \text{..........Equation 5.3a}$$

For FLOWTITE™ Manning "n" may be taken as 0.01 for a clean pipeline. Again this is conservative compared with Australian Standard AS 2200 which provides the range of "n" for thermosetting plastics of 0.008 to 0.009.

Design flow velocities

The Water Services Association of Australia Code WSA 03 provides design recommendations and may be applied to FLOWTITE™ pipe installations. In pumped transmission mains capital cost and discounted running costs should be determined – see Section 5.2. However as a guide the Code suggests that the most economic design is likely to have velocities in the range 0.8m/s to 1.4m/s. In some circumstances, it also suggests that 2.0m/s may be acceptable or 4.0m/s for short periods with 6.0m/s as the maximum. Generally head losses should not exceed 3m/km. Where the water is carrying abrasive material the design velocity should not exceed 3.0m/s.

5.2 Economic considerations

Since energy consumption is a significant factor in pumped pipelines an economic analysis is necessary to optimize the cost of capital involved in building a pipeline and the present worth of the anticipated energy consumption over the life of the pipeline.

An example of a typical present worth calculation to determine the optimum pipe diameter for a particular project is shown in Table 5.1 where a 16km long pipeline is required to carry a flow of 350L/s. The overall capital cost is combined with the present worth of the annual pumping costs over the 50-year life of the system to determine the least expensive option.

The equations needed for these calculations are:

Annual pumping cost 'Y'

$$Y = \left(\frac{0.0098 \times Q \times H}{\text{pump efficiency}}\right) \times C \times T \quad \text{..........Equation 5.4}$$

Present value of annuity 'A' can be calculated from:

$$A = Y \times (1 - (1+i)^{-n}) / i \quad \text{....................Equation 5.5}$$

Where the rate of inflation is to be included, then

$$A = Y \times (1 - (1+j)^{-n}) / j \quad \text{....................Equation 5.6}$$

The adjusted interest rate 'j' is calculated from

$$j = (i-m) / (1+m) \quad \text{....................Equation 5.7}$$

Note that in the special case where i = m then the value of A = n x Y

Table 5.1 shows the calculations for optimizing the pipe size for a major transmission main. It can be concluded from the table that for the assumptions made a DN675 pipeline would be the best option for a minimum present worth cost.

Figure 5.1 – Colebrook-White Flow Resistance Chart FLOWTITE™ GRP SN10000 for PN1, PN6 & PN10 (k = 0.02mm and water temperature 20°C)

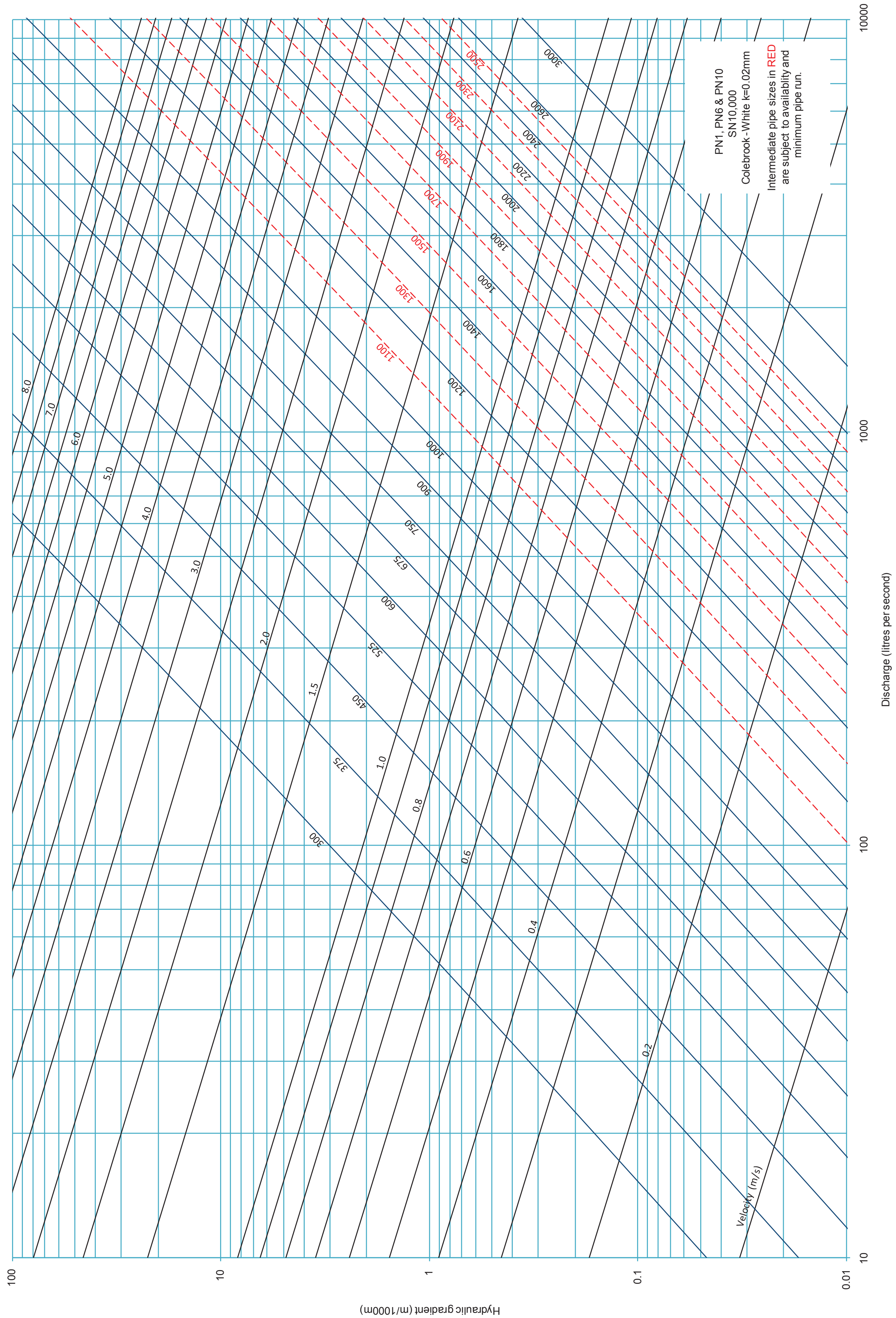


Figure 5.2 – Colebrook-White Flow Resistance Chart FLOWTITE™ GRP SN10000 for PN16 & PN32 (k = 0.02mm and water temperature 20°C)

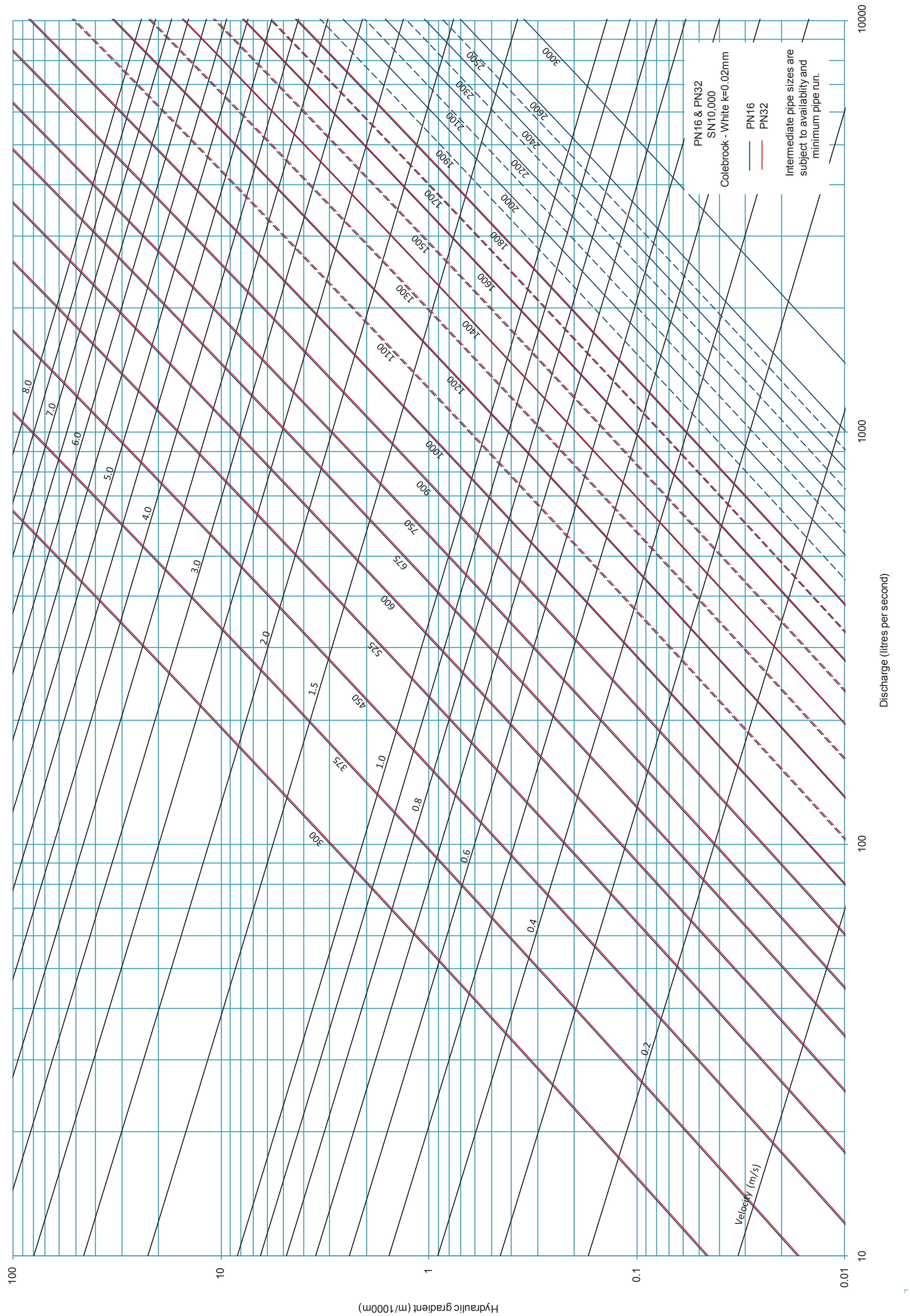


Figure 5.2 (a) – Colebrook-White Flow Resistance Chart FLOWTITE™ GRP SN10000 for PN1 (k = 0.06mm and water temperature 20°C)

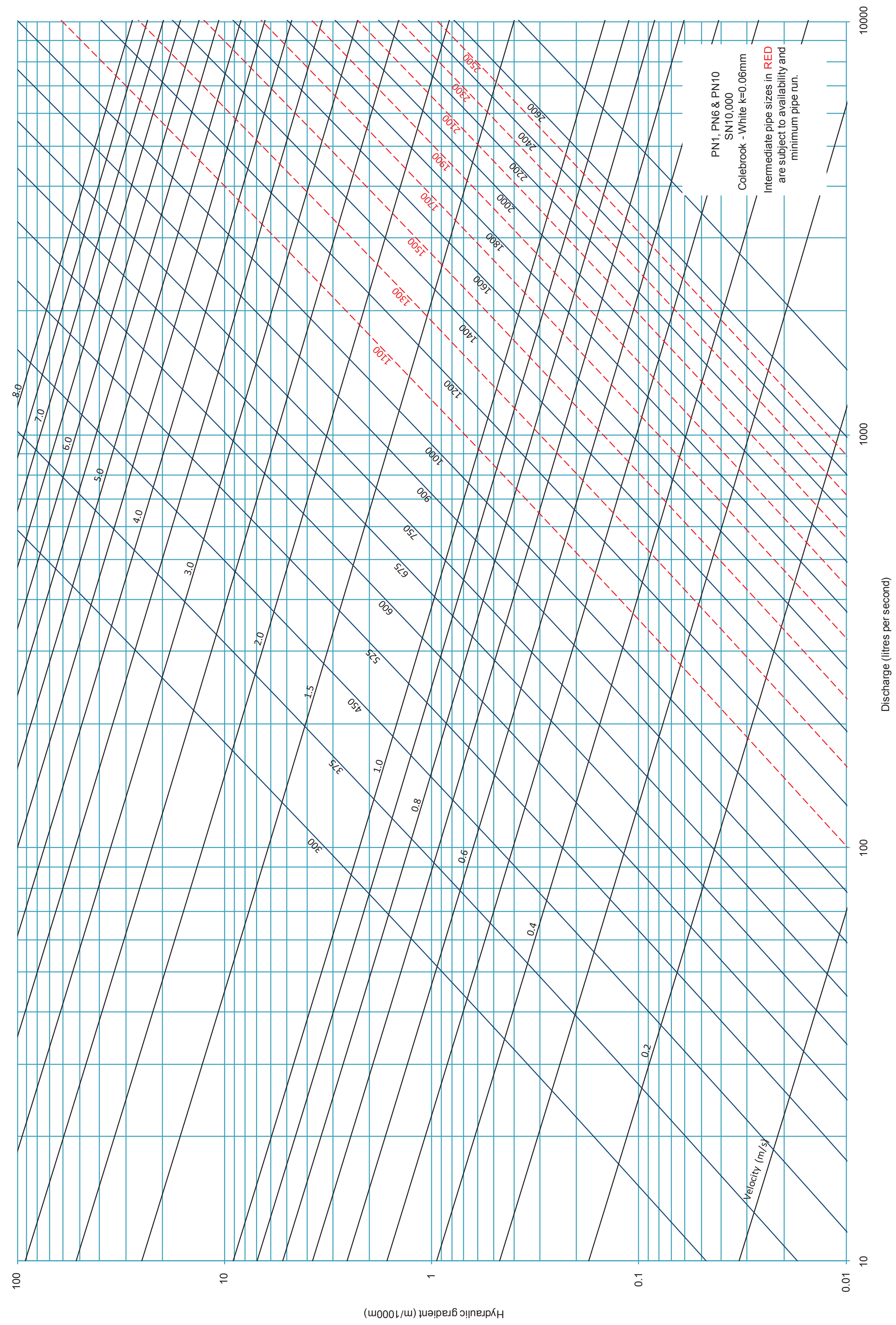


Table 5.1 Example optimizing pipe size on financial basis

Pipe Description:	FLOWTITE™ DN450/16/10,000	FLOWTITE™ DN525/10/10,000	FLOWTITE™ DN600/10/10,000	FLOWTITE™ DN675/10/10,000
Input information				
Flow [L/s]	350	350	350	350
Length [m]	16000	16000	16000	16000
Static lift [m]	30	30	30	30
Cost of Pipeline [$/m][1]	$351.00	$410.00	$483.00	$568.00
Viscosity [m^2/s]	1.0100E-06	1.0100E-06	1.0100E-06	1.0100E-06
Internal diameter [m]	0.489	0.564	0.641	0.718
Roughness "k" [mm]	0.02	0.02	0.02	0.02
Results of calculation				
Head loss due to flow resistance [m/m]	0.00457	0.002267	0.001213	0.000699
Total flow resistance head [m]	73.20	36.27	19.41	11.18
Pump efficiency [%][2]	70.0	70.0	75.0	75.0
Power reqd. [kW]	505.7	324.7	226.0	188.3
Cost per kWh [$/kWh]	$0.22	$0.22	$0.22	$0.22
Operating hours/year	7000	7000	7000	7000
Operating cost [$/year]	$787,747	$500,089	$347,977	$290,056
Return on investment [%/year]	5.50	5.50	5.50	5.50
Life of scheme [years]	50	50	50	50
Present value pumping				
cost [without inflation]	$13,185,372	$8,467,258	$5,891,783	$4,911,091
Total P V [without inflation]	$18,801,372	$15,072,258	$13,619,783	$13,999,091
Energy inflation rate [%]	3.00	3.00	3.00	3.00
Resulting effective interest rate [%]	2.43	2.43	2.43	2.43
Present value of pumping				
cost [including inflation]	$22,412,035	$14,392,349	$10,014,647	$8,347,701
Total present value [including inflation]	$28,028,035	$20,952,349	$17,742,647	$17,435,701

[1] *Assumed installed cost (pipe and installation)*

[2] *High head centrifugal pumps are generally less efficient than low head centrifugal pumps, pump efficiencies are approximate only and may vary.*

Table 5.1 shows that the DN675 pipeline is likely to be the best option. This may be subject to a sensitivity analysis to cover the effect of varying some of the less certain assumptions made.

5.3 Air valves, anti-vacuum valves and scour valves

Air must be expelled from a pressure pipeline during the filling operation and also allowed to enter a pipeline if it is being emptied for any reason. Also, because most water is saturated with air, which will leave the solution when the water pressure is reduced, air will tend to collect at high points in a pipeline system under normal operating conditions. As air accumulates, it has the effect of lessening the effective pipe diameter leading to reduced discharge or increased friction head. In extreme situations the flow may actually cease (see Fig 5.3). Pressure surges of high magnitude may also result from the unstable flow conditions created.

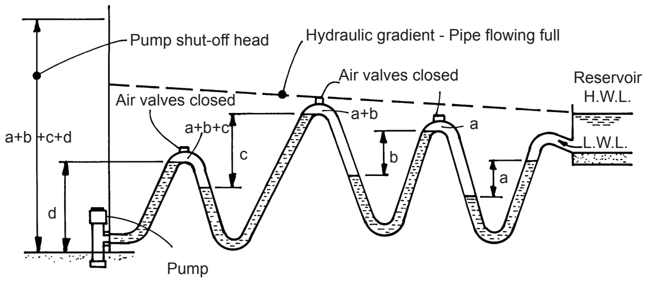


Figure 5.3

An automatic air valve is comprised of a float confined in a chamber with an orifice to atmosphere on top and connection to the pipeline at the bottom. When the chamber is full of water the float seals the orifice, but when air from the line enters the chamber or the pressure drops below atmospheric the float drops. It remains open until water refills the chamber and air is bled from the line.

Where the hydraulic grade is close to the high point of a pipeline a simple vent tube extended above the grade line may be used as an Air Valve.

Location of air valves

Air (and gases) periodically released from the liquid in a pipeline due to temperature changes, water movements etc. will accumulate in the more elevated sections or "peaks". It is good practice in pressure pipelines to grade evenly between these peaks to ensure that the locations of all potential air traps are known. Air valves are required at peaks or sharp changes in grade in the pipeline to allow the air to escape progressively and avoid any reduction of flow capacity or unnecessary pressure surges. Peaks relative to the hydraulic gradient as well as the horizontal datum should be considered for air valve locations.

Generally the large orifice diameter should be at least 0.1 of the pipe diameter. The volume rate of flow air through an orifice is roughly 40 times that of water under the same pressure differential. The following is the list of typical conditions where air valves may be necessary.

1. Where a section of pipeline

a) Runs parallel to the hydraulic gradient

b) Has a long horizontal run. Double air valves are required at the end of a run and single air valves located at every 500-1000 metres of run.

2. Where pipeline peaks above the operating hydraulic gradient but below the higher (source) level, air can be expelled at this point by installing a manually operated gate valve (not an air valve) which is opened when the lower (outlet) level valve is closed. The operation should be carried out at regular intervals. Where the pipeline peak above the higher (source) level, syphoning will occur and special provision will have to be made to expel air such as a vacuum pump. It is recommended that peaking above the hydraulic gradient and the source level should be avoided.

3. Where abrupt changes to the grade occur on both upward and downward slopes, a small orifice air valve should suffice.

4. During long ascents, large orifice air valves are required at 500-1000 metre intervals.

5. During long descents, double air valves are required at 500-1000 metre intervals.

6. On the downstream side of section valves in trunk mains, or where flow on both sides is in both directions.

In large diameter pipelines (e.g. DN600 or greater) consideration should be given to the likely operating conditions. For example where flow capacities are significantly below the design maximum, hydraulic jumps may develop due to the pipeline being partially full or in a "channel flow" mode.

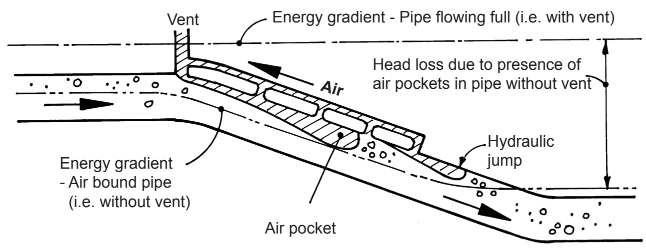


Figure 5.4 – Hydraulic jumps require additional vents

As illustrated in Figure 5.4 a series of unstable hydraulic jumps may cause air to accumulate downstream from the peak. This air may need to be extracted using a series of suitably spaced vents and may be combined with a series of interconnected tapping's to permit air to return to the air space upstream of the jump.

Where air valves are required on mains of major importance it is normal practice to install a gate valve directly onto the tee branch prior to connecting the air valve. Alternatively, an air valve incorporating a control valve can be used. This allows maintenance to be carried out on the air valve without dewatering the pipeline.

Under operating conditions care should be taken to ensure that this valve is always left in the open position.

Single air valves

The single air valve, with a small orifice (Fig 5.5) is used to release small quantities of air, which may accumulate in a charged water main. Although designated by their inlet connection, e.g. 25mm, this has nothing to do with the orifice size, which may be as small as 3mm.

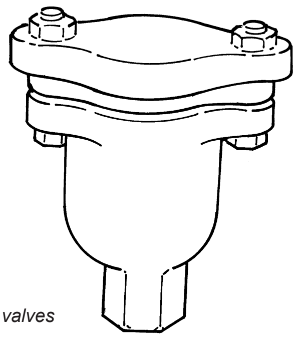


Figure 5.5 - Single air valves

Double air valves

The double air valve, with small and large orifice in separate chambers (Fig 5.6), performs the dual function of releasing a small quantity of air as it collects (similar to the single air valve), and admits or releases large volumes of air when a pipeline is emptied or filled. They are designated by their inlet connection, which is usually slightly smaller than the orifice diameter. Sizes range from 50mm to 100mm.

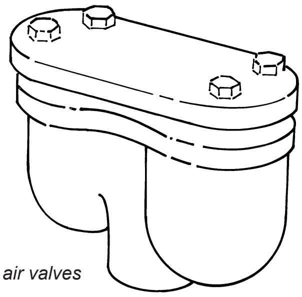


Figure 5.6 - Double air valves

Kinetic air valves

A difficulty sometimes experienced with large orifice air valves is that the ball blows the valve shut when a water main is being filled at a high rate. A pressure differential of 100kPa could lead to air velocities approaching 300m/sec i.e. the speed of sound. The kinetic air valve (Fig 5.7) has a float chamber constructed in such a way that air expelled from a rapidly filled main cannot blow the valve shut, regardless of the high emergent air velocity.

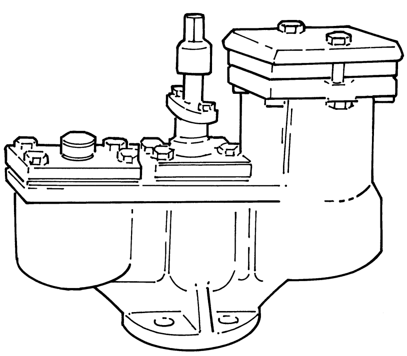


Figure 5.7 - Double kinetic air valves with control valve

Anti-vacuum valves

Anti-vacuum valves have the primary function of preventing the formation of a vacuum in large diameter water mains or hydro-electric penstocks. They are much larger in size than conventional air valves with orifice sizes ranging from DN200 to DN500. The corresponding airflows at 50% vacuum will range from 5m^3 per second to 50m^3 per second respectively.

Scour valves

Scouring points located in depressions along a pressure main are essential so that the line can be drained for maintenance purposes and sediment removal. Special flanged scour tees with branches offset to invert level are available.

The discharge from a scouring point is usually piped to a nearby stormwater drain unless the effluent will cause pollution. In these cases a detention tank has to be provided so that a tanker can remove foul water.

5.4 Surge capacity

FLOWTITE™ pipes are designed to resist surge pressures in excess of the nominal pressure pipe class. FLOWTITE™ pipes designed in accordance with AWWA M-45 ‘Fibreglass Pipe Design Manual’ allow 1.4 times the nominal pressure. AS/NZS 2566.1 ‘Buried flexible pipelines Part 1: Structural design’ recommends a lower value of 1.25 times the nominal pressure.

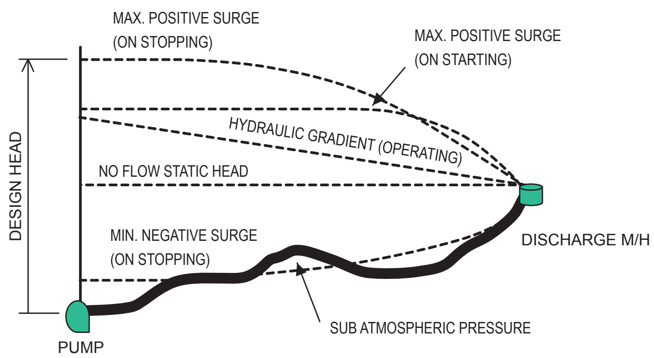


Figure 5.8 - Typical hydraulic grades and surge envelopes required for design

Figure 5.8 illustrates a typical water hammer pressure envelope. These can be determined using computer software such as WATHAM, HYTRAN or equivalent. In this diagram the maximum surge effect has been generated at the pump shutdown, a situation that is quite common.

5.5 Water hammer surge celerity

Water hammer effects are considerably reduced in polymeric pipeline materials including GRP when compared with iron, steel and concrete due to GRP's much lower modulus of elasticity. Typical values for celerities in FLOWTITE™ GRP pipes of different diameters, stiffness's and classes are given in Table 5.2.

Table 5.2 Water hammer celerity for FLOWTITE™ pipe (m/s)

Description	DN 300 - 375	DN 450 - 750	DN 900 - 3000
PN6 SN5000	405	380	370
PN10 SN5000	435	420	410
PN16 SN5000	505	495	480
PN25 SN5000	575	570	560
PN6 SN10000	-	415	410
PN10 SN10000	-	425	415
PN16 SN10000	-	495	485
PN25 SN10000	-	570	560
PN32 SN10000	-	615	615

5.6 Fatigue under cyclical pressure regimes

FLOWTITE™ pipes when manufactured to Australian and ISO standards and used in water, drainage and sewerage applications do not require re-rating for cyclic pressure fatigue.

The standards specify that complying pipes shall be type tested in accordance with the methods of ISO 15306. In the cyclical pressure test the pipe specimen is subjected to pressure cycles ± 0.25 times the nominal pressure for at least one million cycles. For example a PN16 pipe would be subjected to a cyclical pressure range from 1200kPa to 2000kPa at a nominated frequency.

Test reports are available for FLOWTITE™ specimens, which show that, after being subjected to a minimum of one million cycles, they had ultimate, burst strengths and pressure proof test performances equivalent to those of untested new pipes.

These tests illustrate that there is a considerable difference in the fatigue characteristics between GRP pipes made from reinforced thermoset plastics when compared to unreinforced thermoplastics pipes.

5.7 Thermal effects on pressure ratings

Standard FLOWTITE™ pipes are designed to fulfil the requirements of the Australian Standards AS 3571.1 and AS 3571.2 and ISO Standards ISO 10467 and ISO 10639. These standards cover temperatures up to 50°C with rerating for temperatures above 35°C.

The FLOWTITE™ manufacturing process is suited for a variety of applications and if necessary, allows the use of higher performance materials for even more severe operating conditions. The following are general guidelines for temperature rerating of pressure pipes. These have been created to cover all approved materials for the FLOWTITE™ process.

For FLOWTITE™ pipes operating at temperatures up to 35°C and in accordance with Section 2.2, no pressure rerating is required. *Note: Resin selection should also be in accordance with Table 2.2 'Chemical resistance guidelines' where further limitations on temperature may apply depending on the environment.*

For FLOWTITE™ pipes operating at temperatures from 36°C to 50°C and in accordance with Section 2.2, Table 5.3 quantifies the magnitude of pressure rerating to be applied. It is recommended that the next higher standard pressure class (PN) be used, after applying the rerating factor to the system's design or operating pressure. For example, a pipeline intended to operate at 18bar pressure with a continuous operating temperature of 42°C, would result in a rerating of 24bar [18/0.75]. The next higher standard pressure class to select would therefore be PN25.

Table 5.3 Thermal pressure rerating for FLOWTITE™ with standard polyester resin

Long term operating temperature °C	Rerating factor 'R'
up to 35	1.0
36 to 40	0.85
41 to 45	0.75
46 to 50	0.6

The maximum allowable operating pressure (MAOP) = PN x R.

For example a PN16 FLOWTITE™ pipe operating with a continuous operating temperature of 40°C is now rerated as PN(16) x 0.85 = 13.6bar or 1360kPa maximum internal pressure.

For FLOWTITE™ pipes operating at **temperatures from 51°C to 70°C** the design pressure of the pipe must be rerated in accordance with Table 5.4 and manufactured with a full body and liner vinyl-ester resin. Further reference should also be made to Table 2.2 'Chemical resistance guidelines' where temperature limitations may apply depending on the environment.

Table 5.4 Thermal pressure rerating for FLOWTITE™ with vinyl ester resin

Long term operating temperature °C	Rerating factor 'R'
51 to 60	0.6
61 to 70	0.5

Based on the information above, the maximum operating pressure for FLOWTITE™ pipe is dependent on the continuous operating temperature of the system as shown in Table 5.5.

Table 5.5 Maximum operating pressure for FLOWTITE™ pipes

Long term operating temperature °C	Maximum operating pressure (Bar)
36 to 40	25
41 to 45	20
46 to 50	16
51 to 70	16

5.8 Non pressure pipeline design

Gravity sewer and stormwater drainage design

The design of drainage pipe networks is discussed in "Australian Rainfall and Runoff" published by the Institution of Engineers. There are differences from other applications owing to the frequency of inlet and junction pits, which significantly affect the hydraulic capacity of the system. Similar effects are sometimes seen in gravity flow irrigation systems. In both cases high head losses occur through pits. Pits may be rectangular, circular, benched and un-benched, with and without sidelines, with and without entries for surface stormwater from gutters on roadways, and often involve changes in flow direction. The value for K_L in Figure 5.9 can range from 0.2 to 2.5 or more depending on the pit configuration. Appropriate values can be obtained from ARRB Report No.34 "Stormwater drainage design in small urban catchments" by John Argue.

Another consideration affecting flow capacity is the debris and sediment load which stormwater flow often carries.

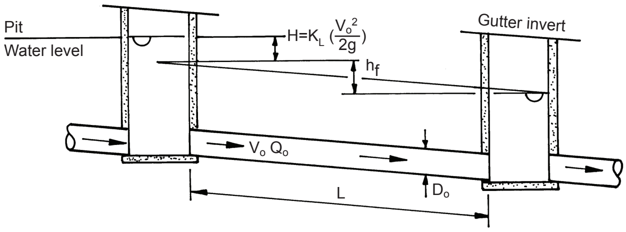


Figure 5.9 – Accounting for head losses through low head chambers

Sewerage design

The design of gravity sewers can be complex owing to the assumptions that must be made to cover wide variations in flows between storm flows and low dry weather sewage flows. Although the pipes must be sized to carry the high wet weather flows, the size and grade must also meet self-cleansing criteria under dry weather conditions.

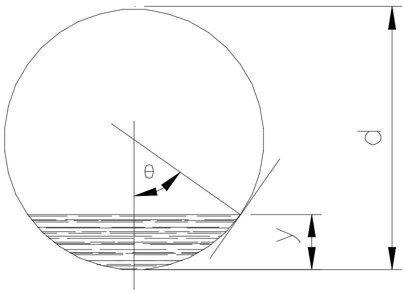


Figure 5.10 – Self-cleansing flow - angle of repose of sediment

Acceptable design methods will vary between authorities and whether the system is to be designed for sewage flows only or combined sewage and stormwater flows. In Australia the separated sewage flow is the usual requirement. Even so these systems often carry considerable stormwater flow in wet weather due to incidental inflow and infiltration of storm water. For design purposes the normal average sewage flow of say 0.003L/s per head of population or "equivalent population" (EP) is increased by a series of empirical factors to allow for peak dry and peak wet weather flows. The resulting maximum design flow is therefore much higher than the average flow. Sewer pipes are sized to carry the maximum design flow (Q_f) flowing full. In addition a check is made to ensure that in dry weather there will be sufficient flow to ensure a self-cleansing flow at least once daily.

Historically, the normal design criterion was that a partial flow with a self-cleansing velocity of 0.6m/s had to be achieved once a day. Today most design methods are based on fluid boundary layer shear theory. Research on movement of sand particles on submerged pipe perimeters at low flows shows that deposition will occur on the flatter parts of the pipe invert where the slope of the pipe wall is less than θ = 35° - refer to Figure 5.10. Boundary layer design theory builds on this fact.

From open channel theory the following expression can be written in terms of average boundary shear stress "τ".

$$\tau = \rho.g.R.S \qquad \text{(Pa)} \quad \textit{Equation 5.8}$$

For a circular sewer flowing part full, since R_f=d/4 Equation 5.8 can be rewritten as,

$$\tau = \rho.g.{}^{d}\!/_{4}.{}^{R_p}\!/_{R_f}.S \qquad \text{(Pa)} \quad \textit{Equation 5.9}$$

It can be assumed for τ ≥ 1.5Pa that the pipe invert will be self-cleansing. Therefore taking this as the value for "τ", the minimum self cleansing slope can be determined by re arranging Equation 5.9:

$$S_{\min} = \frac{4\tau}{\rho.g.d.\left({}^{R_p}\!/_{R_f}\right)} \qquad \text{(m/m)} \quad \textit{Equation 5.10}$$

Using geometrical relationships and Manning's equation (Equation 5.3), the hydraulic elements chart Figure 5.11 has been developed to relate the flow, depth and hydraulic mean radius ratios to each other. With the Q_p/Q_f ratio known, the depth ratio y/d can be found and then from this value the R_p/R_f ratio can be determined for substitution in Equation 5.10

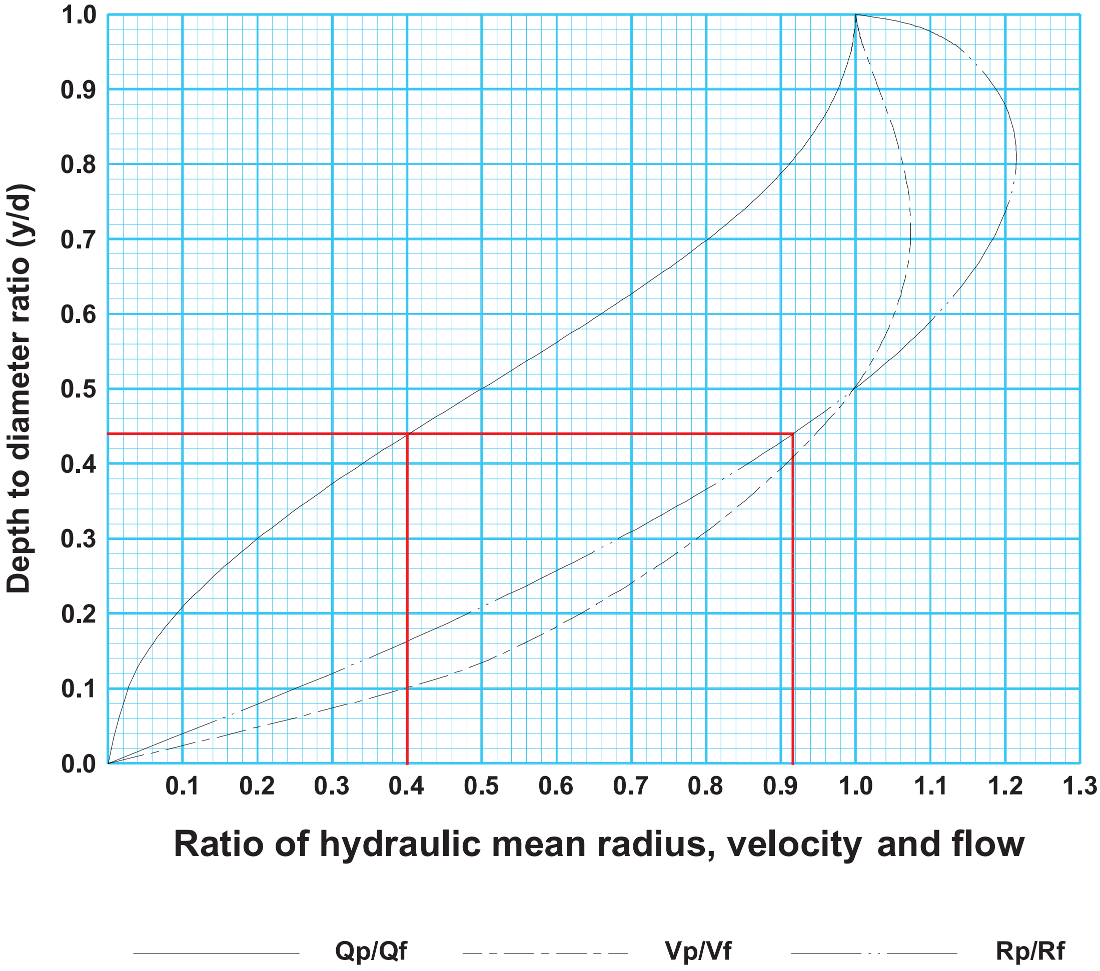


Figure 5.11 – Proportional velocity and discharge in part-full pipes

Example

Problem:

A DN1000 FLOWTITE™ sewer carrier laid at a 0.068% gradient, with an assumed Colebrook White roughness k = 0.06mm, will carry 800L/s when flowing full (See Figure 5.2). The probable daily peak dry weather flow is estimated at 320L/s.

Will this sewer be self-cleansing?

Solution:

From the flow resistance chart Figure 5.2, it can be seen that a DN 1000 FLOWTITE™ pipe has a hydraulic gradient of 0.68m/1000m when flowing at 800L/s.

The ratio Q_p/Q_f = 320 / 800= 0.40

From Figure 5.11; y/D = 0.44 and for this depth ratio R_p/R_f = 0.92

Substituting for R_p/R_f in Equation 5.10 (with τ ≥ 1.5Pa)

= 0.000674 or 0.067%.

As this required grade of 0.067% is less than the 0.068% proposed, the pipeline will be self-cleansing.

Section 6

Structural Design

6.0 Structural Design

6.1 Allowable cover heights

In engineering terminology FLOWTITE™ pipes are considered to be "flexible" pipes. This means they are designed to deform or deflect diametrically within specified limits without structural damage.

The external soil and live loadings above flexible pipes may cause a decrease in the vertical diameter and an increase in the horizontal diameter of the pipe or cause ring instability. The horizontal movement of the pipe walls in the soil material at the sides develops a passive resistance within the soil to support the external load. That is, the pipeline performance at a given cover height is influenced by the native soil type, its stiffness, the pipe embedment material, its compaction, the height of water table, vacuum conditions, live loading such as vehicular loads, and hydrostatic operating pressures. The higher the effective soil modulus at pipe depth, the less the pipe will deflect and the ring stability will be improved.

Initial deflections of up to 3% are permissible and will not affect the pressure rating of the pipe. Software for the complete design procedure can be downloaded from www.iplex.com.au. Contact Iplex Pipelines for further details or refer to AS/NZS 2566.1 "Buried flexible pipelines" Part 1 Structural design.

To properly assess the effect of site conditions on a proposed installation, specific information is needed for design including:

- Pipe diameter (mm)
- Cover height (m)
- Properties of native soil
- Width of embedment (mm)
- Properties of embedment material
- Height of water table (m)
- Traffic loading
- Special requirements, such as concrete encasement or grouting

The appropriate value of the effective soil deformation modulus for a particular installation will depend on the native soil type and condition, the pipe embedment material, its degree of compaction and its geometry (e.g. trench width / embedment width). Geotechnical surveys giving soil types and properties, including soil-bearing capacities, SPT values at pipe depth and embedment compaction, will be relevant to the design.

The following notation is used in this Section:

a = the radius of loaded circular plate (m)

b = embedment width each side of pipe at spring-line (m)

B = trench width at pipe spring-line (m)

D = overall outside diameter of pipe (m)

E_e' = embedment soil deformation modulus (MPa)

E_n' = native soil deformation modulus (MPa)

E' = combined soil deformation modulus (MPa)

H = cover height (m)

h = bedding thickness (m)

k = overlay thickness (m)

p = presumptive (allowable) bearing pressure (kPa)

Δ = displacement or settlement (m)

ξ = Leonhardt correction factor

Geotechnical investigation

The conventional approach to a pipeline route investigation has been to assess the soil conditions at pipe depth by carrying out a drilling and soil sampling program along the alignment. While the intention in the past was often to determine the presence of rock and to estimate trench stability for construction purposes, this investigation is now used for more detailed geotechnical reporting with additional information readily obtained from routine surveys. It includes design data such as the Standard Penetration Test (SPT) blow counts (at pipe depth), identification of native soil type and density, and depth of water table. The designer will need to assess the embedment material chosen to surround the pipe and its compaction.

Derivation of soil deformation modulus values

The correct choice of soil moduli will have significant effects on design decisions. An approximate conversion of SPT blow counts to soil moduli is given in Table 6.1 of AS/NZS 2566.1. However many designers may have more confidence in basing their assessment on the widely available data on foundation design. Often this is contained in records obtained over many years and frequently gives correlations between SPT and allowable soil bearing pressures.

If SPT values are not known for the soils in the pipe zone and the soil has already been exposed by excavation, the Clegg impact hammer can be used to obtain Impact Values (CIVs). These are numerically similar to SPT blow counts and can be substituted in Table 6.2 to obtain an estimate of E_n'.

The soil deformation moduli stated in AS/NZS 2566.1 were originally derived from European design practice using soil bearing plate tests. These moduli can be nearly half the value of deformation moduli measured using standard laboratory tri-axial tests so the two should not be confused. Using allowable foundation bearing pressures, it is possible to derive the plate load or pipe design soil moduli from the Boussinesq's plate bearing theory for an elastic, homogenous, isotropic solid. That is for a rigid plate and a soil Poisson's ratio of 0.5: -

$$\Delta = \frac{1.18\,pa}{E_n}.10^{-3} \qquad \text{..................}\textit{Equation 6.1}$$

For the purposes of obtaining a derivation it can be assumed that the plate is a standard 750mm diameter and the allowable settlement is 15mm. Equation 6.1 then provides a conversion relationship, E_n' = 0.03 x p. Table 6.2 which is partly derived from data published by Sowers (1979) relating SPT to bearing pressure has been extended to show E_n' values obtained by applying this factor.

Values of the soil deformation moduli are needed for both the native and embedment soils within a distance of 2.5 x pipe diameters each side of the pipe centre-line. The modulus for a given pipe embedment soil (E_e') is dependent on the compaction as well as soil type and can be estimated from Table 6.3.

Compaction – standard dry density ratio

Methods for measurement of compaction are given in AS 1289-E3. The actual dry density ratio (previously known as Proctor ratio) of a soil is defined as a percentage of the maximum dry density determined in the laboratory at the optimum moisture content. Then the dry density is derived from the following equation:

$$\rho_d = \frac{100\rho}{100 + w}$$ ....*Equation 6.2*

Where

ρ = wet field density

w = percentage moisture content

The dry density ratio is the field dry density divided by the maximum dry density determined in the laboratory for the soil (expressed as a percentage) when compacted at the optimum moisture content.

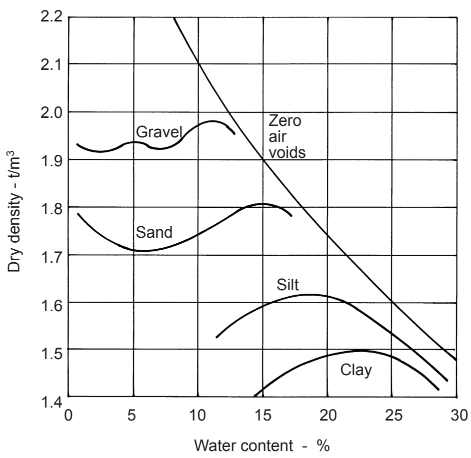


Figure 6.1 – Typical dry densities for different soils

Figure 6.1 shows the effect of compacting at different moisture contents on the dry densities of various soil types. It should be noted that the curve for gravel is relatively flat as water content has minimal effect on the achievable compaction. Therefore these materials are preferred for embedment. The curve shown for sand is concave over the intermediate range of moisture contents. With some fine sands at these moisture contents the density can be more than 20% less than for the compaction achievable at higher moisture levels. Because of this property these "bulking sands" are highly unsuitable as embedment material. The convex curves for cohesive soils such as silt and clay are particularly sensitive with respect to moisture and are difficult to compact adequately in a pipe trench.

The dry density may be determined in the laboratory by either the 'Standard' method or the 'Modified' test method each giving significantly different results. The compaction energy for the 'Modified' is 4.5 times higher than for 'Standard' and the resultant maximum dry density ratio will be lower for a given field test sample. For granular soils the difference is about 5% (less for uniformly graded sand) and about 10% for cohesive soils. AS/NZS 2566.2 refers to standard dry density ratio only.

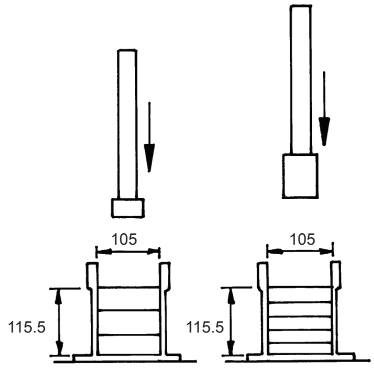


Figure 6.2 – Standard Compaction - 2.7kg rammer is dropped from a height of 300mm - 25 blows per layers (left hand side) and Modified Compaction - 4.9kg rammer is dropped from a height of 450mm - 25 blows per 5 layers (right hand side)

Compaction - density index

An alternative method of evaluating the degree of compaction, which is faster and less expensive for granular soils, is the density index (or relative density). With this method the 'loosest' and 'densest' densities are determined in the laboratory as follows.

A container filled with the soil is vibrated on a vibratory table for 10 minutes or until the settlement ceases to determine a value for the maximum dry density ρmax. The minimum dry density ρmin is determined by gently pouring the soil into the container and measuring the density. Combined with the dry density ρd, which has been measured on site, the density index ID for site compaction can then be determined from equation 6.3.

$$I_D = \frac{\rho_{max}(\rho_D \ \ \rho_{min})}{\rho_D(\rho_{max} \ \ \rho_{min})} \text{x } 100\%$$ ....*Equation 6.3*

These two compaction methods give unrelated percentages that are quite different in magnitude and must not be interchanged. For example in broad terms a compacted soil with a density index of 65% may have a standard dry density ratio of 90%.

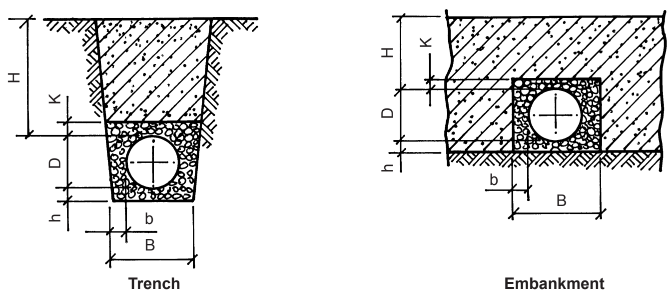


Figure 6.3 – Critical dimensions for design and installation

Table 6.1 Standard embedment widths (from AS/NZS 2566)

Nominal diameter DN	Outside diameter of pipe 'D' (mm)	Side clearance 'b'	Embedment width 'B' (mm)
300	345	200	745
375	426	200	826
450	507	300	1107
525	587	300	1187
600	667	300	1267
675	747	300	1347
750	826	300	1426
900	923	350	1623
1000	1025	350	1725
1200	1229	350	1929

Note: Table 6.1 has been compiled with reference to AS/NZS 2566.1. The side clearances given are conservative to facilitate the compaction of the haunch zone. The embedment widths for larger diameters can be obtained from AS/NZS 2566.

Effective soil modulus

Knowing the proportion of embedment and native soil in the side support zone, that is the trench (or embedment width) to pipe diameter (B/D) and the ratio of the embedment modulus to native soil modulus (E_e'/ E_n'), the "Leonhardt factors" given in Table 6.4 enable an overall effective soil modulus E' to be determined using the equation:

$$E' = \xi . E_e' \qquad \text{....................Equation 6.4}$$

Assuming a density of 20kN/m^3 for the trench fill over the pipe, Tables 6.5a, 6.5b and 6.5c will then give an estimate of the maximum safe cover heights. (See worked example).

Normally the embedment widths 'B' should comply with the dimensions in Table 6.1 and based on these, pre-calculated safe maximum cover heights for a range E' values (i.e. many combinations of native and embedment soils) are given in Tables 6.5a, 6.5b and 6.5c.

Example 6.1

Problem

What is the maximum cover height for a DN900 PN6 SN5000 FLOWTITE™ pipe laid in a trench 1800mm wide? The native soil is firm clay with a minimum SPT of 7 blows per 300mm. The embedment material is graded aggregate placed with a Density Index of 60.

Solution

From Table 6.2 select E_n' = 3MPa, and from Table 6.3 select E_e' = 7.0MPa.

Since B/D = 1800/900 = 2

and E_e'/ E_n' = 7/3 = 2.33

From, Table 6.4 by interpolation, the Leonhardt factor ξ = 0.55.

Therefore the combined soil modulus E' = 0.55 x 7 = 3.85MPa. Referring to Table 6.5c, interpolating for a DN900 SN5000 and an E' of 3.85MPa it appears that the maximum cover height under traffic loading and high water table would be approximately 5.5 metres.

Table 6.2 Typical native soil moduli – obtained from SPT or allowable bearing loads

Soil description	Standard Penetration Resistance (blow count over 300 mm)	Allowable foundation bearing pressures 'p' (kPa)	Derived soil modulus E_n (using Eqn.6.1) (MPa)
Loose sand, dry	5 - 10	70 -140	2.1 - 4.2
Firm sand, dry	11 - 20	150 - 300	4.5 - 9.0
Dense sand, dry	31 - 50	400 - 600	12 - 18
Loose sand, inundated	5 - 10*	40 - 80	1.2 - 2.4
Firm sand, inundated	11 - 20*	80 - 170	2.4 - 5.1
Dense sand, inundated	31 - 50*	240+	7+
Soft clay	2 - 4	30 - 60	0.9 - 1.8
Firm clay	5 - 8	70 - 120	2.1 - 3.6
Stiff clay	9 - 15	150 - 200	4.5 - 6.0
Hard clay	30+	400+	12+
Heavily fractured or partially weathered rock	50+	500 - 1200	15 - 36

**SPT before inundation*

The correlation of SPT to bearing pressure given in Table 6.2 is from George F Sower's "Introductory soil mechanics and foundations: Geotechnical Engineering" published by Macmillan

Table 6.3 Embedment soil moduli

Soil description	Standard dry density ratio (%)	Density Index (%)	Deformation moduli E_e' (MPa)
Aggregate – single size	-	Uncompacted	5
		50	6
		60	7
		70	10
Aggregate – graded	-	Uncompacted	3
		50	5
		60	7
		70	10
Crushed rock	Uncompacted	-	1
	85		3
	90		5
	95		7
Sand and coarse grained soil with less than 12% fines	Uncompacted	-	1
	85		3
	90		5
	95		7
Coarse grained soil with more than 12% fines	85	-	1
	90		3
	95		5

Note: These values are given in AS/NZS 2566.1 Buried flexible pipelines Part 1: Structural design Table

Table 6.4 Leonhardt correction factor "ξ" *

B/D	E_e'/E_n' 0.2	0.4	0.8	1	2	4	6
1.5	2.4	1.8	1.2	1.0	0.6	0.3	0.2
2	1.7	1.5	1.2	1.0	0.6	0.4	0.3
2.5	1.5	1.3	1.1	1.0	0.7	0.5	0.4
3.0	1.2	1.2	1.0	1.0	0.8	0.6	0.5
4.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8
5.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

*Alternatively refer to Figure 3.2 of AS/NZS 2566.1

Figure 6.4 – Compacting sand embedment material in the side support zone of a DN1000 FLOWTITE™ pressure pipeline

Figure 6.5 – DN250 SN10000 FLOWTITE™ being inserted into a host pipe. The allowable grouting pressure can be obtained from Table 6.7

Table 6.5(a) Maximum permissible cover height (metres) for PN10 pressure pipe (DN300 to DN1200) operating at 80 metres head

Nominal diameter DN (all PNs)	Effective (combined) soil modulus E' (Derived from E_n', E_e', ξ and embedment width 'B')							
	1.0 MPa	2.0 MPa	3.0 MPa	4.0 MPa	5.0 MPa	6.0 MPa	7.0 MPa	8.0 MPa
SN5000								
DN300	1.70	3.55	4.95	6.20	7.35	8.40	9.45	10.40
DN375	2.15	4.15	5.75	7.10	8.35	9.50	10.55	11.60
DN450	2.10	4.15	5.70	7.05	8.30	9.45	10.50	11.55
DN525	2.05	4.10	5.65	7.00	8.25	9.40	10.50	11.55
DN600	2.00	3.95	5.50	6.85	8.15	9.30	10.40	11.45
DN675	1.95	4.00	5.55	6.95	8.15	9.30	10.40	11.45
DN750	1.90	3.95	5.55	6.90	8.15	9.30	10.35	11.40
DN900	1.80	3.90	5.45	6.85	8.10	9.25	10.30	11.35
DN1000	1.70	3.85	5.40	6.80	8.05	9.20	10.25	11.30
DN1200	Not safe	3.75	5.30	6.70	7.90	9.10	10.15	11.20
SN10000								
DN300	2.75	4.40	5.90	7.35	8.70	10.00	11.20	12.40
DN375	3.10	5.50	7.40	9.10	10.65	12.10	13.45	14.70
DN450	3.05	5.45	7.35	9.05	10.60	12.05	13.40	14.70
DN525	3.00	5.40	7.35	9.00	10.55	12.00	13.35	14.65
DN600	2.90	5.35	7.20	8.90	10.80	12.00	13.35	14.65
DN675	2.90	5.30	7.25	8.95	10.50	11.90	13.25	14.55
DN750	2.85	5.25	7.20	8.90	10.45	11.85	13.20	14.50
DN900	2.80	5.20	7.15	8.85	10.40	11.80	13.20	14.45
DN1000	2.75	5.15	7.10	8.80	10.35	11.75	13.15	14.40
DN1200	2.60	5.05	7.00	8.70	10.25	11.65	13.00	14.30

Note: Table 6.5(a) is based on the following design parameters

1. *Class PN10 pipes operating at a head of 80 metres*
2. *No negative pressure (i.e. vacuum)*
3. *Allowable design deflections 6%*
4. *Combined factor of safety (hoop and flexural strain) min 1.5*
5. *Buckling factors of safety 2.5*
6. *No water table*
7. *AUSTROADS dual lane T44 highway loading*
8. *Fill density of 20kN/m^3*
9. *Trench width in accordance with Table 6.1*

Minimum cover heights

Cover heights shown in Table 6.5(a) may be insufficient to prevent flotation should the trench become flooded when the pipes are empty. A minimum cover of at least 1.5 x pipe diameter is necessary to avoid this possibility.

Table 6.5(b) Maximum permissible cover height (metres) for PN16 pressure pipe (DN300 to DN1200) operating at 128 metres head

Nominal diameter DN (all PNs)	Effective (combined) soil modulus E' (Derived from E_n', E_e', ξ and embedment width 'B')							
	1.0 MPa	2.0 MPa	3.0 MPa	4.0 MPa	5.0 MPa	6.0 MPa	7.0 MPa	8.0 MPa
SN5000								
DN300	2.20	4.20	5.80	7.15	8.40	9.50	10.60	11.60
DN375	2.15	4.15	5.75	7.10	8.35	9.50	10.55	11.60
DN450	2.10	4.15	5.70	7.05	8.30	9.45	10.50	11.55
DN525	2.05	4.10	5.65	7.00	8.25	9.40	10.50	11.50
DN600	2.00	4.05	5.60	6.95	8.20	9.35	10.45	11.45
DN675	1.95	4.00	5.55	6.95	8.15	9.30	10.40	11.45
DN750	1.90	3.95	5.55	6.90	8.20	9.30	10.35	11.40
DN900	1.80	3.90	5.45	6.85	8.10	9.25	10.30	11.35
DN1000	1.70	3.85	5.40	6.80	8.05	9.20	10.25	11.30
DN1200	Not safe	3.75	5.30	6.70	7.90	9.10	10.15	11.20
SN10000								
DN300	3.15	5.45	7.25	8.80	10.50	12.0	13.40	14.70
DN375	3.10	5.50	7.40	9.10	10.65	12.10	13.45	14.70
DN450	3.05	5.45	7.35	9.05	10.60	12.05	13.40	14.70
DN525	3.00	5.40	7.35	9.00	10.55	12.00	13.35	14.65
DN600	2.95	5.35	7.30	9.00	10.50	11.95	13.30	14.60
DN675	2.90	5.30	7.25	8.95	10.50	11.90	13.25	14.55
DN750	2.85	5.25	7.20	8.90	10.45	11.85	13.25	14.50
DN900	2.80	5.20	7.15	8.85	10.40	11.80	13.20	14.45
DN1000	2.75	5.15	7.10	8.80	10.35	11.75	13.15	14.40
DN1200	2.60	5.05	7.05	8.70	10.25	11.65	13.00	14.30

Note: Table 6.5(b) is based on the following design parameters

1. *Class PN16 pipes operating at a head of 128 metres*
2. *No negative pressure (i.e. vacuum)*
3. *Allowable design deflections, 6%,*
4. *Combined factor of safety (hoop and flexural strain) min 1.5*
5. *Buckling factors of safety 2.5*
6. *No water table*
7. *AUSTROADS dual lane T44 highway loading*
8. *Fill density of 20kN/m^3*
9. *Trench width in accordance with Table 6.1*

Minimum cover height

Cover heights shown in Table 6.5(b) may be insufficient to prevent flotation should the trench become flooded when the pipes are empty. A minimum cover of at least 1.5 x pipe diameter is necessary to avoid this possibility.

Table 6.5(c) Permissible maximum cover height (metres) for PN1 non pressure applications only

Nominal diameter DN (PN1)	Effective (combined) soil modulus E' (Derived from E_n', E_e', ξ and embedment width 'B')							
	1.0 MPa	2.0 MPa	3.0 MPa	4.0 MPa	5.0 MPa	6.0 MPa	7.0 MPa	8.0 MPa
SN5000								
DN300	1.90	3.70	5.10	6.30	7.40	8.45	9.40	10.35
DN375	1.80	3.65	5.05	6.25	7.40	8.40	9.35	10.30
DN450	1.75	3.60	5.00	6.25	7.35	8.35	9.35	10.25
DN525	1.65	3.55	4.95	6.20	7.30	8.30	9.30	10.20
DN600	1.60	3.50	4.90	6.15	7.25	8.30	9.25	10.15
DN675	Not safe	3.45	4.90	6.10	7.20	8.25	9.20	10.10
DN750	Not safe	3.45	4.85	6.05	7.15	8.20	9.15	10.10
DN900	Not safe	3.35	4.80	6.00	7.10	8.15	9.10	10.05
DN1000	Not safe	3.30	4.75	5.95	7.05	8.10	9.05	10.00
DN1200	Not safe	3.20	4.65	5.85	6.95	8.00	8.95	9.90
SN10000								
DN300	2.70	4.85	6.60	8.10	9.50	10.75	11.95	13.10
DN375	2.65	4.85	6.55	8.05	9.45	10.70	11.90	13.05
DN450	2.60	4.80	6.50	8.00	9.40	10.70	11.90	13.05
DN525	2.60	4.75	6.45	8.05	9.35	10.65	11.85	13.00
DN600	2.50	4.70	6.40	7.95	9.30	10.60	11.80	12.95
DN675	2.50	4.65	6.40	7.90	9.25	10.55	11.75	12.90
DN750	2.45	4.60	6.35	7.85	9.25	10.50	11.70	12.85
DN900	2.40	4.55	6.30	7.80	9.20	10.45	11.65	12.80
DN1000	2.30	4.50	6.25	7.75	9.15	10.40	11.60	12.75
DN1200	2.20	4.40	6.15	7.65	9.05	10.30	11.50	12.65

Note: Table 6.5(c) is based on the following design parameters

1. *Pipes are Class PN1 i.e. non pressure*
2. *No negative pressure (i.e. vacuum)*
3. *Allowable design deflections¸ 6%,*
4. *Circumferential flexural strain¸ 0.65%*
5. *Buckling factors of safety¯ 2.5*
6. *Water table at surface*
7. *AUSTROADS dual lane T44 highway loading*
8. *Fill density of 20kN/m^3*
9. *Trench width in accordance with Table 6.1*

Minimum cover height

Cover heights shown in Table 6.5(c) may be insufficient to prevent flotation should the trench become flooded when the pipes are empty. A minimum cover of at least 1.5 x pipe diameter is necessary to avoid this possibility.

Table 6.6 Minimum cover heights

Location	Minimum height of cover H (m)*	Minimum value of E' (MPa)
Not subject to vehicular loading	0.30	Not applicable
Subject to vehicular loading		
- not in roadways	0.45	2.0
- in sealed roadways	0.60	2.0
- in unsealed roadways	0.75	1.5
Pipes in embankment conditions or subject to construction equipment loading	0.75	2.0

** Note these covers may be applied where there is no risk of flotation. Calculations using the methods of AS/NZS 2566 Part 1 show that these values can be used for stiffness of SN5000 or greater and diameters up to DN1400 for the minimum E' shown. The same criteria as for Table 6.5 have been used except for the live load which is AUSROADS T44 dual lane.*

Under roadways only the specified pipe embedment material should be used above the pipes and have a minimum compaction Density Index of 65%. After pipes are laid and centred in the trench, the embedment material should be compacted in layers to the specified density. The embedment should continue above the pipe to provide protection from the back fill. That is a height above the pipe of 100-300mm may be required depending on pipe size and site conditions.

External hydrostatic pressures

When applying buried flexible pipe design principles, soil support significantly enhances the buckling resistance of pipes under external hydrostatic pressure which may occur due to a high water table and/or negative internal pressures.

However where FLOWTITE™ pipes are subjected to external hydrostatic pressures without any significant external soil support, the possibility of buckling due to reduced structural stability of the pipe wall must be considered. Negative heads such as in suction delivery pipelines to pumps or as the result of negative water hammer surge waves may require a minimum stiffness of SN10000 if the pipes are above ground.

If during installation, pipes are to be grouted externally inside another conduit, the allowable liquid grout pressure will be limited by the pipe stiffness - see Table 6.7.

Where pipes are encased in concrete, which in turn is subjected to high external hydrostatic pressures, a further long term buckling possibility exists owing to the permeability of concrete. This mode of collapse should be checked for pipes serving as liners in the structural concrete of tunnels at considerable depths below the standing water table – see Table 6.8.

Values in Table 6.8 have been calculated using the method given by Lo, King and Zhang Jane – "Collapse Resistance Modelling of Encased Pipes" published in Buried Plastic Pipe Technology STP 1222 ASTM Philadelphia 1990.

Table 6.7 Allowable negative / external fluid pressures on unsupported pipes (factor of safety = 2.5)

Stiffness SN	External Pressure (kPa)	
	For intermittent and short term duration (<6 hours)	For continuous long term duration (i.e. 50 years)
5000	44	31
1000	88	61

Table 6.8 Allowable external fluid pressures on pipes in a rigid encasement (i.e. concrete encased with a factor of safety 2.5)

Radial gap as percentage of radius	Stiffness (SN) N/m/m	Enhancement Factor applied to unsupported buckling pressure of Table 6.7	External hydrostatic pressure (kPa) for continuous long term operation
0.001%	5000	14.9	458
	10000	13.0	799
0.01%	5000	14.8	455
	10000	12.9	793
0.1%	5000	14.0	430
	10000	12.0	737
1.0%	5000	8	246
	10000	7.7	473
10.0%	5000	3.5	108
	10000	3.5	215

6.2 Thrust block design for pressure pipelines

Where the pipeline system is rubber ring jointed there will be unbalanced forces at changes of size or direction of the pipeline. That is, at bends, tees, reducers, valves and closed ends. In buried installations, concrete blocks sized according to soil conditions usually restrain fittings. Where bends are in the vertical plane, convex and close to surface, the mass of a concrete anchor block alone may have to be used.

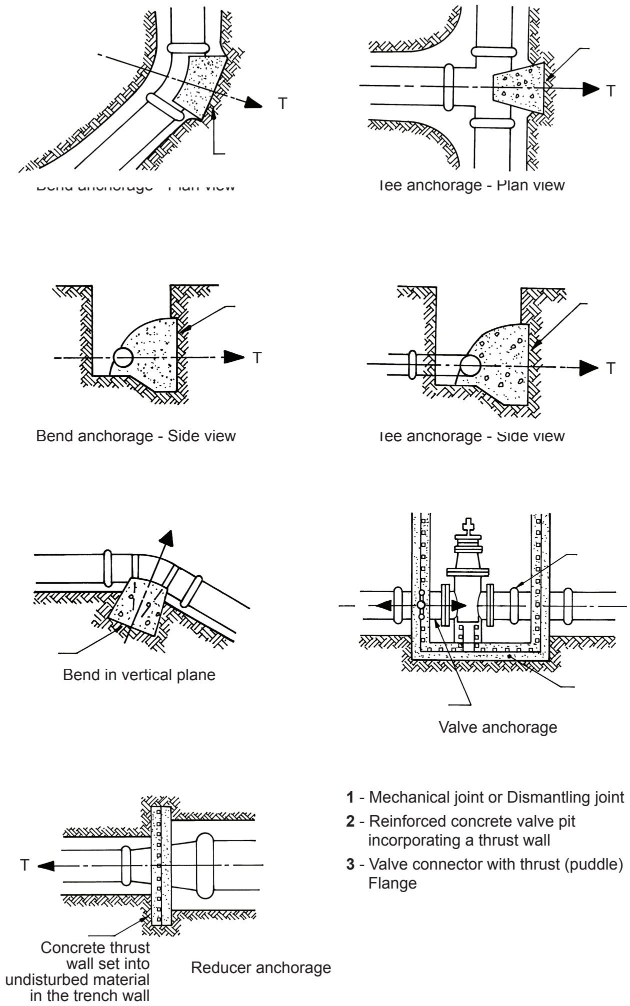


Figure 6.6 – Typical concrete thrust block arrangements for ductile iron fittings

For GRP fittings with operating pressures above 10bar (> PN10) the block must completely surround the fitting. For lower pressures, special fittings can be supplied that allow for partial embedding. The block should be placed either against the undisturbed earth or backfilled with the embedment materials selected and compacted as appropriate to meet the original native soil's strength and stiffness.

For design purpose, the total head at the fitting should be taken as either the maximum recommended working pressure or the relevant class of pipe or the field test pressure, whichever is the greater.

The magnitude of hydrostatic thrusts can be calculated as follows:

Bend

$$R = 2\,(PA + \rho QV)\sin\frac{\theta}{2} \qquad \text{..................}\textit{Equation 6.5}$$

where

R = resulant thrust (N)
P = pressure (Pa)
A = cross sectional area (m^2)
ρ = density of water (1000kg/m^3 at 15ºC)
Q = discharge (m^3/s)
V = velocity of flow (m/s)
θ = angle of bend (degree)

Since the velocity head is negligible in most water supply systems, Equation 6.5 can be reduced to

$$R^1 = 15.4HD^2\sin\frac{\theta}{2} \qquad \text{..................}\textit{Equation 6.5a}$$

Where

H = total head (m)
D = external pipe diameter (mm)
R^1 = resultant force (kN)

Tees or closed ends

$$R^1 = 7.7HD^2 \qquad \text{..................}\textit{Equation 6.5b}$$

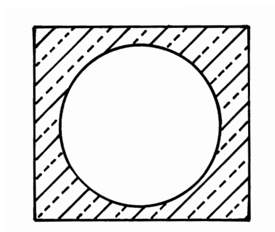
The magnitude of the thrust is equal to that for a 60º bend for the same diameter.

Tapers

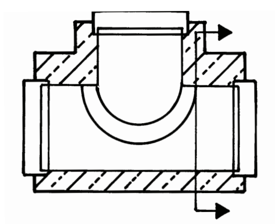
$$R^1 = 7.7HD1^2 - D2^2 \qquad \text{..................}\textit{Equation 6.5c}$$

Where D1 and D2 are the two pipe external diameters in (mm)

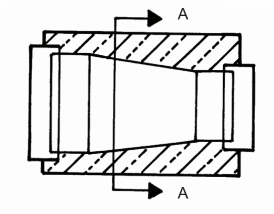
The magnitude of the thrust can be obtained by taking the difference of the two thrusts for closed ends of the two relevant diameters.



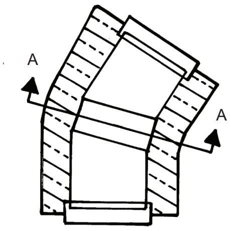
Section A-A



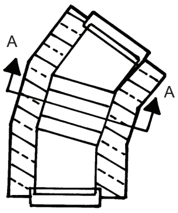
Tee



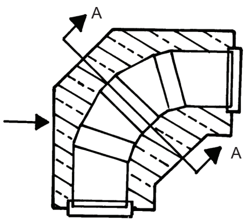
Reducer



Bend up to 30º



Band 31-60º



Band 61-90º

Figure 6.6.1 – Typical concrete thrust block arrangements for GRP pressure fittings

Thrust blocks must be formed so as to distribute the hydrostatic force to a plane surface of undisturbed soil, which is approximately perpendicular to the imposed load. The equation for this calculation is:

$$A = T / b \times f \qquad \text{.......................} \textit{Equation 6.6}$$

Where A = area perpendicular to the force (m^2)

T = hydrostatic thrust (kN)
b = soil bearing capacity (kPa)
f = factor of safety

Example 6.1

Problem

A DN750 PN10 SN5000 pipe laid at a cover height of 1000mm will be subjected to an internal pressure of 1100kPa during the field testing of the pipeline. A design check is required for a thrust block to support a 90-degree Bend that has been constructed against the undisturbed soil. The soils estimated to have a safe horizontal bearing capacity of 100kPa.

Solution

From Table 6.9; the thrust from a 90-degree bend under 100kPa pressure equals 75.78kN.

Therefore the outwards thrust along the axis symmetry of the bend at a test pressure of 1100kPa will be T = 11 x 75.78 = 833.6kN.

To check the area of the concrete/soil interface perpendicular to the line of thrust use Equation 6.6

A = 833.6/100 x 1.1 = 9.17 square metres

Example 6.2

Problem

A DN1200 x 1000 PN16 SN10000 Taper is to be installed in a pipeline. What is required for resisting the unbalanced thrusts on this fitting assuming the maximum test / operating pressure is 1500kPa? The fitting will have a cover height of 1200mm. The native soil has an estimated horizontal bearing capacity of 75kPa.

Solution

For an internal pressure of 1500kPa the axial thrust shown on Table 6.9 on the DN1200 “closed” end of the fitting will be 118.63kN x 15 and on the DN1000 end will be 82.52kN x15. The difference between the two closed ends will be the thrust to be supported by the thrust block i.e. 541.65kN.

Therefore the area of the thrust block at the concrete / native undisturbed soil interface perpendicular to the line of thrust (i.e. parallel to the axis of the fitting - refer to Figure 6.6) can be calculated using Equation 6.6.

A = 542/75 x 1.1 = 7.95 square metres.

Table 6.9 Approximate hydrostatic forces (kN) on rubber ring jointed fittings per 10 metres of hydrostatic head

Pipe DN	Pipe OD (mm)	Bend 90° (kN)	Bend 45° (kN)	Bend 22.5° (kN)	Bend 11.25° (kN)	Tee / Closed end and Valve (kN)
300	345	13.22	7.15	3.65	1.83	9.35
375	426	20.16	10.91	5.56	2.79	14.25
450	507	28.55	15.45	7.88	3.96	20.19
525	587	38.27	20.71	10.56	5.31	27.06
600	667	49.41	26.74	13.63	6.85	34.94
675	747	61.98	33.54	17.10	8.59	43.83
750	826	75.78	41.01	20.91	10.50	53.59
900	923	94.63	51.21	26.11	13.12	66.91
1000	1025	116.70	63.16	32.20	16.18	82.52
1100	1127	141.17	76.40	38.95	19.57	99.76
1200	1229	167.77	90.80	46.29	23.26	118.63
1300	1331	196.90	106.56	54.32	27.29	139.14
1400	1433	228.09	123.44	62.93	31.62	161.28
1500	1535	261.88	141.73	72.25	36.30	185.60
1600	1637	297.65	161.09	82.12	41.26	210.47
1700	1739	336.11	181.90	92.73	46.59	237.51
1800	1841	376.46	203.74	103.86	52.18	266.19
1900	1943	419.60	227.08	115.77	58.16	296.51
2000	2045	464.51	251.39	128.16	64.39	328.46
2100	2148	512.81	277.53	141.48	71.08	362.38
2200	2249	561.81	304.05	155.00	77.88	397.26
2300	2351	614.32	332.47	169.49	85.15	434.11
2400	2453	668.35	361.71	184.40	92.64	472.59
2500	2555	725.55	392.67	200.18	100.57	512.71
2600	2657	784.64	424.64	216.48	108.76	554.46
3000	3065	1043	564.71	287.88	144.64	737.82

Note: For concentric reducers the resultant thrust will be the difference between the "closed end" forces for the two pipe sizes.

Anchoring of valves (General)

Under pressure conditions, in line valves require anchorage to resist the thrust developed when the valve is closed.

There are several methods for anchoring a valve. The best method will be dependent on the pipe diameter and the specific operating conditions for each system.

There are two basic considerations for anchoring in-line valves; are they directly accessible (installed in chambers) or not (direct buried)? Generally, smaller diameter valves are direct buried without the use of concrete chambers. Larger valves are normally installed in a valve pit using a valve connector with a thrust flange. The thrust flange can be cast into the concrete thrust wall set into the undisturbed native soil outside the trench. Refer Figure 6.6 and AS/NZS 2566.2 for further reference.

Direct buried

Where valves are directly buried and encapsulated in its own concrete thrust block, the reinforced concrete thrust block must be properly designed to resist thrust from a closed valve with movement limited to the leak tightness of the joint.

The size of the concrete thrust block is based on the local soil stiffness, backfill materials and installation conditions. Any movement should be limited to 15mm. The flanged socket connectors should be no more than 500mm in length, connecting to a rocker pipe (Figure 6.8).

Alternatively, the valve body can also be anchored allowing access for servicing by having a thrust block adjacent the valve. The limit of use is dependent on the strength of the steel or ductile iron Flanged pipe with thrust flange. For small thrust loads, only one side of the valve needs to be anchored.

The size of the thrust block is based on the local soil stiffness, backfill material and installation conditions. Limit lateral movement to preserve the leak tightness of the joint.

If steel or ductile iron flanged x spigot stubs are used, the use of a flexible steel coupling or dual bolting mechanical coupling is recommended.

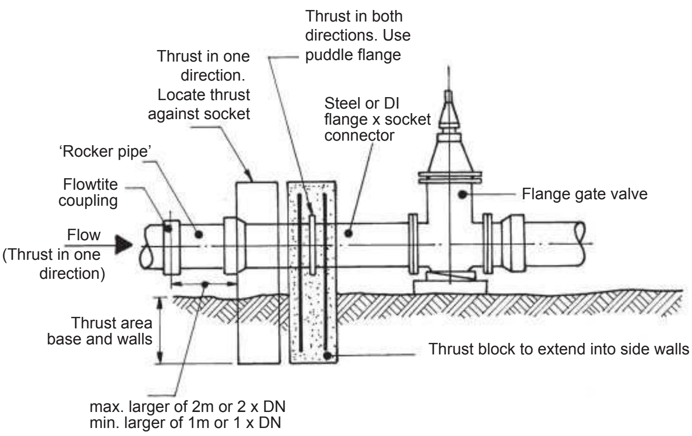


Figure 6.7 – Typical valve restraint for direct buried flanged valves (Illustration only, not to scale)

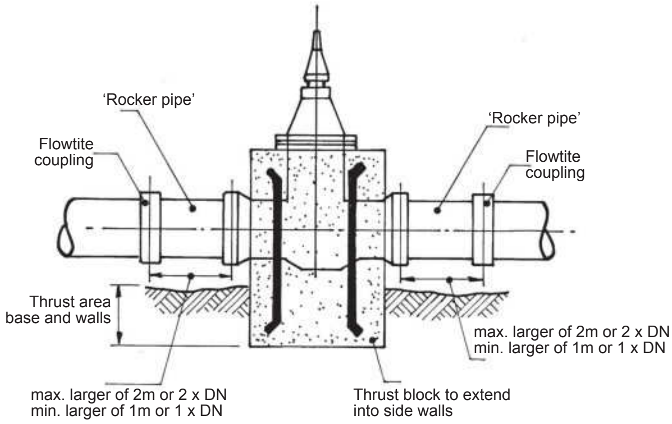


Figure 6.8 – Typical valve restraint for direct buried socketed valves (Illustration only, not to scale)

Installed in valve chambers (Fig.6.6)

This method can be used for all but the larger, higher pressure valves. The limit of use is dependent on the ability to place the structural support system into the valve chamber. The support system must be designed to accept the total axial thrust without over-stressing the valve flanges or the reinforced concrete valve chamber walls. The valve chamber acts as the thrust block and must be designed as such. The thrust restraint is placed on the compression side of the valve to transfer the thrust directly to the chamber wall. The other end of the pipe system is relatively free to move axially allowing for movement due to temperature change and Poisson effect.

Consideration must be given to the possibility of back pressure on a closed valve which could create a thrust load in the opposite direction. To accommodate this possibility the structural support system can be designed to handle load in either direction. The details are left up to the design engineer.

Figure 6.9 – DN1000 PN16 SN10000 FLOWTITE™ pressure pipes being installed on a major recycled water pipeline near Wivenhoe Dam in South East Queensland

Table 6.10 Estimated horizontal soil-bearing capacities (kPa) – apply minimum factor of safety of 1.1 for thrust block design

Soil group description as per AS 1786	Minimum soil cover above fitting supported by thrust block			
	0.75 metre	1.0 metre	1.25 metre	1.5 metre
GW, SW	57	76	95	114
GP, SP	48	64	80	97
GM, SM	48	64	80	96
GC, SC	79	92	105	119
CL	74	85	95	106
ML	69	81	93	106
OH	0	0	0	0

6.3 Design of GRP flanges

GRP flanges may be required for joining to other flanged materials or where external thrust restraints are not practicable. However they are relatively more expensive than the equivalent metal assembly and alternative solutions such as designing GRP fittings so as to eliminate flange connections should be considered. The unique fabrication methods possible with GRP frequently provide more economic solutions for complicated fitting assemblies.

Flange compatibility

For bolting compatibility flange drillings for GRP fittings manufactured to ISO 10639 and ISO 10467, the bolt PCD, outside diameter, number and diameter of bolt holes should be stated on the purchaser's order, or if not specified, then Class 16 of AS/NZS 4087"Metallic flanges for waterworks purposes" would be the default configuration as given in Table 6.11. This coincides with Tables C and D of AS 2129 "Flanges for pipes, valves and fittings". Note that for rated pressures from 1600 to 3500kPa the Class 35 configuration of AS/NZS 4087 should be used which coincides with Tables F and H of AS 2129.

Table 6.11 Compatible bolting configuration for Class 14 and 16 metallic flanges to AS/NZS 4087

DN	Bolting details				
	Outside diameter (mm)	Pitch circle diameter (mm)	No. of holes	Dia. of holes (mm)	Fastener size and thread
300	455	406	12	22	M20
350	525	470	12	26	M24
375	550	495	12	26	M24
400	580	521	12	26	M24
450	640	584	12	26	M24
500	705	641	16	26	M24
600	825	756	16	30	M27
700	910	845	20	30	M27
750	995	927	20	33	M27
800	1060	984	20	36	M33
900	1175	1092	24	36	M33
1000	1255	1175	24	36	M33

Bolt and gasket materials shall comply with AS/NZS 4087 Table 3.2 and WSA 109 "Industry standard for flange gaskets and 'O' rings" respectively.

GRP flange characteristics

The jointing procedures for flanged connections including one or more GRP flanges as compared with all metal-flanged joints are not significantly different. However Iplex recommends that the following points unique to GRP should be observed.

a) Because GRP flanges are pressure rated (e.g. PN6, PN16, etc) in the same way as GRP pipes, the required rating shall be specified by the purchaser. The flange thicknesses will vary accordingly and typically will be substantially thicker than metallic flanges of similar pressure rating.

b) GRP flanges may be either;

1) Flat faced with a full faced gasket (includes flanges with concentric ribbing on the flange or gasket surface),
2) Flat faced with an "O" ring seal,
3) Stub flange with metal backing plate and a matching flat gasket.

"O" ring seals and groove dimensions shall comply with AS/NZS 4087 Appendix B.

c) For higher pressure/torque values, flat face flanges will require a full metal backing plate to avoid risk of crushing the GRP under washers. Alternatively "O" ring seals may be used to reduce torques required at high pressures. I.e. greater than PN12 for larger than DN500. For the maximum allowable torque values see Table 6.12.

d) Flat faced GRP flanges mated with raised face flanges require an insertion plate to support the GRP flange with minimum thicknesses shown in Table 6.14. A second gasket and longer bolts will be required. (The nominated bolt torques are unaffected)

e) GRP stub flanges (with steel backing plate) can be used with raised face flanges without an insertion plate. The torque values of Table 6.12 apply.

f) Metal washers of similar material to the fasteners shall be used with all GRP flanges.

g) Fastener bearing surfaces on GRP flanges are machined all over or spot faced depending on size.

h) Appropriate bolt torques for GRP flange fasteners are listed in Table 6.12. These vary depending on the operating and rated pressure of the flange system and values for intermediate pressures may be interpolated.

i) Flat gaskets 3 mm thick complying with WSA 109 for flanges rated up to PN16 shall be used within a hardness range of 56 to 75 IRHD.

j) If the flange requires an "O" ring seal it shall comply with WSA 109 within hardness range 36 to 55 IRHD.

k) Grade 4.6 galvanised steel or Grade 316 property Class 50 stainless steel fasteners are recommended for GRP flanges. Higher strength bolts are also acceptable i.e. Grade 8.8 galvanised steel and Grade 316 Class 80 stainless steel.

Table 6.12 Bolt tightening torques for flat face and stub flanges

DN	PN6 Torque N.m	PN10 Torque N.m	PN16 Torque N.m
80	25	35	50*
100	35	40	75*
150	35	50	60*
200	50	60	80*
225	50	70	90*
250	50	80	100*
300	70	90	100*
350	70	120	150*
375	70	120	150*
400	70	120	200*
450	75	150*	250*
500	75	150*	250*
600	80	210*	300*
700	100	210*	350*
750	120	200*	400*
800	150	300*	450*
900	190	300*	475*
1000	200	400*	500*

** NB Full metal backing plate required with flat face flange and gasket. Alternatively use "O" ring or ribbed reinforced seals that allow reduced torques.*

Table 6.13 Dimensions of washers to AS 1237-1973 required for flange nuts and bolts

Bolt size	Galvanised steel		Stainless steel	
	Thickness (mm)	OD (mm)	Thickness (mm)	OD (mm)
M16	30	3	30	1.5
M20	37	3	37	2.0
M22	44	4	44	3
M27	50	3	50	3
M33	60	3	60	3

Table 6.14 Backing plates (for full face and stub flanges) and insertion/spacer flanges for raised face installations

DN	Galvanised steel		Stainless steel	
	Thickness (mm)	OD (mm)	Thickness (mm)	OD (mm)
80	8	185	10	185
100	10	215	10	215
150	10	280	13	280
200	16	335	13	335
225	16	370	16	370
250	16	405	16	405
300	19	455	19	455
375	26	550	22	550
400	26	580	22	580
450	26	640	25	640
500	34	705	29	705
600	43	825	32	825
700	51	910	-	-
750	51	995	-	-
800	51	1060	-	-
900	61	1175	-	-
1000	61	1255	-	-

The above table is based on AS/NZS 4087 Table PN16 steel flange thicknesses and drilling patterns.

6.4 Above ground installation – General guidelines

Standard FLOWTITE™ pipes with rubber ring couplings or butt strap joints can be used for permanent above ground pipelines. However when standard FLOWTITE™ pipes with rubber ring jointed couplings are used above ground or in situations without soil support there is a need for careful consideration to be given to the design and location of the supporting structures.

Exposure to sunlight and ultra violet radiation does not affect unprotected FLOWTITE™ structurally although the exterior will become weathered, that is roughened and discoloured with time. If this is not acceptable pipes can be coated with water based acrylic paint finishes.

Should there be unusually high tensile axial loadings exceeding those allowable for standard pipe, special "biaxial" FLOWTITE™ can be specified which has enhanced axial strength up to three times that of standard pipe.

Pressure pipes must be installed on a straight alignment to ensure there are no unanticipated lateral reaction forces due to the hydrostatic pressure in the pipeline. Fittings will need special anchorage to withstand thrusts caused by hydrostatic pressures within the pipe system. In the case of pressure pipes supports are required each side of the coupling, Figures 6.10 and 6.11. This limitation can be increased for low-pressure applications. When a pipe length is supported on more than two supports, the alignment should be kept straight to within the specified tolerance of the span length.

A typical detail for support cradles and hold-down/ anchor straps is shown in Fig 6.12. Compressible material such as insertion rubber should be placed between the pipe wall, the cradle and/or strap. The cradle should extend to 150 degrees of the circumference and have a radius that allows for the protection. Any misalignment of the supports across the joints should be limited to the lesser of 0.5% x DN and 3mm. Although hold down straps is not usually required at every support there should be at least one per pipe, uniformly spaced along the pipeline.

Calculations of the safe span lengths in Table 6.15 have been made on the basis of applying a factor of safety of 6 to the axial strength of the pipe and limiting the deflection to span / 500.

For detailed design and installation of FLOWTITE™ pipes and fittings above ground, refer to the "FLOWTITE™ Installation Guide above Ground with non restrained Joints" available from Iplex Pipelines.

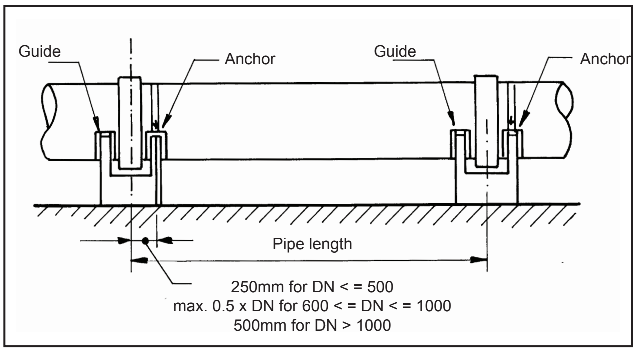


*Figure 6.10 – Typical support locations for pressure pipes on two cradles**

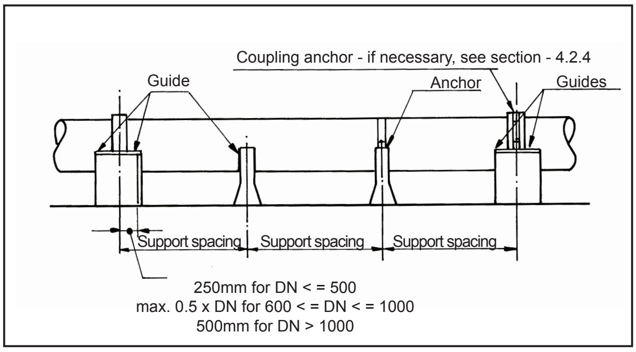
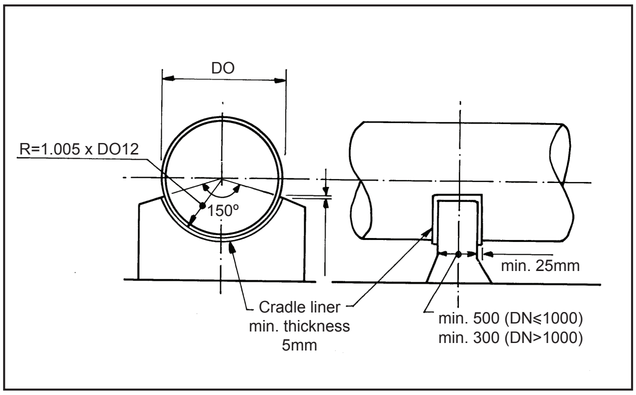
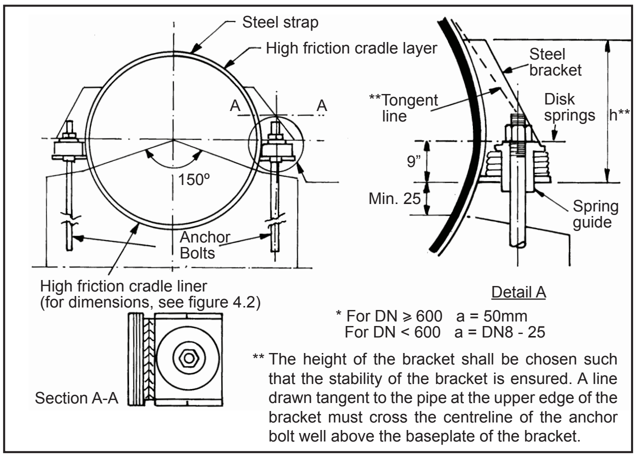


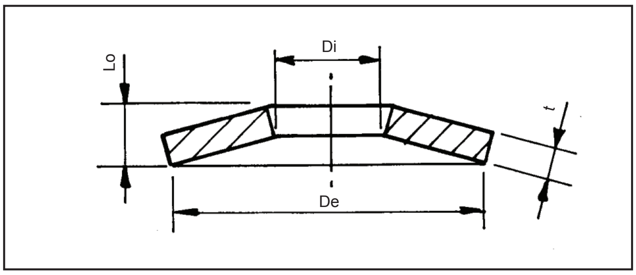
*Figure 6.11 – Typical support locations for pressure pipes on multi cradles**



Cradle design



Clamp design



Disk spring

*Figure 6.12 – Typical support designs**

**** Location and Support designs shown are general only. For detailed design refer to the FLOWTITE™ Installation Guide for Above Ground GRP pipes or contact Iplex Pipelines.***

Figure 6.13 – FLOWTITE™pipes in 12m lengths, being unloaded on site with a suitable forklift, load rated to suit lifting requirements

Table 6.15 Permissible span for standard FLOWTITE™ pipes in metres (m) – simply supported and full of water

DN	SN	PN1	PN6	PN10	PN16	PN20	PN25	PN32
300	5000	-	-	-	-	-	-	-
	10000	-	-	-	4.31	-	-	-
375	5000	4.06	4.47	4.47	4.64	4.81	4.96	5.14
	10000	4.06	4.47	4.47	4.64	4.81	4.96	5.16
450	5000	4.12	5.04	5.04	5.17	5.37	5.55	5.73
	10000	4.12	5.04	5.04	5.17	5.37	5.55	5.73
525	5000	4.14	5.54	5.54	5.69	5.89	6.08	6.28
	10000	4.14	5.54	5.54	5.69	5.89	6.08	6.28
600	5000	4.26	5.97	6.04	6.18	6.39	6.61	6.81
	10000	4.26	6.04	6.04	6.18	6.39	6.61	6.81
675	5000	4.41	6.22	6.40	6.64	6.88	7.11	7.33
	10000	4.41	6.52	6.52	6.64	6.88	7.11	7.33
750	5000	4.58	6.46	6.64	7.09	7.34	7.58	7.82
	10000	4.58	6.96	6.96	7.09	7.34	7.58	7.82
900	5000	4.73	6.76	6.95	7.55	7.90	8.15	8.40
	10000	4.73	7.39	7.39	7.64	7.90	8.15	8.40
1000	5000	4.91	7.03	7.24	7.89	8.29	8.72	8.99
	10000	4.91	7.73	7.73	8.16	8.45	8.72	8.99
1200	5000	5.22	7.57	7.80	8.52	8.96	9.47	10.11
	10000	5.22	8.35	8.35	8.90	9.30	9.75	10.11
1400	5000	5.52	7.54	8.31	9.09	9.31	10.14	11.13
	10000	5.52	8.91	8.91	9.51	9.94	10.45	11.13
1600	5000	5.80	8.57	8.80	9.64	-	-	-
	10000	5.80	9.46	9.46	10.09	-	-	-
1800	5000	6.07	9.01	9.26	10.16	-	-	-
	10000	6.07	9.96	9.96	10.64	-	-	-
2000	5000	6.32	9.44	9.70	10.64	-	-	-
	10000	6.32	10.45	10.45	11.16	-	-	-
2200	5000	6.57	9.85	10.12	-	-	-	-
	10000	6.57	10.92	10.92	-	-	-	-
2400	5000	6.81	10.25	10.52	-	-	-	-
	10000	6.81	11.36	11.36	-	-	-	-
3000	5000	7.48	11.34	-	-	-	-	-
	10000	7.48	12.60	-	-	-	-	-

Section 7

Installation

7.0 Installation

7.1 Transportation and storage

When FLOWTITE™ pipes are unloaded and placed in storage they should be kept in their packs if possible. The storage site should be smooth and level and able to support the packed pipes. If the pipes are not crated they should be placed on horizontal supporting timbers at maximum 4 metre centres, with 2 metre maximum over hang. Supporting timbers should also be used to separate the layers if the pipes are stacked. Stack heights should be limited to prevent excessive ovalisation. The socket and spigot ends should also be placed at alternate ends with sockets protruding so that they will not be subjected to end loads during storage.

Although FLOWTITE™ pipes are light and robust they should not be rolled, dropped, thrown, or allowed to come into contact with sharp objects likely to cause damage.

FLOWTITE™ pipes are packed for road freight on shaped timber bearers with couplings already fitted unless otherwise specified.

Table 7.1 Estimated quantities of FLOWTITE™ pipes on a semi-trailer

DN	Pipe configuration (across x height)	No of 6m or 12m lengths per semi	Metres per semi
300	6 x 5	60 or 30	360
375	5 x 5	50 or 25	300
450	4 x 4	32 or 16	192
525	4 x 4	32 or 16	192
600	3 x 3	18 or 9	108
675	3 x 3	18 or 9	108
750	2 x 3	12 or 6	72
900	2 x 2	8 or 4	48
1000	2 x 2	8 or 4	48
1200	2 x 2	8 or 4	48
1400	1 x 2	4 or 2	24
1500 - 2400	1	2 or 1	12

Unloading fittings

GRP fittings should not be dropped or subjected to impact, particularly at the spigot ends. If mechanical equipment is used, slings must be padded where they come into contact with open ends of heavy fittings.

Ductile iron fittings are provided with lifting lugs which are located at the axis of balance. Care should be exercised during unloading or handling to avoid damaging the spigot ends or coatings or cement linings of ductile iron fittings.

Figure 7.1 – Semi-trailer with FLOWTITE™ pipe packed with shaped timber bearers, ready for transport to site

Excavation and associated works

FLOWTITE™ is a flexible pipe and is designed to deflect diametrically under vertical soil loads within specified limits without structural damage. The external load above the pipe causes a reduction in the vertical diameter and an increase in the horizontal diameter. The horizontal movement of the pipe walls into the soil develops a passive resistance which helps support the external loads. AS/NZS 2566.2 "Buried Flexible Pipelines – Part 2 Installation" provides extensive guidance on installation requirements.

Trench excavation

Excavate the trench to the line and grade specified. The trench width must be sufficient to permit compaction of the pipe embedment materials with suitable equipment. The minimum pipe trench width required is typically equal to pipe OD + 400mm to OD + OD/2 mm depending on pipe diameter – see Table 6.1 for widths as per AS/NZS 2566.2. The trench bottom should be even and free of large clods and stones.

Safe work practices

Operations in trenches are carried out in potentially hazardous conditions. Where appropriate shore, sheet, brace, slope or otherwise support the trench walls to protect any person in the trench. Take precautions to prevent objects falling into the trench, or collapes caused by the position or movements of adjacent machinery or equipment, while the trench is occupied. Excavated material should be deposited in a safe distance from the edge of the trench, and the proximity and height of the soil bank should not be allowed to endanger the stability of the excavation.

Foundation

The native soil in the foundation zone should be carefully excavated to grade to permit the pipeline to be correctly aligned and allow a minimum thickness of 75mm to 150mm of bedding beneath the pipe, depending on the diameter.

Unstable and wet ground conditions

When wet and/or unstable soil conditions are encountered, precautions must be taken to maintain firm and permanent side support for the pipes once installed. Where groundwater is present and there will be a risk of the fine soil particles migrating across the interface between the native and embedment soils, it is recommended that the embedment material should be fully enveloped with geo-textile material. Details of soil gradings where this can occur are given in AS/NZS 2566.2.

Pipe installation should be carried out in a trench free of water. Where there is a possibility of a continuing high rate of ground water inflow it may be necessary to facilitate drainage of the trench by the use of a porous layer of bedding material in the foundation zone. Generally this will be a coarse granular material which will need to be fully encapsulated in a geo-textile fabric and is sometimes described as a drainage "mattress".

Trench shields

Where trench shields or soil boxes are required, it is desirable for them to be a close fit against the excavated trench walls and for the bottom edge to be kept above the top of the pipe.

If for safety reasons they must extend to the bottom of the trench, compaction of the embedment after the shields are lifted is necessary to eliminate any voids that may otherwise develop (see Figures 7.2a and 7.2b).

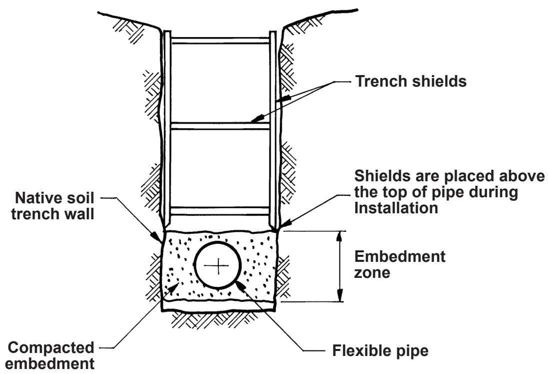


Figure 7.2a – Trench shields above side support zone

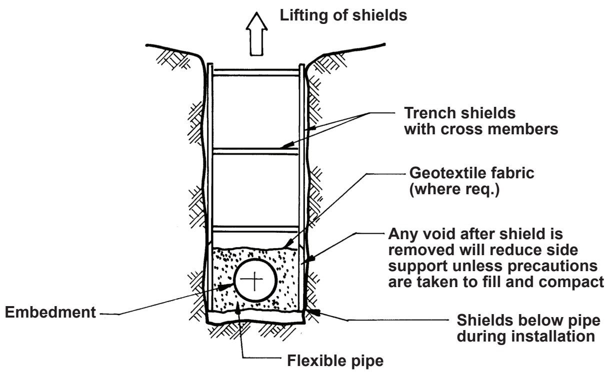


Figure 7.2b – Trench shields in side support zone

Soil boxes used in open excavations are prone to accumulate loose debris between the box and the trench wall. As this poor quality material can adversely affect the available side support, it is good practice to place high quality embedment material in this part of the side support zone as soon as possible to exclude any debris or material which may slough from the trench wall (see Figure 7.3)

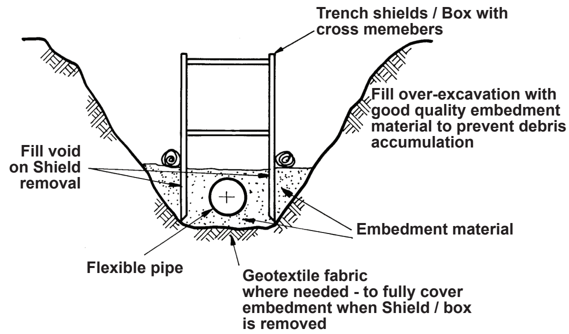


Figure 7.3 – Trench shields in wide trench

7.2 Pipe laying

Bedding

The pipe bedding should be comprised of embedment material used to provide uniform support and load distribution along the pipe barrel as well as supporting the side support embedment material. A layer of granular material of at least 100mm clear thickness should be placed and compacted as specified. A slight depression should be formed under each socket to ensure that the complete length of the pipe barrel is evenly supported. When aligned as specified, the pipes should be on the centreline of the trench. If groundwater is present, the trench should be de-watered so that the pipes can be installed in a relatively dry trench. In unstable soils additional bedding may be required to provide a sound foundation where unsatisfactory native material has been removed from the foundation zone.

Once the trench and bedding has been prepared, pipes can be lowered into the trench with suitable lifting equipment (chains should not be used). Generally an excavator/backhoe can be used with a nylon sling at the midpoint of a pipe. The following procedure is recommended when installing FLOWTITE™ rubber ring jointed pipes and fittings.

Jointing of pipes and fittings (rubber ring types)

1. FLOWTITE™ pipes are delivered to site with a coupling already fitted on each length. It is normal practice to string pipes so that they can be laid by starting from the down-stream end with the coupling or "socket" end facing in the up-stream direction.

2. Thoroughly clean the coupling grooves for the rubber seal and central register stoppers.

Figure 7.4 – Inspecting and cleaning the coupling grooves and ring before joining DN750 FLOWTITE™ pressure pipes

Figure 7.5 – Applying an approved jointing fluid to the pipe spigot prior to inserting the spigot into the coupling

Figure 7.6 – A petrol powered disk cutter is used to cut the pipe

3. If the joint is to be made using a cut pipe length, the pipe spigot diameter must first be checked to ensure it is within tolerance. Cutting with a portable circular saw fitted with a diamond tipped or abrasive masonry blade can be used. As FLOWTITE™ pipes contain significant amounts of silica sand it is essential precautions are taken against the inhaling of dust produced during the cutting process, see 'Safe Work Practices' in Section 7 (After cut pipe spigot end preparation).

   Approximately 20% to 30% of pipe lengths supplied (Adjustment pipes ≤ PN16) on a project will be suitable for cutting and joining without any machining. If the pipe has been cut the spigot should be chamfered and a new witness mark made with a black marker pen at a distance from the spigot end equal to the socket insertion depth. Refer to Figure 4.1.

4. Ensure each pipe is progressively placed on the bedding material at the correct line and grade. Insert the REKA ring seal in the groove with the tapered side facing outwards and ribbing exposed. It will help if the ring is allowed to form two loops opposite each other while the ring is progressively being pushed into the recess as the ring is being compressed circumferentially during this process. Ensure the ring is uniformly seated. Only at this stage should a thin layer of Iplex jointing fluid be applied to the exposed rubber seal surface. Also apply jointing fluid liberally to the spigot up to the witness mark. **(Under no circumstances should mineral oils or greases be used, as these compounds will cause long-term degradation of the rubber seal. In an emergency common soap can be used)**.

5. The jointing force must be applied in an axial direction without jerking. If mechanical plant such as an excavator bucket is being used, timber packing must be provided to protect the GRP surfaces. Alternatively one or two cum-along-winches attached to nylon slings wrapped around each pipe can be used.
   Note: The approximate mounting force in kg is DN in mm x 2.
   E.g. DN600 FLOWTITE™ pipe = 600 x 2 = 1200kg force.

6. Push (or pull) the joint home and use the witness mark on the pipe spigot to determine when it is fully inserted.

7. Where a change in alignment is to be made at a joint the offset should be made after pushing the pipe fully home without any misalignment. The pipe can then be moved to the required angular deflection limits shown in Table 7.3.

Table 7.2 The quantity of jointing lubricant normally supplied with an order

Nominal diameter	Approx number of joints per tin	
	1kg	4kg
300	6.5	26
375	6.5	26
450	5	20
525	4	16
600	3	13
675	2.5	11
750	2.5	10
900	2	9
1000	2	8
1200	1.5	6
1300	1.5	6
1400	1	5
1600	1	5
1800	1	4
2000	1	4
2200	0.5	3
2400	0.5	3
3000	0.5	2

Angular deflection limits for FLOWTITE™ couplings

The maximum angular deflection at each coupling joint must not exceed the values given in Tables 7.3 and 7.4. It will be noted from Table 7.4 that pipe lengths shorter than standard may be useful were the pipe alignment needs to be curved without the use of bend fittings. The normal angular deflection permitted for FLOWTITE™ coupling joints is shown in Table 7.3 however for diameters larger than DN525 where both sides of the coupling are mobilised the permissible overall joint deflection can be as much as TWICE that tabulated.

Note that where these deflections result in a convex vertical curve in the pipeline alignment, the depth of cover should be increased to at least 1.2m above the pipeline if the operating pressure is more than 1500kPa.

Table 7.3 Angular deflections 'θ' (rotation) at a FLOWTITE™ coupling joint (degrees)

DN	PN1 - PN16	PN20	PN25	PN32
DN300 - DN450	3.0°	2.5°	2.0°	1.5°
DN525 - DN900	2.0°	1.5°	1.3°	1.0°
DN1000 - DN1800	1.0°	0.8°	0.5°	0.5°
DN1900 - DN3000	0.5°	NA	NA	NA

Table 7.4 Offsets in millimetres for each angular joint deflection and pipe lengths shown.

Deflection angle 'Y' (degree)	3m length	6m length	12m length
3.0°	157	314	628
2.5°	136	261	523
2.0°	105	209	419
1.5°	78	157	313
1.3°	65	120	240
1.0°	52	105	209
0.8°	39	78	156

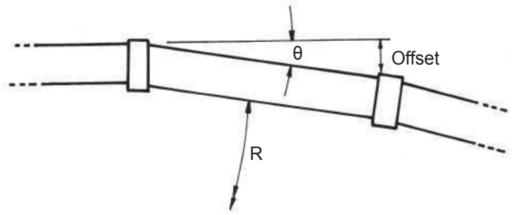


Figure 7.7 – Joint geometry - angular deflection 'θ' includes both sides of coupling

Table 7.5 Nominal radii of curvature 'R' in m, for each angular joint deflection and pipe lengths shown.

Deflection angle 'Y' (degrees)	3m length	6m length	12m length
3.0°	57	115	230
2.5°	69	137	274
2.0°	86	172	344
1.5°	114	228	456
1.3°	132	265	532
1.0°	172	344	688
0.8°	215	430	860

Figure 7.8 – FLOWTITE™ GRP pipes designed for curvilinear alignment and angular joint deflection

Cut pipe spigot-end preparation

It is important to select an ‘Adjustment’ pipe (branded ‘ADJ’ or ‘ADJUST’) for cutting as this pipe will be fully toleranced along the entire length of the pipe to the required spigot tolerances and allow the use of a standard FLOWTITE™ coupling without any machining required. The cut end should be chamfered at a 20-degree angle (to the pipe axis) for the distance given in Table 4.1 and Figure 4.1.

Safe work practices

When handling FLOWTITE™ pipes and fittings always wear appropriate Personal Protective Equipment (PPE) including eye protection, dust mask, long sleeved shirt and trousers, hearing protection, gloves and safety footwear. A wet saw system shall be used to suppress dust.

Joint misalignment

The maximum sideways or vertical shear displacement (i.e. misalignment) between pipe spigots when joined with FLOWTITE™ couplings is limited to 5 millimetres. Therefore attention must be given to the possibility of differential settlement between the pipeline components or associated structures to avoid exceeding this limit over time.

Field closures

FLOWTITE™ couplings can be used as slip collars if the central rubber stops are removed and the pipe ends to be joined are within the same tolerances as adjustment pipes. This can be checked in the field by removing the rubber rings and ensuring that the coupling will slide over the pipe for the required distance.

If the pipe ODs are too large for the FLOWTITE™ slip collar procedure then proprietary mechanical joints such as Teekay, Straub, Norma or in the smaller diameters (< DN750) Gibault joints will be required for cut-ins . For larger diameters at higher pressures, Klamflex and Viking Johnson couplings may be necessary. The coupling manufacturer’s recommendations with respect to assembly and bolt tightening must be followed.

Tapped connections

As with most pipe materials FLOWTITE™ pipes cannot be direct tapped and will require either an approved tapping band, Multi-Fit™ joint or socket x flanged branch Tee, depending on the diameter of the branch required. Specialist contractors with equipment for live (under pressure) tapping should be used when tapping mains under pressure. No tapping should be closer than 2 x main diameter to the end of a pipe and should be limited to pipes not subject to significant axial stresses.

For small off-takes (service connections 20 and 25BSP), approved tapping bands such as a Taptite™ are recommended. Taptite™ tapping bands are available in sizes DN300 to DN600, and are suitable for working pressures up to 1600kPa. Holes should be drilled using tungsten tipped masonry drill or similarly a hole trepanning cutter.

For larger off-takes (> DN25) approved pressure tees with flanged off-takes are recommended with a tapped blank plate as specified or Multi-Fit™ couplings (DN300 to DN600) with BSP tapping.

Where under pressure cut-in connections are required, they should not exceed the following ‘nozzle diameter in mm, to the main diameter’ percentage ratio for the given stiffness of pipe:

SN5000	25%
SN10000	30%

Only approved tapped sleeves should be used, that is proprietary types which have been tested on GRP pipes. The manufacturer’s instructions must be followed with particular attention paid to applying the correct bolt torques.

Flanged joints

The procedure for assembling flanged joints is as follows: -

1. The mating flanges and gasket must be clean, smooth and properly aligned at the start of the assembly process. If an ‘O’ ring seal is used instead of a full face gasket, it should be correctly seated in the prescribed groove. The mating flange shall not be grooved.

2. Insert lubricated fasteners with washers for GRP surfaces. A molybdenum disulphide grease or equivalent nickel based anti-seize compound is recommended for lubrication. Ensure that there are no traces of petroleum oil or grease contaminaing the flange faces or rubber gasket.

3. Tighten the fasteners using the usual “ star ” sequence pattern – See Figure 7.10, with torque increments per cycle not exceed ing the lesser of 25N.m or 20% of the final torque requirement.

4. On achieving the recommended torque value given in Table 6.12 allow a one-hour “rest” period and re-check torques. Do not over tighten as this may damage the joint components, e.g. localised crushing of the GRP under the washers or of the gasket, leading to potential leakage in service.

5. Where possible leave access to flanged connections for inspec tion purposes until after acceptance testing is complete.

6. If leakage is observed under test, it is preferable to eliminate the hydrostatic pressure before relaxing and retightening the fasteners.

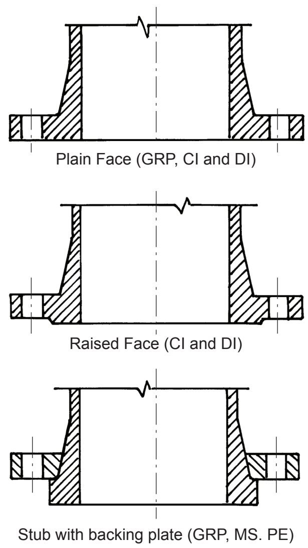


Figure 7.9 – Different types of Flanges

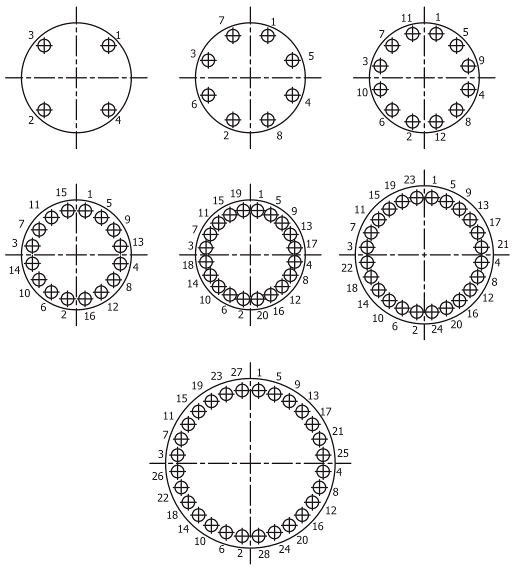


Figure 7.10 – Fastener tightening using 'star' sequence

Figure 7.11 – Flanged off-takes for scours – Note the stub flanges and backing plates, which are the preferred option

7.3 Side support and overlay

Embedment – haunching and side support

Generally, material used in the embedment zone should be uniform selected cohesion-less soil. Information regarding selection is given in Appendices G and H of AS/NZS 2566.2. The most important aspect for the successful installation of FLOWTITE™ pipe is the selection and compaction of the embedment, i.e. the material around the pipe. Embedment material should be of a granular nature, which is readily compactable. Crushed rock, aggregate and graded sand are commonly used but occasionally native soils, (e.g. beach and mallee sand) may also be suitable, provided they are free flowing and readily compacted.

The embedment must be evenly compacted between the pipe and the surrounding native soil given that the side support zone can extend beyond the pipe horizontally for a distance of up to twice the pipe diameter in the pipe zone. Care must be taken not to move the pipe from its alignment when compacting the embedment material.

Where trench shields or boxes are used, special care must be taken to ensure any voids resulting from their use are completely filled with the same approved compacted embedment material. If there is a possibility of migration of fines between the embedment and the native soil, a geo-textile fabric should be used at the interface, to completely envelope the embedment including the bedding. (See Section 4 of AS/NZS 2566.2 and Appendix J for further information)

Attention to the quality and the degree of compaction of the embedment material placed on each side of the FLOWTITE™ pipeline is fundamental to its structural integrity. Table 7.6, shows the default values given in AS/NZS 2566.2 for the appropriate degrees of relative compaction of the embedment bedding and side support zone.

Overlay

The embedment material should extend to a cover height of 100mm to 300mm above the pipe (depending on the diameter) to provide protection during placement of fill material and the operation of compaction equipment.

7.4 Trench and embankment fill (i.e. above embedment / overlay)

Backfill over FLOWTITE™ pipelines may involve the use of excavated material providing the thickness of overlay is adequate. Care must be taken to avoid the inclusion of large stones, rocks or hard clumps that may cause point loading on the pipeline.

Compaction of the final backfill by large vibrating power compactors should not be used until there is adequate height of fill over the pipes. This will vary, depending on the capacity of the machine but generally a minimum cover height of 0.5 metres is desirable.

Monitoring embedment compaction

After the filling operation is complete, the adequacy of the embedment and compaction and the use of correct backfilling techniques may be assessed either by soil stiffness/density testing during placement or by measuring the diametrical deflection of the pipe after the backfilling has been completed.

The deflection check described in Section 8.3 is particularly useful in the early stages of construction for pipes with more than 2 metres cover. Acceptable deflection values will vary depending on the elapsed time after installation. AS/NZS 2566.2 gives factors which can be applied depending on the time intervals after completion of the backfilling e.g. the maximum recommended allowable deflection at 24 hours is 2.8% for FLOWTITE™ and at 30 days, 4%. Refer to Table 6.2 of AS/NZS 2566.2 for allowable deflections at other time periods.

Note: During compaction of the backfill in the pipe embedment zone, an increase in the vertical diameter and a decrease in the horizontal diameter may occur. This is not detrimental, providing the magnitude of the horizontal diametrical deformation does not exceed the prescribed allowable deflections. See Section 8 for the test procedure.

Table 7.6 Minimum relative compactions (extract from AS/NZS 2566.2 Table 5.5)

Soil type	Test method	Trafficable areas		Non trafficable areas	
		Embedment material %	Trench / embankment fill material %	Embedment material %	Trench / embankment fill material %
Cohesion-less	Density Index	70	70	60	Compaction to suit site requirements
Cohesive	Standard Dry Density Ratio, or Hilf Density Ratio	95	95	90	

Grouting

In situations where it is necessary to pressure grout the annulus between FLOWTITE™ pipes and an enveloping conduit, e.g. when using FLOWTITE™ to reline a deteriorated pipeline, it is important to ensure the grout is introduced into the annulus evenly. The pipe must be adequately chocked to resist flotation and bending. Placement of chocks must be checked to minimise loads on the pipe. The allowable hydrostatic grout pressure will depend on its setting time but typically must not exceed P'_{allow} (Equation 7.1) to ensure an adequate factor of safety (of 2.5) against buckling instability which, may lead to pipe collapse. See also Table 6.8 for more accurate detail.

$$P'_{allow} = 24 \times SN \times 10^{-3} / SF \qquad \text{.......} \textit{Equation 7.1}$$

where

P'_{allow} = Allowable buckling pressure in kPa

SN = Nominal pipe stiffness in N/m/m

SF = Safety factor as per AS/NZS 2566 (Normally 2.5)

If necessary the effect of grout pressures can be substantially reduced by filling the pipeline with water. Alternatively it may be possible to stage the grouting process in two or even three “lifts”, allowing the grout to solidify in the annulus below the spring line before the top section is filled.

7.5 Joints subject to differential settlement

Relative settlement

Where FLOWTITE™ pipes are connected to significant concrete structures it is recommended that short pipe lengths or “rocker pipes” be used adjacent to the structure as described in AS/NZS 2566.2. This will allow the pipes to accommodate differential settlement without damage through a small amount of rotation of the rocker pipe together with joint deflection. Minimum length = larger of 1m or 1 x D and maximum length = larger of 2m or 2 x D.

Installation of FLOWTITE™ pipes on slopes (Parallel)

General

The angle at which slopes can become unstable depends on the quality of the soil. The risk of unstable conditions increases dramatically with slope angle. In general, pipes should not be installed on slopes greater than 15 degrees, or in areas where slope instability is suspected, unless supporting conditions have been verified by a proper geotechnical investigation.

Aboveground installation

Before pipes are installed underground on slopes greater than 15 degrees, it is recommended that a Geo-technical engineer be consulted. FLOWTITE™ pipes may be installed on slopes greater than 15 degrees provided the following minimum conditions are achieved:

1. Long-term stability of the installation can be ensured with a proper geo-technical design. For slopes over 15 degrees, use a cement-stabilised embedment in the pipe zone as backfill material.

2. For slopes greater than 15 degrees, use one anchor rib at the centre of each pipe section.

3. Installation should always proceed from the low point and progress up the slope. Each pipe should be properly backfilled to grade before the next pipe is placed in the trench.

4. The surface over the completed pipe trench must be protected against erosion from flowing water.

5. Pipes are installed in straight alignment (plus or minus 0.2 degrees) with a minimum gap between pipe spigots.

6. Absolute long-term movement of the embedment in the axial direction of the pipe must be less than 20mm.

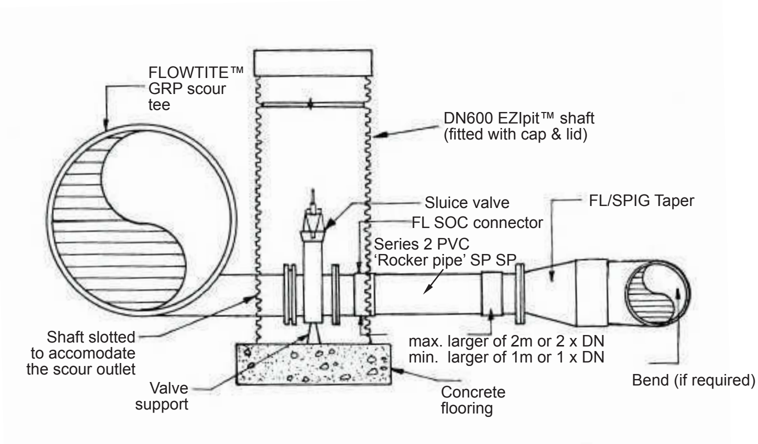
8. The installation is properly drained to avoid washout of materials and ensure adequate soil shear strength.

9. Stability of individual pipes is monitored throughout the construction phase and the first phases of operation. This can be done by controlling the gap between pipe spigots. A special pipe design may be required.

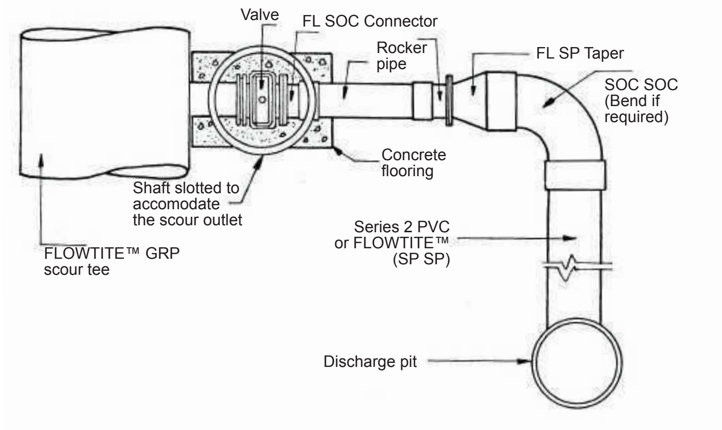
Perpendicular to the hillside

When FLOWTITE™ pipes are installed perpendicular to the fall line of a steep slope, consultation with a geotechnical engineer is recommended when the slope angle exceeds 15 degrees to assure that the hillside remains stable.

The surface of the completed trench must be configured to eliminate depressions and preclude the formation of puddles water. The collection of water on a slope may reduce the stability of the slope.

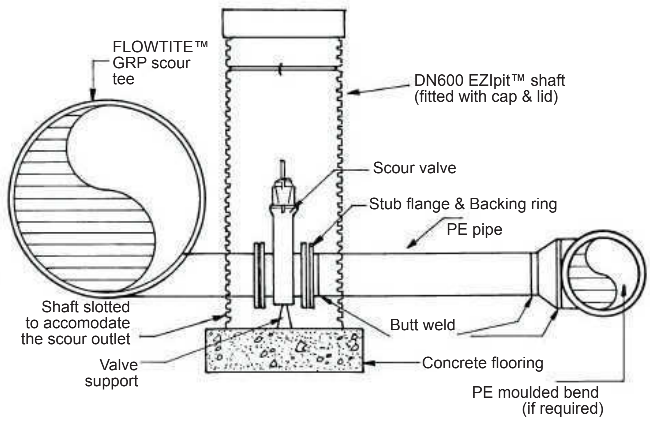


Side view of scour valve pit with rocker pipe

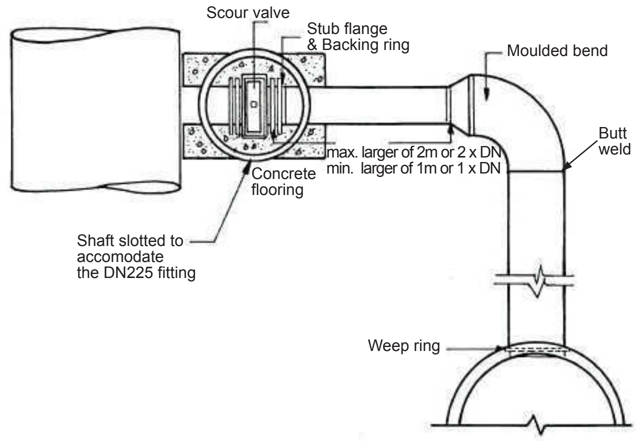


Plan view of scour valve pit with rocker pipe

Figure 7.12 – Use of a "rocker" pipe



Side view of a PE pipe being used to provide flexibility between the mainline and scour structure



Plan view of a PE pipe being used to provide flexibility between the FLOWTITE™ mainline and scour structure

Figure 7.13 – Use of flexible PE spool pipe

Pipe / concrete interface

FLOWTITE™ pipes can be directly embedded into concrete. However it is recommended that at the entry and exit points, i.e. at the face of the concrete, the pipe should be wrapped in a compressible material. Alternatively a FLOWTITE™ coupling should be located and cast into the concrete face so that the rubber ring joint can accommodate any movement.

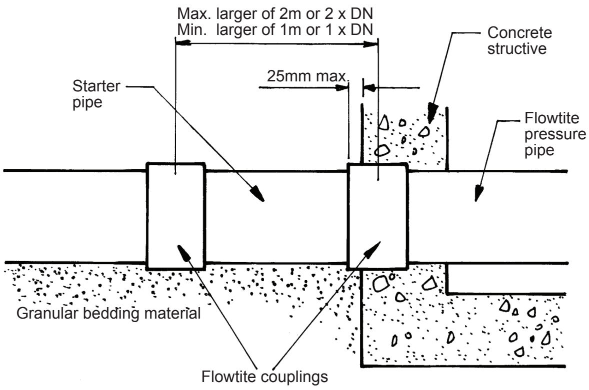


Figure 7.13a – Standard connection. Coupling cast in concrete for pressure applications.

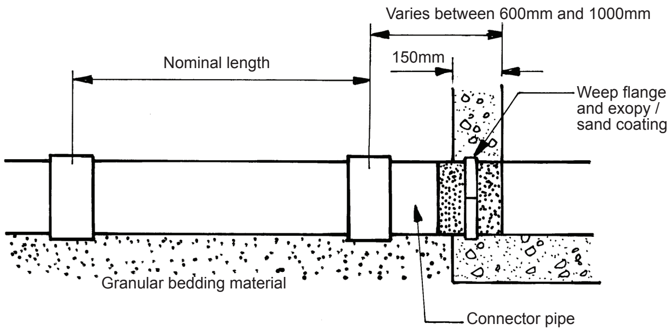


Figure 7.13b – Standard connection. Manhole connector cast in concrete for non pressure applications

Auxiliary pipe connections

Scour and air valve structures are often associated with flanged pipe work which in turn must be connected to small diameter flanged off-takes on the mainline. As there is potential for differential settlement or movement between these assemblies provision must be made for this. The usual method is to provide a “rocker pipe” which is designed to articulate between two introduced rubber ring joints as illustrated in Figure 7.12.

Alternatively a similar length of a small diameter polyethylene pipe spool with stub flanges and backing plates can be inserted between the two assemblies. Any relative movement is then absorbed by the flexibility of the polyethylene. Figure 7.13 shows a scour arrangement using PE pipes and fittings.

7.6 Cutting into or repairing installed GRP pipelines

If it is necessary to remove a section of an installed FLOWTITE™ GRP pipeline to insert a fitting or replace a damaged pipe the following procedure is a guide.

Repair kits

In addition to the replacement item which is assumed to have ends to FLOWTITE™ pipe tolerances (of which at least one is a spigot), the materials required for its insertion into the pipeline will depend on whether there is an in situ adjustment pipe in the vicinity of the intended replacement:

(i) If this were the case, the “repair kit” would comprise of three FLOWTITE™ couplings and a short “closure” length (say 3m minimum in length) of adjustment pipe.

(ii) If it is not the case the repair kit could comprise of two FLOWTITE™ couplings, a mechanical coupling and a short “closure” length (say 3m minimum in length) of adjustment pipe, or

(iii) Alternatively, if a larger excavation is possible so as to expose another joint then a full length adjustment pipe (usually 6m or 12m) for the closure should be used. This will enable all joints to have correctly toleranced ends suitable FLOWTITE™ slip collars

Note: Jointing lubricant is required for both FLOWTITE™ and mechanical couplings.

Safe work practices

FLOWTITE™ pipe is derived from hydrocarbons and as such is flammable. It is therefore not recommended for use in applications in which it may be exposed to potential ignition sources. During installation care must be taken to avoid exposure to welding sparks or flame cutting torches. This precaution is particulary important when working with volatile chemicals in making lay-up joints, repairing or modifying the pipe in the field.

Procedure

1) Dewater the pipeline.

2) If a pipe, fitting or coupling has to be removed from the installed pipeline select a position at about 1.5 metres away on one of the GRP pipes located adjacent to the item to be removed. This will be the location of the initial two "rough cuts". If there is an option of these cuts being made in an adjustment pipe this should be selected for cutting.

3) This initial opening in the line should be made by making two parallel rough cuts at least 450mm apart i.e. more than the 330mm coupling width. After clearing debris from the gap it should be possible to pull the item to be removed in an axial direction into this gap. Once free it should be possible to lift it out of the trench.

4) The in-situ rough-cut pipe end must then be prepared for a new joint by cutting back to allow for the insertion of the replacement plus closure pipe. The distance from the newly prepared spigot to the spigot end replacement piece should be calculated so as to allow for 20mm clearance allowance in between spigots

5) Care must be taken to achieve the required squareness tolerances and it will need to be sanded smooth and chamfered to the same dimensions as factory made pipe spigots. If this spigot is an adjustment pipe or a pipe to adjustment pipe dimensions, it will be possible to plan for slipping a FLOWTITE™ coupling over the pipe-to-pipe joint.

6) If the spigot is not to the required jointing tolerances for a FLOWTITE™ coupling then a mechanical coupling will be required for the pipe-to-pipe joint.

7) Because the closure pipe is an adjustment pipe, it will be possible to use a FLOWTITE™ coupling on the pipe-to-replacement joint as a slip collar. If the in-situ pipe is also to acceptable tolerances (even if not an adjustment pipe), a slip joint using a FLOWTITE™ coupling will also be possible for the pipe-to-pipe joint.

8) Note that the central stops are removed when using FLOWTITE™ couplings as slip collars.

9) Ensure that new rubber rings are used for any reused couplings.

10) If not already socketed, make up the replacement piece with a single FLOWTITE™ coupling (only) pre-fitted. Prepare bedding material in the trench to the correct level and lower the replacement into the trench. Once aligned this replacement-to-pipe joint should be made in the normal way.

11) Where both ends of the closure pipe can be slip jointed with FLOWTITE™ couplings, lubricate each in turn for a distance of 340mm (i.e. double the normal distance). Place slip couplings on both ends. They must be pushed clear of the pipe ends. Refer to Figure 7.15. Special attention is needed during this operation to ensure that the second ring is eased into position because it is being slid in the opposite direction to normal. Ensure witness marks are made on the in-situ replacement and pipe spigots and carefully align the short length in the trench. Push each slip coupling over the lubricated in-situ spigots as far as the witness marks.

12) Where a mechanical coupling has to be used for the closure pipe follow the separate General Assembly Guide specifically for this joint. Typically bolt torques for PN16 joints should be in the range of 80 to 120N.m. Note that mechanical couplings also require lubrication.

13) IMPORTANT: Use the information in the Iplex Technical Note to check the distortion Figure 7.18 of the pipe under the mechanical gasket to ensure the allowable bending strain in the pipe in the axial direction wall has not been exceeded. Adjust bolt tensions where necessary.

14) It is desirable to leave mechanical joints exposed until the completion of hydrostatic testing, as bolts may need to be re-tightened.

Note: FLOWTITE™ pipes comply with the spigot outside diameters of Table 4.3 and Table 4.4

Figure 7.14 – DN10000 FLOWTITE™ GRP adjustment pipe being inserted as a "closure pipe" using FLOWTITE™ couplings for slip action

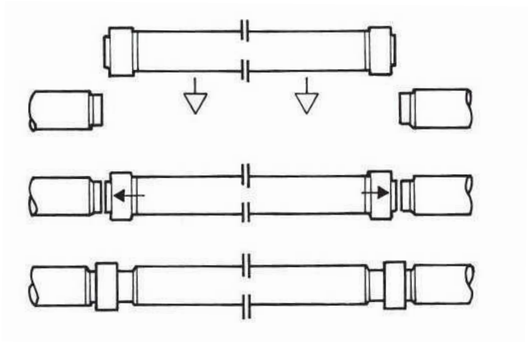


Figure 7.15 – shows the sequence for inserting the "closure pipe" using slip couplings and/or mechanical couplings on each end

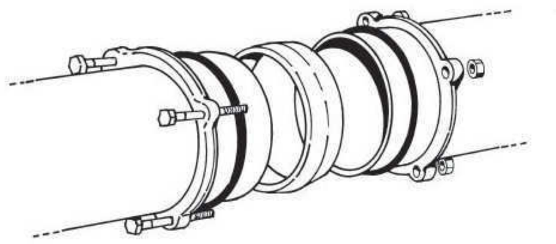


Figure 7.16 – Gibault, Viking Johnson and Klamflex couplings

Flexible steel couplings (Straub, Teekay, Norma, etc.)

When connecting FLOWTITE™ pipe to other pipe materials with different diameters, flexible steel couplings are one of the preferred jointing methods. These couplings consist of a steel mantle with an interior rubber sealing sleeve. They may also be used to join FLOWTITE™ pipe sections together, for example in a repair or for closure.

Control of the bolting torque of flexible steel couplings is very important. Do not over torque when tightening as this may over stress the bolts or the pipe. Follow the coupling manufacturer's recommended assembly instructions, **but with the pipe supplier's recommended bolt torque limits**. Consult Iplex Pipelines for further details.

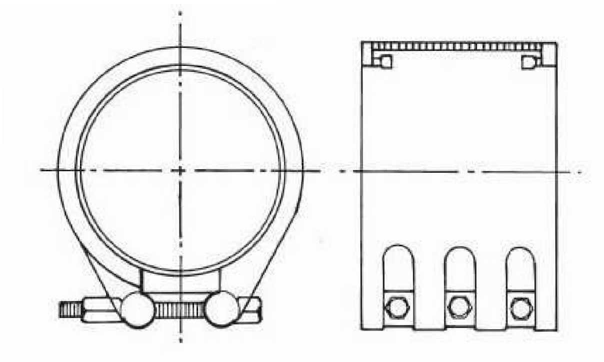


Figure 7.17 – Teekay, Norma and Straub couplings

Mechanical steel couplings (Gibault joints, Viking Johnson, Klamflex, etc.)

Mechanical couplings have been used to join pipes of different materials and diameters and to adapt to flange outlets. FLOWTITE™ Technology has found a wide manufacturing variance in these couplings, including bolt size, number of bolts and gasket design which makes standardized recommendations impossible.

Consequently, we cannot recommend the general use of mechanical couplings with FLOWTITE™ pipe. If the installer intends to use a specific design (brand and model) of mechanical coupling, he is advised to consult with Iplex Pipelines prior to its purchase. The pipe supplier can then advise under what specific conditions, if any, this design might be suitable for use with FLOWTITE™.

If using mechanical couplings to connect FLOWTITE™ to other materials, it is required that a transition mechanical coupling, that is one that utilizes two separate bolting systems on each end, be used. This is to prevent overloading the FLOWTITE™ pipe when attempting to get a watertight seal on the other material.

The pressure classes will be size dependent and may vary between the various types or brands which must be considered prior to purchase.

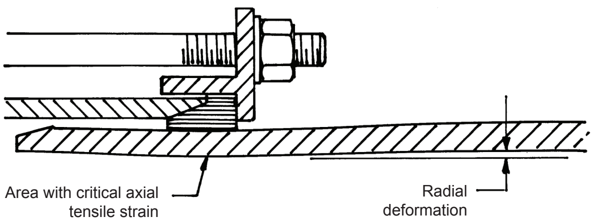


Figure 7.18

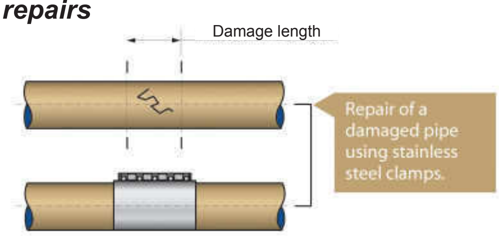
Note: The magnitude of any distortion under the gasket of large diameter mechanical couplings should be monitored internally during installation - see separate Iplex technical note.

Field repairs with mechanical couplings

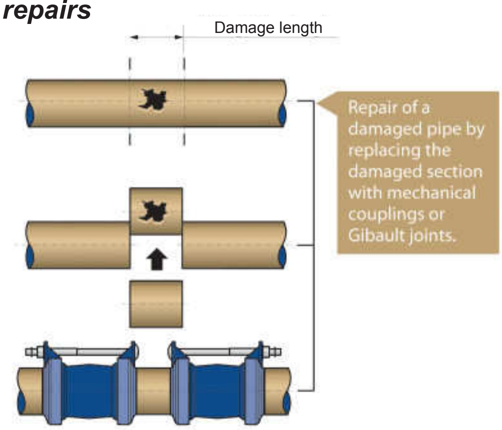
Approved Gibault joints or mechanical couplings can be used for repairing FLOWTITE™ pipes. For minor damage, stainless steel repair clamps are available. *Note: Couplings and clamps may be limited by size and pressure class. Consult Iplex Pipelines for further information.*

The following illustrations provide details of typical pipe repair methods and cut-ins.

Minor repairs

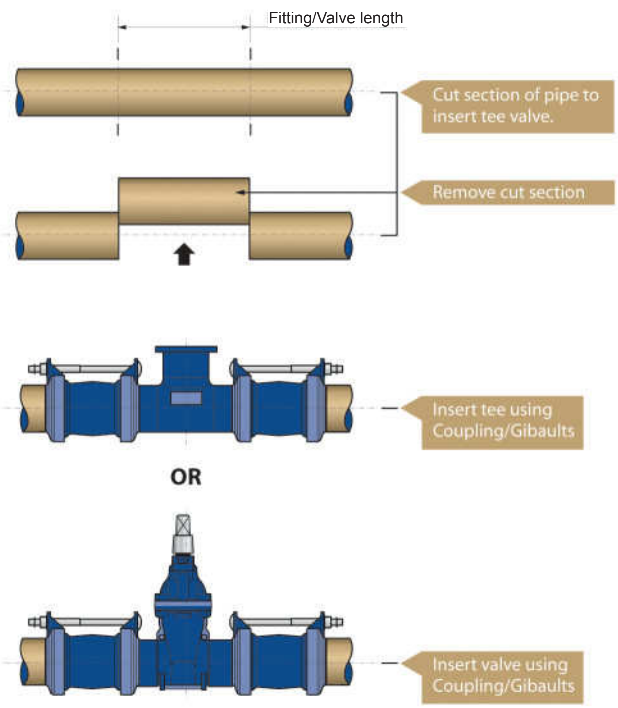


Major repairs



Post installation - Cut-ins

(typical spigoted valve or fitting insertion with gibault or mechanical joints)



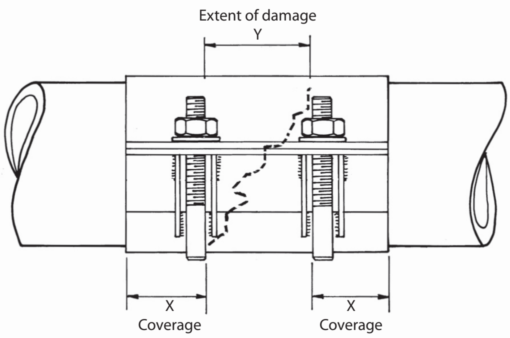
General description

Stainless steel clamps are suitable for tapping and repairing pressure pipelines up to PN16 (1600kPa). Clamps are designed to wrap around GRP pipes.

All clamps are manufactured with 316 stainless steel and can be used for above and below, ground installations. The standard sealing gasket or 'mat' is nitrile rubber complying with AS 1646 - 'Elastomeric seals for water works purposes'. *Note: Stainless steel repair clamps are not recommended for joining two pipe ends.*

Standard stainless steel 'repair clamps'

Repair clamps provide a quick solution for the repair of pressure and non-pressure pipelines. Repair clamps are designed to wrap around the affected area, eliminating the need to cut out the damaged pipe section. Repair clamps are suitable for water pipelines with operating pressures up to 1600kPa.



'X' coverage for DN300 is 100mm and pipe sizes DN375 to DN600 150mm.

Standard stainless steel 'tapped clamps'

Tapped stainless steel clamps provide an efficient method for tapping into existing pressure water or irrigation lines. The wide band distributes even pressure and support along the entire barrel of the pipe.

Sizes range from DN300 to DN600 with standard tapping sizes from dn25 to dn100mm BSP thread. This is only limited by the nominal diameter (DN) of the pipe to be tapped. Clamps are designed for pressures up to 1600kPa.

Notes: For larger sizes (DN375 and above) the allowable pressure ratings will need to be confirmed by Iplex pipelines.

Standard stainless steel 'flanged clamps'

Flanged clamps allow an under pressure cut in connection, without the need to shut down the line, cut out a section of the main and insert a tee. Flanged clamps are suitable for pressures up to 1600kPa and are available in sizes DN300 to DN600.

For flanged off-takes the sizes dn80 to dn300, are only limited by the nominal diameter (DN) of the pipe to be tapped. See Tapped Connections in Section 7.

Note: Other flange configurations are available on request only.

Flanges comply with AS/NZS 4087 - 'Metallic flanges for waterworks purposes' figure B7 with table D drillings to AS 2129 - 'Flanges for pipes, fittings and valves'

The installation procedures for Flanged off take clamps given in 'general installation instructions' can be used provided the flanged outlet is positioned correctly. It is very important that any valve or assembly attached to the flange is supported fully and aligned to eliminate any stress on the clamp. Refer to the installation instructions attached to the clamp or contact Iplex Pipelines for further information.

General installation instructions

Select the correct clamp

1. Ensure the correct clamp is selected for the appropriate pipe material and application. E.g. Type F (flexible) for GRP pipe.

2. If repairing a damaged pipe, the size range and length of the repair clamp also becomes critical. The pipe outside diameter and the length of the damage must be confirmed first prior to selecting the repair clamp.

Pipe preparation

3. Ensure the pipe surface is clean and smooth and does not contain grease, dirt, scores, which could reduce the sealing capabilities of the clamp.

Clamp installation

4. Undo the clamp leaving the nuts on the ends of the bolts.

5. Lubricate the rubber mat and pipe with an approved pipe jointing lubricant.

6. Fit the clamp around the pipe and bring the parts together using the lock washer plate. Ensure the rubber mat is correctly located and clean.

7. Lock in place and squeeze the lugs together while spinning the nuts down.

8. Prior to tightening the nuts, ensure the clamp is correctly located and has not moved.

Tightening the nuts

9. Tighten each nut evenly, starting from the centre and working outwards. Ensure all nuts are tensioned to the recommended torque, usually 80Nm to 100Nm.

10. Allow the rubber mat to seat and re torque to the recommended tension.

Section 8

Field Testing

8.0 Field Testing

8.1 Leakage testing – pressure pipelines

The test procedures of Clause 6.3.4 of AS/NZS 2566.2 “Buried flexible pipelines, Part 2: Installation” are recommended for FLOWTITE™. The recommended test pressure should be not less than the maximum design pressure and at the same time not exceed 1.25 times the pipe rating at any point along the pipeline that is not exceeding 2000kPa.

Before carrying out the test, pipes should be substantially backfilled to ensure they cannot move. Where joints are exposed some movement of the witness mark away from the socket may be apparent due to the “Poisson effect” that is the shortening of the pipes under circumferential working stress.

If no make-up water is required to maintain pressure after one hour at test pressure or after the time needed to inspect the whole pipeline, it can be considered that the test has passed. The need for make-up water may not indicate a leak if it is within certain limits. The following equation for calculating the allowable make-up water to maintain the test pressure is given in the Standard as: -

$$Q \leq 0.14xLDH \qquad \text{....................} \textit{Equation 8.1}$$

Where

Q = allowable make-up water, litres per hour

D = nominal diameter, in metres

L = test length, in kilometres

H = average test head over length of pipeline under test, in metres

This allowance is intended to compensate for the apparent loss due to entrapped air being forced into solution.

Prior to carrying out a hydrostatic test it is normal to complete the pipe installation including the backfilling and allow sufficient time to elapse for the curing of concrete thrust and anchor blocks. It is recommended that mechanical joints and flanged connections remain exposed so that they can be visually checked for leaks. When testing against closed valves, arrangements should be made for checking these for leaks. Appendix M4 of AS/NZS 2566.2 describes the test procedure and Figure 8.1 illustrates the usual test equipment arrangement.

WARNING:

High pressure (i.e. >30kPa) air testing is not recommended for safety reasons as the energy stored by a significant volume of compressed air or other gases in a pipeline can be both extremely destructive and life threatening if released accidentally.

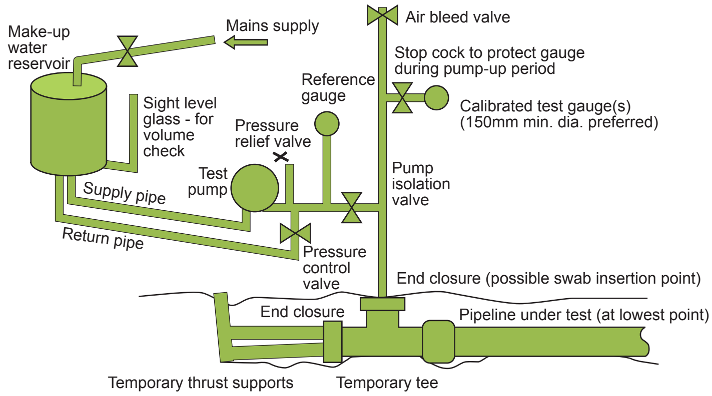


Figure 8.1 – Typical arrangement of pipeline testing equipment

Individual joint testing

For large (man entry) diameter pipelines in situations where it is impractical to charge the pipeline with water for hydrostatic testing purposes, individual joints can be proof tested using portable equipment inside the pipe as shown in Figure 8.2. This purpose built equipment is comprised of segmented circular moulds, which support twin sealing gaskets. These rubber gaskets are hollow and designed to be inflated with water under pressure to create a seal against the inside surface of the pipe. When the equipment is placed across a joint, it is possible to pressurise the annular joint space using a hand operated hydrostatic test pump. Water can be obtained from a small water cart not shown in Figure 8.2.

Typically this equipment is limited to about 60kPa but for higher-pressure mains this may still be sufficient for a proof test. Note that pipes must be backfilled before attempting this test to stop the joint separating. In some situations it may be possible to substitute air with water, but the test pressure must be limited to a safe level – See warning.

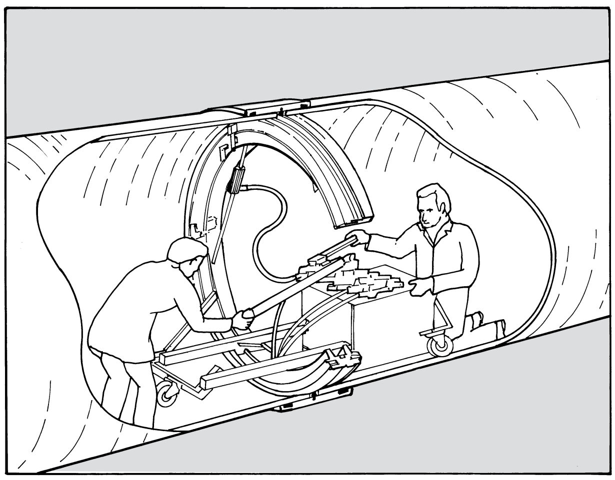


Figure 8.2 – Typical arrangement of joint testing equipment

8.2 Leakage testing – non-pressure pipelines

Field testing is used for revealing damaged pipes, unsatisfactory embedment, joints incorrectly installed, or other laying deficiencies. Where watertight pipelines are required as in the case of sewers, leakage testing is usually required before acceptance.

A leakage check on a buried non-pressure pipeline can be completed using any one of the following methods:

- Hydrostatic pressure test
- Vacuum test
- Low pressure air test
- Infiltration test

The air and vacuum tests are usually more convenient as they do not require water. An infiltration/observation test measurement is a further option where a pipeline has been laid well below the water table.

Hydrostatic (exfiltration) testing

The pipeline should be filled with water to a height of not less than 1m above the natural ground level at the highest point of the test length but not exceeding 6m at the lowest point of the test length. A minimum of 2 hours should elapse to allow temperature changes to stabilise. Then during a minimum time of 30 minutes any fall in water level in the test vessel must not exceed the hourly allowance amount shown in Table 8.1

Table 8.1 Hydrostatic - leakage limits for non pressure pipes

DN	Make-up allowance* (L/m/Hr)	DN	Make-up allowance* (L/m/Hr)
300	0.14	1200	0.60
375	0.19	1400	0.70
450	0.23	1600	0.80
525	0.26	1800	0.90
600	0.30	2000	1.00
675	0.34	2200	1.10
750	0.37	2400	1.20
900	0.45	3000	1.50
1000	0.50	-	-

** Based on an allowance of 0.5 litres per hour per mm diameter per km (Ref. AS/NZS 2566.2)*

If this is not achieved the pipeline should be carefully examined visually for leaks and any defects repaired. The pipeline should then be retested.

Low pressure air (exfiltration) testing

The test length of a pipeline should be generally restricted to lengths between access chambers. (The most convenient places for fixing temporary bulkheads).

The procedure for low-pressure air testing of large diameter pipelines is potentially hazardous at higher pressures because of the very large forces to be resisted by temporary bulkheads and the serious consequences of accidental bulkhead blow-out.

The procedure should be as follows:

- Pump in air slowly until a pressure of 28kPa above any external ground water pressure is reached (but do not exceed 50kPa gauge).
- Maintain the pressure for at least 3 minutes.
- If no leaks are detected, shut off the air supply.

The low pressure air test for a test length of pipeline is satisfactory if the test pressure does not drop more than 7kPa, within the time period shown in Table 8.2 after the shut-off of the air supply. *Note that if there is no discernible pressure loss after 1 hour has elapsed, the test can be considered satisfactory and terminated.*

If the pipeline fails the test, re-pressurise to 28kPa and check for leaks. This may be assisted by the use of leak detecting equipment. Establish the source of any leak. Leaks in small installations with joints exposed may be detected by pouring a concentrated solution of soft soap and water over joints and fittings. Repair and then repeat the test.

Table 8.2 Minimum allowable times for test (for 7kPa pressure drop)

DN	Minimum allowable time* (minutes) for different test lengths		
	50m	100m	150m
225	4	5	8
300	6	9	14
375	7	14	22
450	10	21	31
525	14	28	42
600	18	37	55
675	23	46	70
750	29	57	86
900	41	83	124
1000	51	102	153
1200	73	147	220

** These times may be halved where a pressure drop of 3.5kPa is used. Refer to AS/NZS 2566.2 for calculation basis.*

Infiltration testing

Where a freestanding water table exists at a level of at least 1.5m above the pipeline and 150mm above any sideline connections, the absence of infiltration can remove the need for either of the previous pressure tests. In all cases where infiltration is observed the source should be investigated and the leak plugged. Where the size of the catchment and number of side connections precludes this approach then the inflow should be measured over a 24-hour period and the principal informed for determination of the acceptable allowable inflow. Generally this should not exceed 5 litres / mm diameter / km length / day.

8.3 Structural assessment on installation

Compaction testing

A method of monitoring the compaction of the bedding and side support zones of the embedment material around all flexible pipelines is desirable for proper quality control of a buried flexible pipeline at the time of installation. Some soil compaction tests used for civil earthworks may be inappropriate for pipeline work as they are more suited to the higher levels of compaction control needed, for example, with pavement construction. There may also be some delay while samples are being checked at an offsite laboratory. However, methods employing the Clegg Impact Hammers are readily adaptable for pipeline work and have the added advantage that the impact figures obtained can be read as an approximation to the soil deformation modulus.

Deflection testing

Deflection measurements are a useful means of checking that the installation requirements have been met and should be completed as soon as possible after the installation is finished. These measurements are frequently used as a quality control device for indirectly assessing the relative embedment compactions achieved during installation. Typical deflections that might be expected in a normal installation would be about half of the values given in Table 8.3.

For non-man entry pipes AS/NZS 2566.2 gives a deflection test method using pull-through "go / no go provers" prover design

Suitable types of provers are described in AS/NZS 2566.2. A lightweight vaned type with a minimum of eight vanes between 1.0 and 1.3 pipe diameters in length may be used. The acceptable prover diameter should be determined after giving consideration to the effect of different time periods 'T' after completion of construction. Table 8.3 shows the outside diameter of provers required for the maximum allowable deflections (less a further clearance of 2.5mm) at various times after the completion of the installation. The prover should be pulled through the pipeline by hand or means of a hand-operated winch. A tail rope should be attached, to ensure it can be retrieved if the pipes are found to be over-deflected.

Where a prover cannot pass along the test length, the cause of the obstruction should be determined, generally by a CCTV investigation and appropriate remedial construction undertaken. In extreme situations the affected section of the pipeline may have to be exposed and proper compaction of the side support zone material carried out. FLOWTITE™ pipes are rarely damaged by greater than normal deflections. A visual inspection of any pipe that has been over-deflected is usually sufficient to determine if further embedment compaction or a pipe relay is required.

In larger pipe sizes a visual line-of-site inspection will usually indicate any abnormal deflections. Measured deflections should be based on the following calculations:

$$\text{Deflection (\%)} = \frac{\text{(Actual ID – installed vertical ID) x 100}}{\text{Actual ID}}$$

The "actual ID" or internal diameter is determined by measuring accessible loose pipes of the same class and stiffness, which have not been installed (and with no pipes stacked above them). That is:

$$\text{Actual ID} = \frac{\text{(Vertical ID + Horizontal ID)}}{2}$$

Note: The values in table 8.3 would be different for pipe stiffness other than SN10,000. I.e SN5000

Table 8.3 – Maximum prover outside diameters for PN1 SN10000 FLOWTITE™ pipe at various times after backfill completion

Time / Period T		24 Hours	3 Days	7 Days	14 Days	30 Days	3 Months	1 Year
Adjustment factor		0.7	0.75	0.85	0.95	1	1.1	1.2
Deflection (%)		2.8	3	3.4	3.8	4	4.4	4.8
DN	Pipe ID (mm)	Prover outside diameter (mm)						
300	328	316	316	314	313	312	311	310
375	409	395	394	393	391	390	389	387
450	487	471	470	468	466	465	463	461
525	564	546	545	542	540	539	537	534
600	641	621	619	617	614	613	610	608
675	718	695	694	691	688	687	684	681
750	794	769	768	765	761	760	757	753

Correcting over-deflected pipes

For pipes deflected up to 10% of diameter:

1) Excavate to a level about 40% below the crown of the pipe using hand tools to avoid damaging the pipe.

2) Check the exposed pipes for damage. If pipes are damaged they must be repaired or replaced.

3) Recompact the embedment material to the specified degree in the side support zone.

4) Replace the overlay and backfill to the final level.

5) Check that the deflection complies with the specification or Table 8.3.

For pipes deflected more than 10% there is a possibility that the pipes will need to be replaced. Check with Iplex Pipelines for advice.

8.4 High pressure water cleaning

There are several methods used to clean pipes, depending on the diameter and the degree and nature of blockage, which may use either mechanical means or water jets.

Whenever mechanical means are employed, use plastic scrapers to avoid damaging the pipe's inner surface.

The use of high-pressure water emitted through jet nozzles is a practice used to clean pipe internal surfaces. If not properly controlled, water emitted under high-pressure through a jet nozzle can damage most pipeline materials.

Based on experience gained with water jet cleaning of FLOWTITE™ sewer pipes, the following guidelines must be followed to avoid damage to pipes.

Cleaning of FLOWTITE™ pressure pipes

1. Limit maximum pressure to 8,300kPa (1,200psi or 83bar). Due to the smooth interior surface of FLOWTITE™ GRP pipe, adequate cleaning and removal of blockages can be achieved below this pressure.

2. Nozzles with jet holes around the circumference are preferred. Nozzles with cleaning chains, wires, or rotating, aggressive damaging nozzles must not be used.

3. The water discharge angle must be between 6° and 15° relative to the pipe axis. See Figure 8.3.

4. The number of jet holes should be 6 to 8 or more and holes size must be at least 2.4mm.

5. The external surface of the nozzle shall be smooth and the maximum weight 2.5kg. See Figure 8.4.

6. The forward and backward moving speed of the nozzle shall be limited to 30m/min. Uncontrolled movement of the nozzle is not allowed. When inserting the nozzle into FLOWTITE™ pipe, care should be taken to prevent it from hitting the pipe wall.

7. Jetting/swabbing sleds with several runners are required giving a greater distance between nozzle and pipe wall. See Figure 8.3.

8. The use of equipment or pressures that do not meet the above criteria could cause damage to the installed pipe.

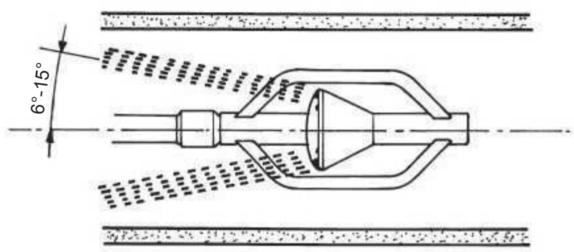


Figure 8.3 – Water jet discharge angle

Figure 8.4 – Nozzle weight 2.5 kg

Section 9

Product Codes

9.0 Product Codes

The computer identification codes for FLOWTITE™ pipes and fittings used by Iplex Pipelines are given in Table 9.1 and 9.2 and are in the form.

Table 9.1 Typical IPLEX product codes for FLOWTITE™ pipes

Product designation		Pressure class		Nominal diameter		Stiffness		Pipe length	
Description	Codes "XXX(X)(X)"	PN	Code "X(X)"	DN	Code "XX(X)(X)"	SN	Code "X"	Meters	Code "X"
Standard pipe (including coupling) all polyester	FTPRP	1	01	300	300	5000	5	1	A
				375	375	10000	10		
Standard pipe (without coupling) all polyester	FTSP	6	06	450	450			2	B
Adjustment pipe (including coupling) all polyester	FTA	10	10	525	525			3	C
				600	600				
Adjustment pipe (without coupling) all polyester	FTASP	12	12	675	675			4	D
Standard pipe (including coupling) all vinyl ester	FTVF	16	16	750	750			5	E
Standard pipe (without coupling) all vinyl ester	FTSPVF	20	20	900	900			6	(Blank)
				1000	1000				
Adjustment pipe (including coupling) all vinyl ester	FTAVF	25	25	1100	1100			12	M
Adjustment pipe (without coupling) all vinyl ester	FTASPVF	32	32	1200	1200				

Example 1: The Code for DN900 PN16 SN10000 FLOWTITE™ pipe with full vinyl ester complete with coupling as a 12 metre length is:-

	FTVF		16		900		10		M

Example 2: The Code for DN1400 PN1 SN5000 FLOWTITE™ pipe, without coupling as a 6 metre length is:-

	FTSP		01		1400		5		

Table 9.2 Typical IPLEX product codes for FLOWTITE™ fittings

(Assuming all fittings are spigot ended without couplings and a minimum stiffness of SN10000. A different stiffness will require an additional digit to be added to the code)

Product description	Codes "XXXXX"	PN	Code "X(X)"	DN(1)	Code "X(X)(X)"	DN(2) or angle	"X(X)(X)"
Bends	FT210	1	01	300	30	30	30
Tees (equal and unequal)	FT511	6	06	375	37	to	to
Air valve tees	FT613	10	10	450	45	3000	3000
Scour tees	FT713	12	12	525	52		
Concentric reducers	FT310	16	16	600	60	or for angle	or for angle
Flange spigot connectors	FT430	20	20	to	to	5°	5°
Slope junctions	FT811	25	25	3000	300	--	--
FLOWTITE™ couplings	FT007	32	32			90°	90°

Product description (PN1 only)	Codes "XXXXX"	DN(1)	Code "X(X)(X)"	DN(2) or angle	Code "X(X)(X)(X)"	Angle	"X(X)"
Manhole connectors	FT091	300 375	30 37	30 to	30 to		
Closed couplings	FT006	450	45	3000	3000	5°	5°
Saddle junctions 45°	FT0	525	52			--	--
Saddle junctions 90°	FT1	600	60	or for angle	or for angle	90°	90°
Slope riley (drop) junctions	FT025	to	to	5°	5°		
Manhole drop bends	FT026	3000	300	-- 90°	-- 90°		

Example 1: The Code for DN750 PN6 SN10000 FLOWTITE™ 45 degree bend supplied without couplings is:-

	FT210		06		75		45

Example 2: The Code for DN1400 x 750 PN1 slope junction without couplings is:-

	FT811		01		140		75

Index

Index

Index

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