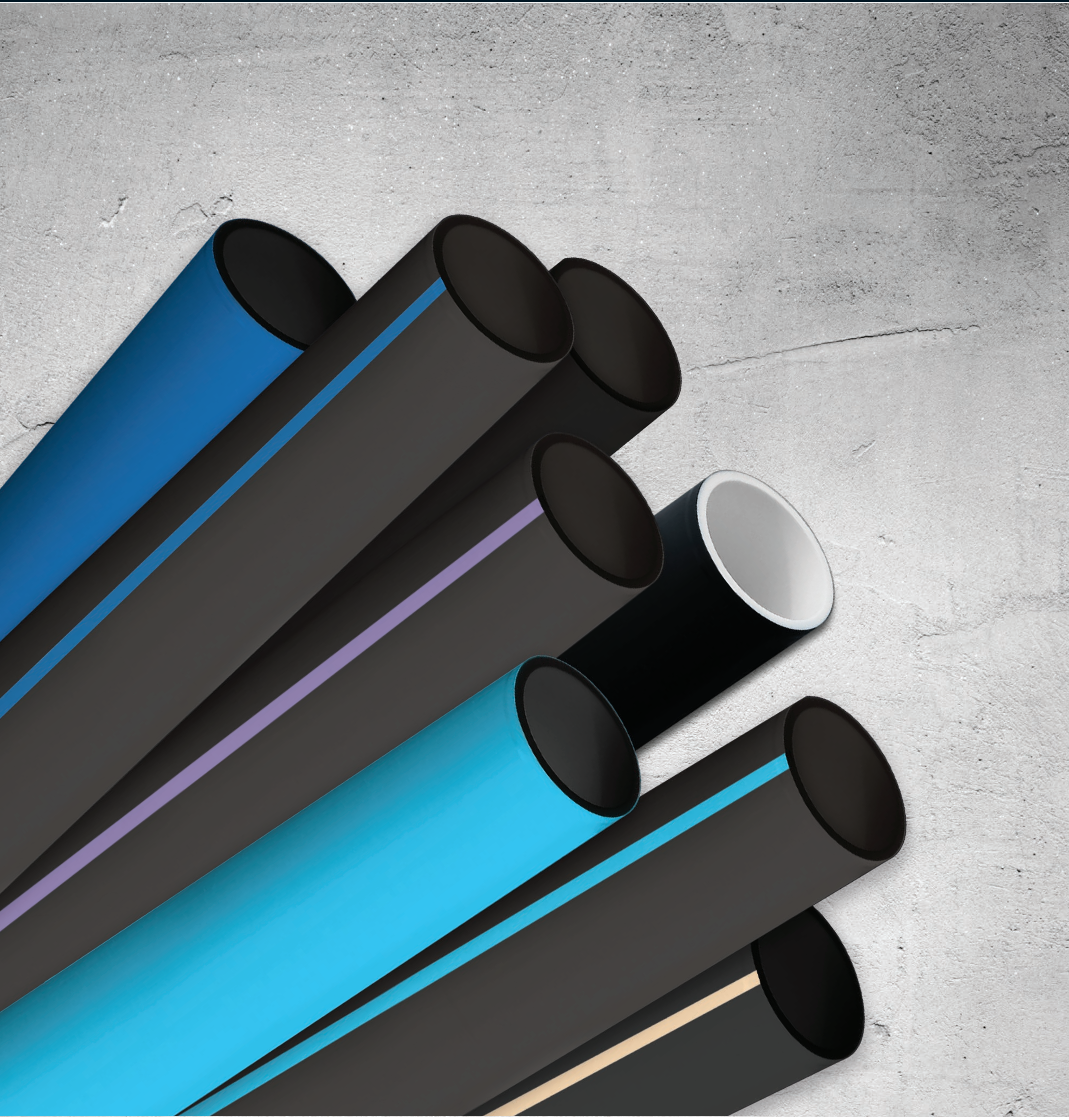
Marley Polyethylene Systems

Solutions for a wide range of applications



Utilities Solutions

MARLEY

by aliaxis

POLYETHYLENE (PE)
PIPE COLOUR INDENTIFICATION

WATER

PE80
1200 Series Sky Blue Skin
AS/NZS 4130

PE100
1210 Series Royal Blue Skin
AS/NZS 4130

PE80/PE100
300/310 Series Black Skin
AS/NZS 4130

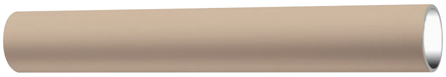
PE80
DN50 + 63 out of CHCH DN-7
AS/NZS 4130

PE100
1210 Series Black with Royal Blue Stripe
AS/NZS 4130

Recycled Water PE100
310 Series Black with Lilac Stripe
AS/NZS 4130

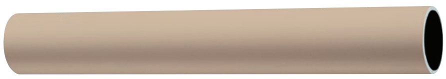
SEWER/STORMWATER

Waste Water PE80
SBW Series Black Skin white inside
AS/NZS 5065



Waste Water PE80
SGW Series Grey Skin white inside
AS/NZS 5065

Waste Water PE80/PE100
300/310 Series Black Skin
AS/NZS 4130



Pressure Sewer PE100
310 Series Cream Skin
AS/NZS 4130

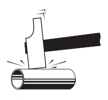
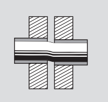
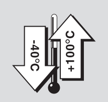
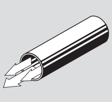
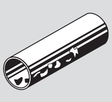
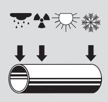
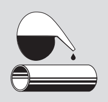
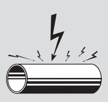
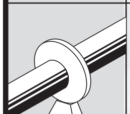
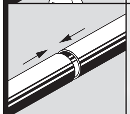
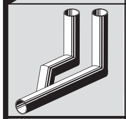
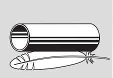
Pressure Sewer PE100
310 Series Black with Cream Stripe
AS/NZS 4130

CONTENTS

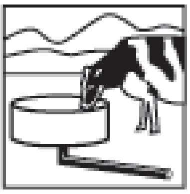
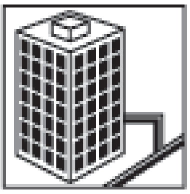
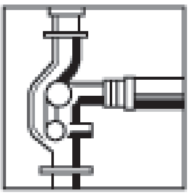
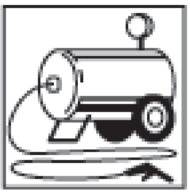
PLASTIC PIPELINES
- GENERAL

- Properties and Benefits of Polyethylene
- Market Area and Product Guide
- Plastics Pipes for Pressure Applications
- PE Pipe Material
- Strength
- Service Lifetime Variations
- The Stress Regression Line for Hoop Stress
- Weatherability and Temperature Changes
- Elevated Temperatures
- Elevated Temperatures Pressure De-rating
- Expansion and Contraction
- Toughness
- Hydraulic Properties
- Fire Rating
- Chemical Resistance and Stability
- Factors Affecting Chemical Resistance
- Permeability
- Chemicals Potentially Harmful to PE Pipes

Properties and Benefits of PE

PE properties		**Benefits**
	Impact-resistant and tough	Unbreakable at temperatures > 5 °C
	Elastic	Suitable for underground pipes to accommodate local ground movement, available in coils
	Thermal resistant	Application possible between -40°C and 100°C
	Smooth internal wall	Low blockage risk due to low deposit/residue effects
	Wear resistant	Lower costs due to relatively long life
	Weather-resistant/ UV resistant	Application in open air unrestricted in black pipe through colouring with carbon black
	Chemical resistant	Suitable for transport of polluted waste water
	Insulating	Non conductive
	Non-toxic	Environmental friendly
	Poor heat conductivity	No condensation during short periods of cooling
	Highly suitable for welding	Easy installation using buttwelding and electrofusion techniques
	Homogeneous welded joints	Pull tight and leak proof
	Prefabrication	Fast and cost-saving installation
	Light in weight	Cost-saving in transport and handling
	Trenchless technology rehabilitation techniques	Installation methods: Directional drilling, Mole ploughing, Impact moling, Narrow trenching

Market Area and Product Guide

Market	Product	Product Code
 House Connections	Marley Blue/Black	1200 series
 Agriculture	Marley Ag Pipe Marley Enduroflex	300 series 900 series
 Territorial Water Mains	Marley Pressure	1200 series Blue PE80B 1210 series Royal Blue PE100 310 series Black PE100
 Territorial Rider Mains	Marley Pressure	1200 series Blue PE80B 1210 series Royal Blue PE100
 Sewer Main	Marley J Pipe	SBW series
 DWV Drains in Building	Marley Akavent J Pipe	SBW series
 Compressed Air	Marley Pressure	1200 series Blue PE80B
 Underground Power and Communication Duct	Marley Subduct Marley Comduct	300 series PE80B COMD. series PE80B

PLASTIC PIPES FOR PRESSURE APPLICATIONS

This manual has been designed to detail the properties, design and installation requirements for polyethylene pipe systems produced by Marley New Zealand Limited. The main applications are:

Marley Blue/Black Pressure Pipe for house connection and territorial supply water mains. 12Bar rated, manufactured in sizes from 20mm to 630mm, from PE80B (1200 series Light Blue) or PE100 (1210 series Royal Blue)

Marley Black Pressure Pipe for all general pressure applications. Sized to suit flow requirement, with SDR to suit head pressure requirement. Manufactured from PE80B or PE100 (300 or 310 series of pipe)

Non Pressure Drainage Applications

Marley manufacture a range of “J Pipe” (jacketed pipe) for sewer and foul water applications and ducts for drainage and ducting applications. Sized to suit the flow requirements with the appropriate SDR to suit stiffness requirement and soil loading. Manufactured from HDPE for stiffness and ESCR.

Marley manufacture a comprehensive range of other PE pressure pipe and non pressure ducting pipes for the gas, air, rural, electrical and communication industries in both lengths and coils which can be suitably colour coded to suit the application.

PE PIPE MATERIAL

Pressure pipe materials are produced from natural gas and selected catalysts in a specialised controlled polymerisation process. Current PE80B and PE100 resins have densities of 0.94 to 0.97kg/m^3.

Pressure pipe materials have:

✓ exceptionally high resistance to stress cracking (ESCR)
✓ very high creep resistance
✓ very high resistance to rapid crack propagation
✓ long-term tensile strength.

STANDARDS

Relevant Standards for PE pipe

AS/NZS4130 :2003 Polyethylene (PE) Pipes for Pressure Applications
AS/NZS4129 :2003 Polyethylene (PE) Fittings for Pressure Applications
AS/NZS5065 Polyethylene and Polypropylene Pipes and Fittings for Drainage and Sewerage Applications
AS/NZS2566.1 Buried Flexible Pipe : Structural Design
AS/NZS2566.2 Buried Flexible Pipe : Installation
AS2033 Installation of PE Pipe Systems
NZS4404 Design for Urban Subdivision
ISO 13953:2001 Polyethylene (PE) Pipes and Fitting Determination of the tensile strength and failure of test pieces for Butt – Fuse Welding
ISO 13954 Peel Decohesion test for Polyethylene (PE) Electron Fusion Assemblies
ISO 11414 PIPA-POP003 Plastic Pipe and Fittings – Butt Fusion Jointing procedure for Polyethylene (PE) Pipe and Fittings used in the construction of gas and water distribution systems.

STRENGTH

The “strength” of a pipe may be considered as its ability to withstand (hoop) stress in the pipe material under internal pressure over a prolonged period of time. The design stress for local authorities is chosen to ensure a life in excess of 50 to 100 years.

The strength of plastics pipes is known to be time/temperature dependent. This characteristic is used to assess the future available strength of the pipe material by undertaking hydrostatic pressure tests and generating regression curves from varying stress/life to failure tests at varying temperature. These prolonged tests, in excess of 10,000 hours, are accelerated for quality control purposes by using elevated temperatures (typically 80°C) for all pressure pipe material to ensure the pipe will not fail in a brittle manner from Rapid Crack Propogation (RCP). The method identifies a Minimum Required Strength (MRS) value derived from the 50 year extrapolated 97.5% lower confidence limit (LCL) failure stress.

A safety factor is applied to the MRS to determine the design stress permissable safety factor.

The following safety factors are currently in use:

PE80B 1.25 - AS/NZ - 4130 • 2003
PE100 1.25 - AS/NZ - 4130 • 2003

SERVICE LIFETIME VARIATIONS

The adoption of a 50 year design life to establish a value for hoop stress is arbitrary and does not relate to the actual lifetime of the pipeline.

Where pipelines are used in installations such as water supply, where economic evaluations such as present value calculations are performed, the lifetimes of PE lines designed and operated within the NZ guidelines may be regarded as 70/100 years for the purpose of the calculations.

Any values beyond these figures are meaningless as the assumptions made in other parts of the economic evaluations outweigh the effect of pipe lifetime.

Introduction:

PVC and PE pipes and fittings were introduced into Australia during the 1950's, mainly for water supply and irrigation, but also for fuel gas and industrial applications.

The first Australian Standard for PE pressure pipes was ASK119-1962 and the first for PVC pressure pipes was ASK138-1963.

The creep rupture characteristics of these materials necessitated a new method for selection of design stress, compared with other materials in use at the time – AC, CI, GWI, etc.

The method adopted was that already in use in Europe – using the creep rupture (stress regression) curve, select a time and establish the associated burst stress.

Apply a design factor to the burst stress to give the design stress.

The time chosen was 50 years, already adopted in Europe, and is still in use today in AS/NZS, ISO, and CEN Standards.

The use of this time has led to the misunderstanding that it represents the pipe life. Similarly, the use of 50 year modulus values for use in ring deflection calculations for non-pressure pipes has also led to misunderstanding regarding life.

The following extract from WSA01-2004, Polyethylene Pipeline Code, explains why prediction of a system life should not be based on the arbitrarily chosen time value.

Pressure

Selection of allowable stress is based on long term pressure testing in the laboratory and regression analysis applied to the data obtained. The 50 year point is arbitrarily chosen for this basis, as for all thermoplastics pipes. A factor is applied to the 50 year point in order to provide the design stress.

It shall not be taken that either:

(a) the pipes weaken with time; or

(b) the predicted life is 50 years.

System life is dependent on many factors. If the design stress were used in relation to the regression curve, predicted pipe life would be indefinite, not 50 years.

As with other materials, the life is dependent on manufacture, transport, handling, installation, operation, protection from third party damage and other external factors.

Provided that PE pipeline system components area appraised and supplied to nominated industry standards under third-party product certification systems, and provided pipelines are designed and constructed correctly, then the likelihood of failure is minimised. For correctly manufactured and installed systems, the actual life cannot be predicted, but can logically be expected to be well in excess of 100 years before major rehabilitation is required.

If a system life is to be assigned beyond 100 years, it shall be based on the likelihood of failure arising from the above factors, not the pipe regression curve.

Pipe strength has been shown not to decrease with time – in fact, it increases slightly. "Instantaneous" burst pressure after a period in service will be at least equal to that of new pipe.

Non-Pressure

The life of non-pressure PE pipelines will be dependent on performance under four main conditions:

(a) Soil mechanics and pipe mechanics stability.

(b) Pipe material strength

(c) Chemical and biological stability

(d) Functional stability.

The life of thermoplastic non-pressure pipeline systems has been extensively studied and reported. For example, the report titled "Plastics Pipes – How Long Can They Last", by Prof. Lars-Eric Janson of VBB Sweco Consulting Group reaffirmed a 1987 report concluding that the answer to the above question was "at least 100 years". The latest report, produced in 1996, states that "....it has been clearly found that nothing has emerged, which contradicts the statement made in 1987." It also states that the report refers mainly to buried gravity sewer pipes, but the conclusions can in most cases be applied for pressure applications. The aim of the work was to verify the claim of "at least 100 years".

The summary states that "...one can thus conclude that everything is pointing to at least 100 years practical service life tor today's buried sewer pipes make of high quality virgin PVC-U and PE resins, on condition that the pipes are used in accordance with the prevalent national standard installation instructions."

Provided that PE pipeline system components are appraised and supplied to nominated industry standards under third-party product certification systems, and provided pipelines are designed and constructed correctly, then the likelihood of failure is minimised. For correctly manufactured and installed systems, the actual life cannot be predicted, but can logically be expected to be well in excess of 100 years before major rehabilitation is required.

Such applications may occur in mining installations where the economic lifetime of the ore body may be 5 or 10 years or for dredging operations where the project may only be operational for 6 months.

For situations involving high costs of downtime and repair, a higher factor should be used. For less critical situations, lower factors would be quite in order. Where factors such as transient pressures (eg. water hammer) and other loads are predicted and allowed for, lower factors of safety as appropriate.

THE STRESS REGRESSION LINE FOR HOOP STRESS

The traditional method for portraying the tensile strength of plastic pipe is through a graph of log stress vs log time to failure.

This is known as the stress regression line. This chart is a plot of circumferential stress in the pipe wall against time to failure.

Practical tests are done subjecting pipe samples to different hoop stresses and the results of the times to failure are plotted over a range of times up to at least 10,000 hours. A linear regression line (log log) is established and extrapolated to the longer term.

An appropriate factor of safety is established on the long term ultimate stress to give a working stress for design purposes.

The confidence of extrapolated data such as this depends on a number of factors:

1. The linearity of the data
2. The scatter of the data (data fit)
3. Data available concerning closely allied materials.

PE80C pressure material exhibits a knee in the regression line. Testing is done at an elevated level to determine the exact position of the knee. This stress regression which is used to define the knee is used only as a design basis and does not predict the system life which has been shown to be significantly greater in PE80B and PE100 than the conservative predictions.

For polyethylene pipes the method of classifying the material is by reference to its Minimum Required Strength (MRS). The MRS is determined by using the value of the predicted hoop stress (97.5% lower confidence limit) at the 50 year point.

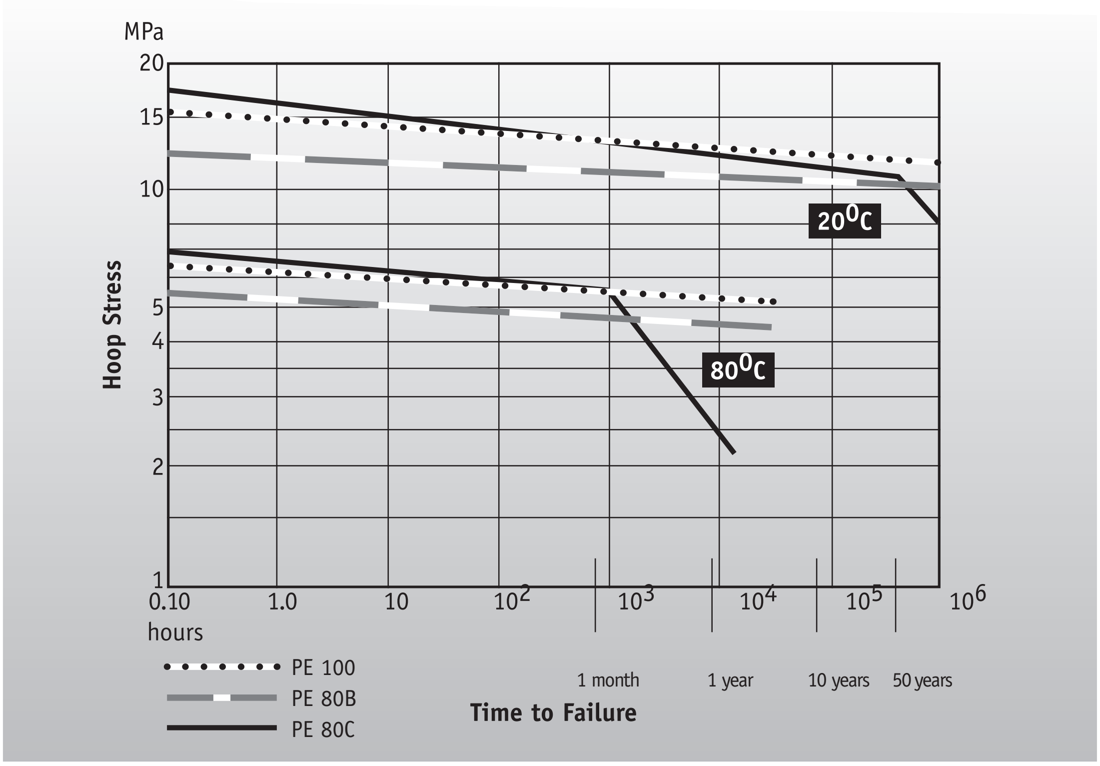
The hydrostatic design stress (HDS) is obtained by the application of a factor, not less than 1.25, to the MRS value.

The wall thickness of Marley's pressure pipes are established by use of the Barlow formula as detailed in AS/NZS4130.

$$T = \frac{PD}{2S + P} \quad \text{and} \quad S = MRS/C$$

T = minimum wall thickness (mm)
P = working pressure (MPa)
D = minimum mean OD (mm)
S = design hoop stress (MPa)
MRS = Minimum Required Strength
C = Safety Factor Typically 1.25 for water

TYPICAL STRESS REGRESSION CURVES FOR MDPE



WEATHERABILITY AND TEMPERATURE CHANGES

Black PE material has generally excellent prolonged weatherability properties and can readily withstand wide variations of weather without degradation. Black PE pipes contain carbon black pigments which act both as a pigment and as an ultra violet radiation stabiliser and these pipes require no additional protection for external storage, or prolonged use in natural conditions.

Blue MDPE pipe is subject to a degree of degradation when exposed to ultra violet light (sunlight) for prolonged periods. UV stabilisers are used to counteract this effect and such material has withstood practical exposures for periods in excess of a year without apparent deleterious effects.

Any surface degradation has a significant impact with fusion jointing techniques. All surfaces must be peeled using an appropriate tool to remove the surface and be cleaned with isopropanol.

Blue MDPE is basically intended for use in buried conditions unless protected from prolonged sunlight exposure. This is reflected in the current recommendation to provide protection against UV exposure when used in above ground situations or when stored outside for periods greater than one year.

Black MDPE should be purchased for continuous unshaded above ground use.

ELEVATED TEMPERATURES

Reversion

The term "reversion" refers to dimensional change in plastic products as a consequence of "material memory". Plastic products "memorise" their original formed shape and if they are subsequently drawn down during extrusion, they will return to their original shape under heat.

Theoretically, reversion proceeds at all temperatures, but with high quality extrusion it is of no practical significance in plain pipe at temperatures below 60°C.

Pressure Ratings at Elevated Temperatures

The mechanical properties of polyethylene pipes are referenced at 20°C. Thermoplastics generally decrease in strength and increase in ductility as the temperature rises and design stresses must be adjusted accordingly.

ELEVATED TEMPERATURE PRESSURE DE-RATING

PE80B MDPE Material

Maximum Working Pressure (Metres Head)

Temp °C	PN4	PN6.3	PN8	PN10	PN12.5	PN16
20	40	63	80	100	125	160
25	36	57	72	90	113	144
30	32	51	64	81	101	130
35	30	45	57	72	90	115
40	25	39	50	62	78	100
45	21	32	42	52	65	83
50	16	25	34	43	56	72

PE100 Material

Maximum Working Pressure (Metres Head)

Temp °C	PN4	PN6.3	PN8	PN10	PN12.5	PN16
20	40	63	80	100	125	160
25	37	59	75	94	112	156
30	35	55	70	87	109	140
35	32	51	74	80	100	128
40	29	46	58	73	91	117
45	26	42	53	66	83	106
50	24	37	47	59	74	94

The above tables are based on ISO 4427 Standard

For systems requiring life in excess of 50 years. Increases in the head pressure will reduce the design safety factor and may reduce total expected performance.

The material temperature in question here is the average temperature of the pipe wall under operational conditions.

Temperature is averaged in two ways:

1. Across the wall of the pipe:
Where a temperature differential exists between the fluid in the pipe and the external environment, the operating temperature may be taken as the mean of the internal and external pipe surface temperatures.
It should be noted that the pressure condition where flow is stopped for prolonged periods should also be checked. In this event, water temperature and outside temperature may equalise.

2. With respect to time:

The average temperature may be considered to be the weighted average of temperatures in accordance with the percentage of time spent at each temperature under operational pressures:

$$T_m = T_1L_1 + T_2L_2 + \ldots + T_nL_n$$

where L_n = proportion of life spent at temperature T_n

This approximation is reasonable provided the temperature variations from the mean do not exceed ±10°C which is generally the case for pipes buried below 300 mm.

For most underground water supply systems, the overall mean temperature from meteorological records is appropriate for class selection purposes, since this represents the mean of the annual and diurnal sinusoidal temperature patterns.

For systems subjected to larger variations, the temperature for rating purposes should be taken as the maximum less 10°C. However the peak temperature should not exceed 60°C.

Example

A reticulation system is to be installed in a town with a mean ground temperature at pipe depth of 20°C. The December-February average is 25°C. Although diurnal variations occur with air temperatures up to 40°C during heatwave periods, water temperatures and ground temperatures at pipe depth do not exceed the mean of 27°C.

Weighted average temperature:

$$Tm = 25(3/12) + 20.5(6/12) + 15(3/12) = 6.25 + 10.25 + 3.75 = 20.25°C$$

Therefore use rating for 20°C. This is the same result as taking the mean.

EXPANSION AND CONTRACTION

The coefficient of thermal expansion for MDPE is 2.0×10^{-4}/°C.

A handy rule is 14mm change in length for every 10 metres for every 10°C change in temperature.

Therefore this characteristic must be considered carefully in the design of the pipeline and during installation.

In buried pipelines the main consideration of thermal movement is during installation in high ambient temperatures.

Under these conditions the black PE pipe will be at its maximum surface temperature and when placed into a shaded trench and backfilled, will undergo the maximum temperature change and hence thermal movement.

In these cases the effects of thermal movement can be minimised by some minor snaking of the pipe in the trench for small diameter sizes (up to 110mm).

For large diameter pipe the final connection should be left until the pipe temperature has stabilised to that of the surrounding soil.

Above ground pipes require no expansion/ contraction considerations for free ended pipe or where lateral movement is of no concern on site. Alternatively, pipes may be anchored at intervals to allow lateral movement to be spread evenly along the length of the pipeline.

A pipeline should be allowed to expand and contract freely.

Wherever possible, expansion and contraction should be taken up by changes in direction.

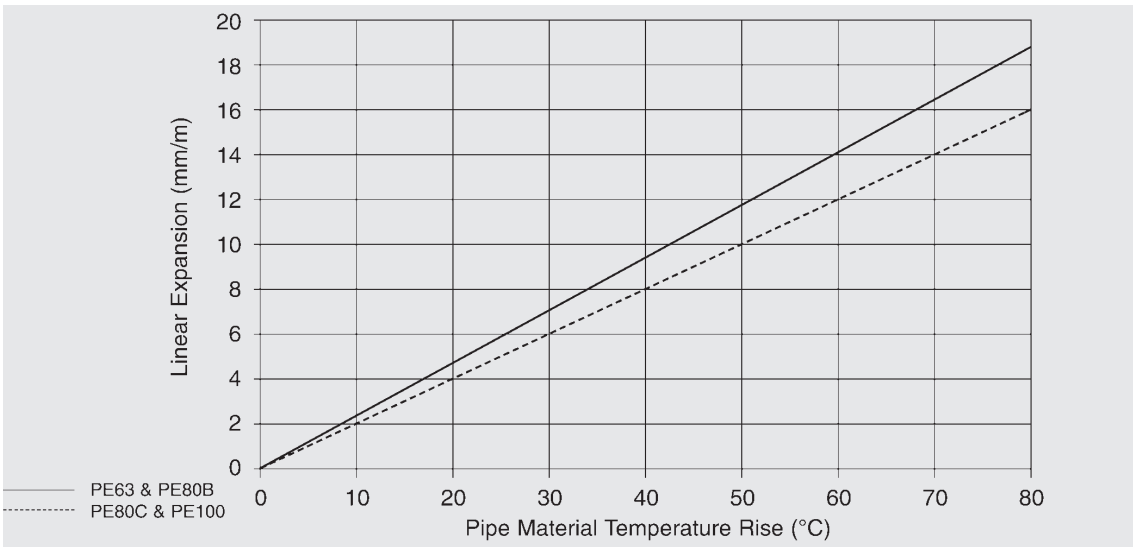
Careful positioning of fixed points will enable the direction of expansion and contraction to be controlled.

Expansion bellows and O-ring slip joints should be used only as a last resort; the pipes must then be suitably protected against separation.

Care must be taken in the positioning of loose brackets, as these can sometimes create conditions in which there may be a risk of shearing.

Valves and heavy components must be independently supported so that no stresses are imposed on the pipeline.

THERMAL LINEAR EXPANSION OF POLYETHYLENE PIPE



TOUGHNESS

General
In practice it is recognised that PE is a tough, resilient material capable of withstanding the normal rigours of pipelaying and service conditions. The many years of successful installation and service of MDPE pipe in the water industry confirms this confidence.

Abrasion
PE pipes have high resistance to abrasion by suspended particles being carried in the water, however the external surface can be scratched and gouged by sharp objects. Careful handling is required for pressure pipes but provided the depth of any surface notch is no greater than 10% of the wall thickness, there is no significant loss in the stress rupture performance of the pipe.

The properties of PE pipes including flexibility, ease of handling and robustness have led to their widespread use for abrasive applications such as mine tailings and slurry transportation.

Abrasion occurs as a result of friction between the pipe wall and the transported particles.

The actual amount and rate of abrasion of the pipe wall is determined by a combination of:

- the specific gravity of the solids
- the solids content in the slurry
- solid particle shape, hardness and size
- fluid velocity
- pipe material

In general terms PE pipes have superior abrasion resistance to steel, cast and ductile iron, asbestos and fibre reinforced cement pipes and provide a more cost effective solution for abrasive slurry installations.

Laboratory test programs have been performed in the UK, Germany and the USA on standardised slurries to obtain relative wear comparisons for various materials using sliding and rotating pipe surfaces.

The results of test programs using the Darmstadt method of Kirschmer and reported by Meldt (Hoechst AG) for a slurry of quartz sand/gravel water with a solids content 46% by volume and a flow velocity of 0.36 m/s are shown.

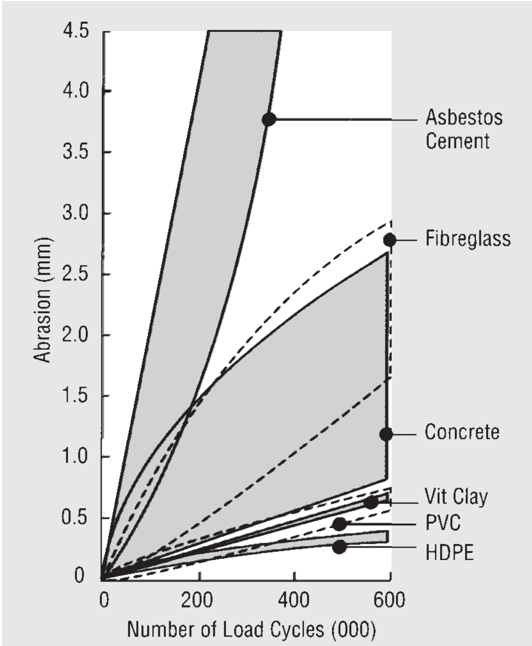
These were performed across a range of materials and show the excellent abrasion resistance of MDPE.

Conductivity
PE pipes are poor conductors. At all times PE pipe should be protected against radiant heat that could raise its surface temperature above 60C.

PE pipes are also poor conductors of electricity and no attempt should, therefore, be made to use pipework constructed of the material as means of earthing electrical equipment.

Because of their electrical resistivity, caution is required in the handling and use of PE pipes where the generation of high levels of static electricity may present a hazard.

COMPARATIVE ABRASION RATES OF PIPE MATERIALS



HYDRAULIC PROPERTIES
The smooth bore of PE pipes enables them to be treated as `hydraulically smooth` when used for the conveyance of potable water.

The smooth surface discourages the formation of scale in hard water areas but certain waters may, at times, give rise to slime and silt deposits, particularly at joints or fittings and this may increase frictional losses.

For the purpose of calculation of flow rates in new plastics pipelines, the Colebrook-White formula may be used in which the value of the hydraulic roughness factor Ks is 0.003 mm for clean water. Further details of hydraulic constants, flow charts and frictional losses are given.

MAXIMUM WORKING PRESSURE

CLASS	METRES HEAD	MPa	PSi
PN6	61	0.6	87
PN9	91	0.9	130
PN12.5	122	1.2	178
PN15	153	1.5	217
PN18	184	1.8	260

There are, however, many factors which must be considered when determining the severity of service and the appropriate class of pipe. In some instances, standard factors of safety may be too conservative, in others too risky. The final choice is up to the designer in the light of his knowledge of his particular situation.

FIRE RATING
PE pipe systems will support combustion and as such are not suitable for use in fire rated zones in buildings without protection.

In multi-storey buildings PE systems penetrating floor cavities must be enclosed in fire rated service ducts.

CHEMICAL RESISTANCE AND STABILITY

Corrosion Resistance

For all practical purposes, PE pipes are chemically inert within their normal temperature range of use. They do not rot, rust, pit, corrode or lose wall thickness through chemical or electrical reaction with the surrounding soil. They do not normally support the growth of, nor is it affected by algae, bacteria or fungi.

Chemical Effects

PE pipes have a good resistance to a wide range of chemicals. For water supply, the main concern is the effect of certain chemicals existing in contaminated ground, some of which can have harmful effect upon the pipe material or may cause taste problems in extreme cases due to permeation through the material wall. In broad terms the most common harmful chemicals are oxidisers and cracking agents. Refer to the Chemical Resistance Table.

Where pipelines are to be laid in environments where significant concentrations of such chemicals may prevail (e.g. garage forecourts, within certain processing works, etc) where taint in drinking could be an issue PE is NOT recommended unless suitably sleeved, although it is noted leakage of this nature is not acceptable under the Resource Management Act.

For the effects of specific chemicals on PE pipes see chemical resistance table.

Chemical Attack

Polyethylene material is renowned for its good resistance to chemical attack.

Chemicals that attack PE do so at differing rates and in differing ways. There are two general types of chemical attack on PE:

1. Swelling of the PE occurs but the PE returns to its original condition if the chemical is removed.

2. The base resin or polymer molecules are changed by crosslinking, oxidation, substitution reactions or chain scission. In these situations the PE cannot be restored by the removal of the chemical.

FACTORS AFFECTING CHEMICAL RESISTANCE

A number of factors can affect the rate and type of chemical attack that may occur. These are:

Concentration: In general, the rate of attack increases with concentration, but in many cases there are threshold levels below which no significant chemical effect will be noted.

Temperature: As with all processes, rate of attack increases as temperature rises. Again, threshold temperatures may exist.

Period of Contact: In many cases rates of attack are slow and of significance only with sustained contact.

Stress: Some PE under stress can undergo higher rates of attack. In general PE is considered relatively insensitive to "stress corrosion".

Considerations for PE Pipe

For normal water supply work, PE pipes are totally unaffected by soil and water chemicals. The question of chemical resistance is likely to arise only if they are used in unusual environments or if they are used to convey chemical substances. See Chemical Resistance Chart.

For applications characterised as food conveyance or storage, health regulations should be observed. Specific advice should be obtained on the use of PE pipes.

PERMEABILITY

PE pipes can be shown to be permeable to certain organic compounds (aliphatic hydrocarbons) under extreme conditions causing taint issues, the rate of permeation being mainly dependent upon the thickness of the pipe, the concentration, time and temperature.

Permeation of natural gas into the water supply pipe causing taste problems should be of no concern provided reasonable separation distances are maintained and line water is not static.

CHEMICALS POTENTIALLY HARMFUL TO PE PIPES

Group	Generalised Examples	Effect on PE
Oxidisers	Very strong acids	Degradation.
Cracking agents	Concentrated detergents	No degradation. (Under high temperatures, accelerates cracking under stress in brittle manner).
Solvents	Hydrocarbons, such as petrols and oils.	No degradation but may be absorbed into pipe wall causing reduction in hoop strength and possible taste problems.
Alkaline Solutions	Strong alkalines	No degradation

Note: For detailed information refer to Chemical Resistance Chart.

CONSIDERATIONS BEFORE COMMENCEMENT OF PROJECT

- Design Considerations
- Installation Considerations

CONSIDERATIONS BEFORE COMMENCEMENT OF PROJECT`

Design Considerations

1. PE pipes are normally joined using fusion techniques. Butt fusion jointing is usually carried out above ground and after cooling, long lengths of pipe are snaked into the trench. This procedure requires consideration of appropriate storage areas, jointing canopies and working space at the trench side away from the spoil areas. Attention must be given to the additional inconvenience caused to both pedestrian and vehicular traffic. Extra signs and protection barriers will be required.

2. Installation: PE systems are ideally suited to directional drilling and a variety of other innovative installation techniques which can reduce disruption to the public, buildings, roading and public property with lower labour and reinstatement cost compared to normal open trenching.

3. The flexual properties of PE make pipelines particularly suitable for areas subject to ground movement due to seismic forces, mining subsidence, compaction of filled sites or the disturbance caused by the activities of other utilities in the vicinity.

4. Where PE is to be used in environments with temperatures greater than 20°C for prolonged periods, the allowable operating pressure should be reduced in accordance with our recommendations, to maintain the expected life of the pipe.

5. Corrosive ground (e.g. ground with low pH or high sulphate characteristics) has no known effect upon PE but all metal fittings, ancillary equipment, bolts etc should be carefully protected against corrosion in the normal way.

6. Contaminated ground, however, must be considered carefully. PE is resistant to most chemicals, but is vulnerable to petroleum products and certain solvents which can permeate through the wall of potable water pipe. In this instance PE should NOT be used unless suitably protected. Where any doubt exists, soil sampling should be undertaken and specialist advice sought.

7. Where the natural ground water table is high, or the construction trench is liable to flooding, special consideration should be given to the possibility of flotation of the pipe. This particularly applies to the larger diameters where special anchoring or weighting may be necessary prior to the backfill being installed.

8. Direct connection of MDPE PE80B and PE100 to sources of high frequency such as pump outlet flanges should be avoided and a flexible joint should be used to isolate such vibration.

9. The sub surface material to be excavated should be assessed for its suitability as backfill material, i.e. free from large sharp stones, heavy clay, etc. If the material is unsuitable for bedding and surround to the pipe then imported material should be utilised and the surplus spoil removed from site.

Installation Considerations

1. Gradual changes in direction of PE pipelines can be accommodated by pipe deflection but every effort should be made to keep the pipe as central as possible within the trench to enable correct side-fill compaction. Similar care should be taken when any distortion of coiled pipe has occurred.

2. During the pipelaying of continuous fusion joint systems, allowance should be made for the movement likely to occur due to the thermal expansion/contraction of the material. This effect is most pronounced at the end connections to fixed positions and at branch connections.

3. For summertime installations, with two fixed connection points, a slightly longer length of polyethylene may be required to compensate for contraction of the pipe in the cooler trench bottom. The snaking of the pipe in the trench which naturally occurs with pipe sized 90mm and below, is normally sufficient to compensate for this anticipated thermal contraction.

4. During a winter installation, the exact length of pipe should be used. Pipe which is too short or not aligned must not be drawn up by the bolts of a flanged connection because of potential overstressing of the stub end, flanged adaptor and ultimately the valve or fixture to which it is connected.

5. It is advisable to defer the final tie-in connections until thermal stabilisation of the pipeline has occurred. Once a pipeline is installed and in service, the temperature variation is usually small, occurring over an extended period of time and is not likely to induce any significant stress or movement in the pipe system.

6. Whenever possible, a minimum distance of 300mm from obstructions and other services should be maintained. This distance is often possible when laying parallel to other services but not always practicable when crossing other services. A separation distance of 75mm may be allowed for a square crossing but suitable protection should be provided from possible joint loading, interference, damage or contamination.

CONSIDERATIONS BEFORE COMMENCEMENT OF PROJECT`

7. Polyethylene is not a conductor of electricity and no attempt should be made to use PE pipework as a means of earthing electrical equipment. Similarly, because of its high electrical resistivity, caution is required in the use of the material where the avoidance of static electricity may be an important consideration.

8. The bending of polyethylene is permissible and the properties of fusion jointed systems enable changes of direction without recourse to the provision of special bends or anchor blocks. However, the pipe should not normally be cold bent to a radius smaller than 20 times the diameter. For push-fit or mechanical non end-load resistant jointing systems, anchor blocks to withstand the resultant thrusts must be provided in the traditional manner.

9. Although the hot bending of PE pipe is possible under carefully controlled conditions, under no circumstances should hot bending be attempted on site.

10. Polyethylene is a poor conductor of heat but is flammable and should not be exposed to naked flame.

11. The installation of flanged fittings such as sluice valves, hydrant tees, end caps etc usually requires the use of polyethylene stub flanges complete with backing rings and gaskets. Care should be taken when tightening these flanges to provide even and balanced torque. Provision should be made where heavy fittings are installed for concrete support both for the weight and to resist the turning moments associated with valves and hydrants.

12. Where there are large diameter fabricated fittings installed in the main, similar concrete support may be necessary to counteract the inbalance of forces under working conditions. Consideration should be given to introducing a flanged connection on the branch outlet of the tee so that the branch main joint can be made in a separate operation.

13. Polyethylene pipes and fittings may be partially or completely surrounded by concrete but the pipe should be protected by a heavy duty polyethylene membrane to avoid possible damage during pouring or compaction and to prevent high localised stresses.

All concrete bedding should be at least 100mm thick.

14. After completion of an installation, pipework and fittings should be inspected and made ready for testing to ensure the safety and efficiency of the system. If the system is a large one it should be made ready to be tested in sections of convenient length.

15. The degree to which the trench is backfilled prior to testing will be influenced by:

- the prevailing site and/or traffic conditions;
- the potential risk of flotation;
- the unbalanced forces due to configuration and imposed test pressure.

Where practical it is advisable to consider leaving at least the mechanical joints exposed throughout the test.

16. As part of the preparation for the hydrostatic pressure test, all anchorages and struts should be checked to ensure they are adequate to withstand the excess pressure and it is advisable to retighten all bolted flanged joints and to check that all intermediate control valves are open.

17. Complete and accurate records should be taken of the installation. It is useful for records to be taken before the pipes are buried whilst memories are fresh and key elements are still visible. Photographic records of important or complex features should be considered.

18. The marker tape and detection wires should be laid along the line of the water main and connected at each end to either a sluice valve or hydrant. The recommended position of the indicators is 350mm below the surface directly above the crown of the pipe.

MATERIAL PROPERTIES, DIMENSIONS, FLOW CHARTS

- Material Properties

- Pipe Dimensions

  -PE 80B (PN 4 to PN 8; PN 10 to PN 16)

  -PE 100 (PN 4 to PN 8; PN 10 to PN 16)

- Flow Charts

  -Small Bore PE: DN 16 - DN 75 (PE 80)

  -SDR 41 (PE 80: PN 3.2 & PE 100: PN 4)

  -SDR 33 (PE 80: PN 4)

  -SDR 26 (PE 100: PN 6.3)

  -SDR 21 (PE 80: PN 6.3 & PE 100: PN 8)

  -SDR 17 (PE 80: PN 8 & PE 100: PN 10)

  -SDR 13.6 (PE 80: PN 10 & PE 100: PN 12.5)

  -SDR 11 (PE 80: PN 12.5 & PE 100: PN 16)

- Drainage – Gradient Flow

1.1 Mechanical Properties of Polyethylene @ 20.0°C

	PE80B	PE80C	PE100
Density			
-Blue	>944 kg/m^3		>950 kg/m^3
-Black	>949 kg/m^3	>959 kg/m^3	>959 kg/m^3
Hardness	67 (Shore D)	67 (Shore D)	67 (Shore D)
Izod Impact Strength @(-20°C)	90 J/m	86 J/m	90 J/m
Roughness Coefficient (Colebrook - White)	0.007mm	0.007mm	0.007mm
Ultimate Tensile Strength	27 N/mm^2	37 N/mm^2	30 N/mm^2
	(50mm/min)		(50mm/min)
Tensile strength at yield	18 MPa	21 MPa	22 MPa
Elongation at Break	>600%	>500%	>600%
Environmental Stress Cracking resistance	>1000h	>1000h	>1000h
Abrasion (Relative increase of strain)	0.1%	0.1%	0.1%
Minimum Required Strength	8.0 MPa		10.0 MPa
Elastic Flexural Modulus	700 GPa	1000 GPa	1000 GPa
Shear Modulus	400-470 N/mm2	600 N/mm2	600 N/mm2
Charpy Impact strength	22-35 kJ/m2	17-26 kJ/m2	17-26 kJ/m2

1.2 Electrical Properties

Dielectric Strength	70 kV/mm	22-53 kV/mm	22-53 kV/mm
Specific Volume Resistivity	10^{15} OHM.cm	10^{15} OHM.cm	10^{15} OHM.cm
Surface Resistivity	>10^{15} OHM	>10^{15} OHM	>10^{15} OHM
Dissipation Factor	5.5 (50 Hz)	5.5 (50 Hz)	5.5 (50 Hz)
	2.5 (106 Hz)	2.5 (106 Hz)	2.5 (106 Hz)

1.3 Thermal Properties

Vicat Softening Point	116 °C	124 °C	124 °C
Thermal Conductivity	0.42-0.45W/m°K	0.4W/m°K	0.4W/m°K
Specific Heat	2.6 KJ/[kg.K]	2.6 KJ/[kg.K]	2.6 KJ/[kg.K]
Brittleness Temperature	<-70 °C	<-30 °C	<-100 °C
Linear Thermal Expansion	2.4x10^{-4}/K	2.0x10^{-4}/K	2.3x10^{-4}/K

3.0 PE80B Pipe Dimensions

Standard AS/NZS 4130

		PN4 SDR 33				PN5 SDR 26				PN6.3 SDR 21				PN8 SDR17			
Nominal Size	Mean OD	Mean Bore	T Min	T Max	Mass kg/m	Mean Bore	T Min	T Max	Mass kg/m	Mean Bore	T Min	T Max	Mass kg/m	Mean Bore	T Min	T Max	Mass kg/m
20	20.2	16.7	1.6	1.9	0.096	16.7	1.6	1.9	0.096	16.7	1.6	1.9	0.096	16.7	1.6	1.9	0.096
25	25.2	21.7	1.6	1.9	0.122	21.7	1.6	1.9	0.122	21.7	1.6	1.9	0.122	21.7	1.6	1.9	0.122
32	32.2	28.7	1.6	1.9	0.159	28.7	1.6	1.9	0.159	28.7	1.6	1.9	0.159	28.1	1.9	2.2	0.184
40	40.2	36.7	1.6	1.9	0.201	36.7	1.6	1.9	0.201	36.1	1.9	2.2	0.233	35.0	2.4	2.8	0.292
50	50.3	46.8	1.6	1.9	0.254	46.0	2.0	2.3	0.309	45.1	2.4	2.8	0.370	43.9	3.0	3.4	0.450
63	63.3	59.0	2.0	2.3	0.392	58.1	2.4	2.8	0.471	56.9	3.0	3.4	0.574	55.2	3.8	4.3	0.716
75	75.4	70.4	2.3	2.7	0.544	69.2	2.9	3.3	0.669	67.7	3.6	4.1	0.822	65.8	4.5	5.1	1.011
90	90.5	84.5	2.8	3.2	0.783	83.0	3.5	4.0	0.971	81.3	4.3	4.9	1.179	79.0	5.4	6.1	1.454
110	110.5	103.2	3.4	3.9	1.164	101.9	4.3	4.9	1.454	99.2	5.3	6.0	1.768	96.5	6.6	7.4	2.162
125	125.6	117.3	3.9	4.4	1.504	115.4	4.8	5.4	1.834	112.9	6.0	6.7	2.260	109.9	7.4	8.3	2.759
140	140.7	131.5	4.3	4.9	1.868	129.2	5.4	6.1	2.316	126.5	6.7	7.5	2.831	123.1	8.3	9.3	3.464
160	160.8	150.4	4.9	5.5	2.415	147.6	6.2	7.0	3.037	144.5	7.7	8.6	3.713	140.7	9.5	10.6	4.522
180	180.9	169.2	5.5	6.2	3.056	166.3	6.9	7.7	3.782	162.7	8.6	9.6	4.666	158.3	10.7	11.9	5.720
200	200.9	187.7	6.2	7.0	3.827	184.6	7.7	8.6	4.688	180.6	9.6	10.7	5.778	175.8	11.9	13.2	7.055
225	226.1	211.5	6.9	7.7	4.767	207.9	8.6	9.6	5.894	203.3	10.8	12.0	7.305	197.8	13.4	14.9	8.951
250	251.2	234.9	7.7	8.6	5.912	230.9	9.6	10.7	7.302	226.1	11.9	13.2	8.939	220.0	14.8	16.4	10.969
280	281.3	263.1	8.6	9.6	7.393	258.7	10.7	11.9	9.106	253.0	13.4	14.9	11.282	246.3	16.6	18.4	13.778
315	316.5	296.0	9.7	10.8	9.369	290.9	12.1	13.5	11.602	284.9	15.0	16.6	14.180	277.1	18.7	20.7	17.450
355	356.6	333.6	10.9	12.1	11.844	327.9	13.6	15.1	14.658	321.0	16.9	18.7	17.999	311.1	21.1	23.4	22.203
400	401.8	375.8	12.3	13.7	15.085	369.5	15.3	17.0	18.588	361.5	19.1	21.2	22.952	351.9	23.7	26.2	28.062
450	452.1	423.0	13.8	15.3	19.000	415.8	17.2	19.1	23.507	406.8	21.5	23.8	29.030	395.9	26.7	29.5	35.559
500	502.3	470.0	15.3	17.0	23.432	462.0	19.1	21.2	28.996	452.0	23.9	26.4	35.815	440.0	29.6	32.7	43.802
560	562.5	526.3	17.2	19.1	29.487	517.4	21.4	23.7	36.339	506.4	26.7	29.5	44.817	492.7	33.2	36.7	55.028
630	632.9	592.2	19.3	21.4	37.203	582.1	24.1	26.7	46.053	569.8	30.0	33.1	56.624	554.4	37.3	41.2	69.541
710	713.2	667.3	21.8	24.1	47.278	655.9	27.2	30.1	58.533	641.9	33.9	37.4	72.090	624.6	42.1	46.5	88.438
800	803.6	752.0	24.5	27.1	59.891	739.2	30.6	33.8	74.133	723.4	38.1	42.1	91.375	703.9	47.4	52.3	112.141
1000	1004.5	940.1	30.6	33.8	93.439	924.1	38.2	42.2	115.694	904.2	47.7	52.6	142.841	879.8	59.3	65.4	175.319

3.0 PE80B Pipe Dimensions

Standard AS/NZS 4130

		PN10 SDR 13.6				PN12.5 SDR 11				PN16 SDR 9			
Nominal Size	Mean OD	Mean Bore	T Min	T Max	Mass kg/m	Mean Bore	T Min	T Max	Mass kg/m	Mean Bore	T Min	T Max	Mass kg/m
20	20.2	16.7	1.6	1.9	0.096	16.1	1.9	2.2	0.110	15.2	2.3	2.7	0.132
25	25.2	21.1	1.9	2.2	0.142	20.2	2.3	2.7	0.168	19.2	2.8	3.2	0.199
32	32.2	27.0	2.4	2.8	0.230	26.0	2.9	3.3	0.266	24.5	3.6	4.1	0.326
40	40.2	33.8	3.0	3.4	0.353	32.3	3.7	4.2	0.423	30.6	4.5	5.1	0.507
50	50.3	42.4	3.7	4.2	0.546	40.4	4.6	5.2	0.657	38.4	5.6	6.3	0.788
63	63.3	53.3	4.7	5.3	0.870	51.0	5.8	6.5	1.038	48.2	7.1	8.0	1.256
75	75.4	63.7	5.5	6.2	1.214	61.0	6.8	7.6	1.450	57.6	8.4	9.4	1.766
90	90.5	76.5	6.6	7.4	1.744	73.1	8.2	9.2	2.102	69.1	10.1	11.3	2.548
110	110.5	93.3	8.1	9.1	2.615	89.4	10.0	11.1	3.114	84.5	12.3	13.7	3.783
125	125.6	106.1	9.2	10.3	3.371	101.5	11.4	12.7	4.041	96.1	14.0	15.5	4.880
140	140.7	118.9	10.3	11.5	4.223	113.9	12.7	14.1	5.037	107.6	15.7	17.4	6.132
160	160.8	135.9	11.8	13.1	5.512	130.0	14.6	16.2	6.612	123.1	17.9	19.8	7.986
180	180.9	152.8	13.3	14.8	6.996	146.3	16.4	18.2	8.358	138.5	20.1	22.3	10.104
200	200.9	169.9	14.7	16.3	8.577	162.5	18.2	20.2	10.302	153.7	22.4	24.8	12.488
225	226.1	191.1	16.6	18.4	10.895	182.9	20.5	22.7	13.044	173.2	25.1	27.8	15.760
250	251.2	212.4	18.4	20.4	13.421	203.4	22.7	25.1	16.043	192.5	27.9	30.8	19.433
280	281.3	237.9	20.6	22.8	16.813	227.8	25.4	28.1	20.108	215.4	31.3	34.6	24.423
315	316.5	267.6	23.2	25.7	21.311	256.3	28.6	31.6	25.458	242.4	35.2	38.9	30.901
355	356.6	301.6	26.1	28.9	27.011	288.8	32.2	35.6	32.305	273.3	39.6	43.7	39.150
400	401.8	339.9	29.4	32.5	34.256	325.4	36.3	40.1	41.017	307.8	44.7	49.3	49.769
450	452.1	382.4	33.1	36.6	43.398	366.1	40.9	45.1	51.949	346.5	50.2	55.4	62.923
500	502.3	424.9	36.8	40.6	53.546	406.8	45.4	50.1	64.096	385.0	55.8	61.5	77.657
560	562.5	475.9	41.2	45.5	67.167	455.8	50.8	56.0	80.283				
630	632.9	535.5	46.3	51.1	84.911	512.6	57.2	63.1	101.737				
710	713.2	603.4	52.2	57.6	107.862								
800	803.6	680.0	58.8	64.8	136.820								
1000	1004.5												

PE100: SDR 41 - SDR 21

PE100 Pipe Dimensions

Standard AS/NZS 4130

		PN4 SDR 41				PN6.3 SDR 26				PN8 SDR 21			
Nominal Size	Mean OD	Mean Bore	T Min	T Max	Mass kg/m	Mean Bore	T Min	T Max	Mass kg/m	Mean Bore	T Min	T Max	Mass kg/m
20	20.2	16.7	1.6	1.9	0.096	16.7	1.6	1.9	0.096	16.7	1.6	1.9	0.096
25	25.2	21.7	1.6	1.9	0.122	21.7	1.6	1.9	0.122	21.7	1.6	1.9	0.122
32	32.2	28.7	1.6	1.9	0.159	28.7	1.6	1.9	0.159	28.7	1.6	1.9	0.159
40	40.2	36.7	1.6	1.9	0.201	36.7	1.6	1.9	0.201	36.1	1.9	2.2	0.233
50	50.3	46.8	1.6	1.9	0.254	46.0	2.0	2.3	0.309	45.1	2.4	2.8	0.370
63	63.3	59.0	2.0	2.3	0.392	58.1	2.4	2.8	0.471	56.9	3.0	3.4	0.574
75	75.4	70.4	2.3	2.7	0.544	69.2	2.9	3.3	0.669	67.7	3.6	4.1	0.822
90	90.5	85.5	2.3	2.7	0.783	83.0	3.5	4.0	0.971	81.3	4.3	4.9	1.179
110	110.5	104.7	2.7	3.1	1.164	101.3	4.3	4.9	1.454	99.2	5.3	6.0	1.768
125	125.6	118.9	3.1	3.6	1.504	115.4	4.8	5.4	1.834	112.9	6.0	6.7	2.260
140	140.7	133.2	3.5	4.0	1.868	129.2	5.4	6.1	2.316	126.5	6.7	7.5	2.831
160	160.8	152.3	4.0	4.5	2.415	147.6	6.2	7.0	3.037	144.5	7.7	8.6	3.713
180	180.9	171.5	4.4	5.0	3.056	166.3	6.9	7.7	3.782	162.7	8.6	9.6	4.666
200	200.9	190.5	4.9	5.5	3.827	184.6	7.7	8.6	4.688	180.6	9.6	10.7	5.778
225	226.1	214.4	5.5	6.2	4.767	207.9	8.6	9.6	5.894	203.3	10.8	12.0	7.305
250	251.2	238.0	6.2	7.0	5.912	230.9	9.6	10.7	7.302	226.1	11.9	13.2	8.939
280	281.3	266.7	6.9	7.7	7.393	258.7	10.7	11.9	9.106	253.0	13.4	14.9	11.282
315	316.5	300.2	7.7	8.6	9.369	290.9	12.1	13.5	11.602	284.9	15.0	16.6	14.180
355	356.6	338.2	8.7	9.7	11.844	327.9	13.6	15.1	14.658	321.0	16.9	18.7	17.999
400	401.8	381.1	9.8	10.9	15.085	369.5	15.3	17.0	18.588	361.5	19.1	21.2	22.952
450	452.1	428.9	11.0	12.2	19.000	415.8	17.2	19.1	23.507	406.8	21.5	23.8	29.030
500	502.3	476.3	12.3	13.7	23.432	462.0	19.1	21.2	28.996	452.0	23.9	26.4	35.815
560	562.5	533.6	13.7	15.2	29.487	517.4	21.4	23.7	36.339	506.4	26.7	29.5	44.817
630	632.9	600.4	15.4	17.1	37.203	582.1	24.1	26.7	46.053	569.8	30.0	33.1	56.624
710	713.2	676.5	17.4	19.3	47.278	656.2	27.2	30.1	58.533	641.9	33.9	37.4	72.090
800	803.6	762.3	19.6	21.7	59.891	739.2	30.6	33.8	74.133	723.4	38.1	42.1	91.375
1000	1004.5	952.9	24.5	27.1	93.439	924.1	38.2	42.2	115.694	904.2	47.7	52.6	142.841

PE100: SDR 17 - SDR 11

PE100 Pipe Dimensions

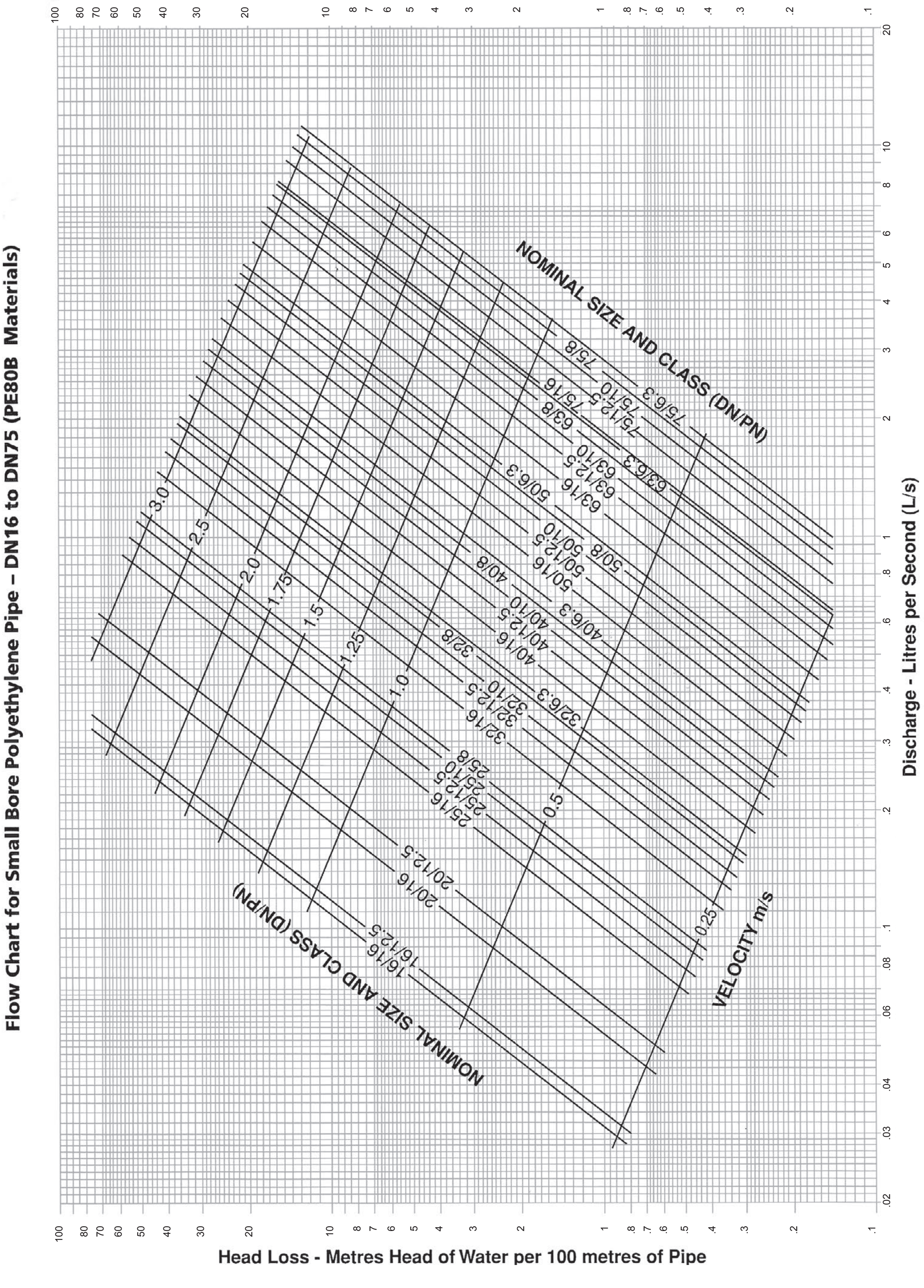
Standard AS/NZS 4130

		PN10 SDR 17				PN12.5 SDR 13.6				PN16 SDR 11			
Nominal Size	Mean OD	Mean Bore	T Min	T Max	Mass kg/m	Mean Bore	T Min	T Max	Mass kg/m	Mean Bore	T Min	T Max	Mass kg/m
20	20.2	16.7	1.6	1.9	0.096	16.7	1.6	1.9	0.096	16.1	1.9	2.2	0.110
25	25.2	21.7	1.6	1.9	0.122	21.1	1.9	2.2	0.142	20.2	2.3	2.7	0.168
32	32.2	28.1	1.9	2.2	0.184	27.0	2.4	2.8	0.230	26.0	2.9	3.3	0.266
40	40.2	35.0	2.4	2.8	0.292	33.8	3.0	3.4	0.353	32.3	3.7	4.2	0.423
50	50.3	43.9	3.0	3.4	0.450	42.4	3.7	4.2	0.546	40.4	4.6	5.2	0.657
63	63.3	55.2	3.8	4.3	0.716	53.3	4.7	5.3	0.870	51.0	5.8	6.5	1.038
75	75.4	65.8	4.5	5.1	1.011	63.7	5.5	6.2	1.214	61.0	6.8	7.6	1.450
90	90.5	79.0	5.4	6.1	1.454	76.5	6.6	7.4	1.744	73.1	8.2	9.2	2.102
110	110.5	96.5	6.6	7.4	2.162	93.3	8.1	9.1	2.615	89.4	10.0	11.1	3.114
125	125.6	109.9	7.4	8.3	2.759	106.1	9.2	10.3	3.371	101.5	11.4	12.7	4.041
140	140.7	123.1	8.3	9.3	3.464	118.9	10.3	11.5	4.223	113.9	12.7	14.1	5.037
160	160.8	140.7	9.5	10.6	4.522	135.9	11.8	13.1	5.512	130.0	14.6	16.2	6.612
180	180.9	158.3	10.7	11.9	5.720	152.8	13.3	14.8	6.996	146.3	16.4	18.2	8.358
200	200.9	175.8	11.9	13.2	7.055	169.9	14.7	16.3	8.577	162.5	18.2	20.2	10.302
225	226.1	197.8	13.4	14.9	8.951	191.1	16.6	18.4	10.895	182.9	20.5	22.7	13.044
250	251.2	220.0	14.8	16.4	10.969	212.4	18.4	20.4	13.421	203.4	22.7	25.1	16.043
280	281.3	246.3	16.6	18.4	13.778	237.9	20.6	22.8	16.813	227.8	25.4	28.1	20.108
315	316.5	277.1	18.7	20.7	17.450	267.6	23.2	25.7	21.311	256.3	28.6	31.6	25.458
355	356.6	311.1	21.1	23.4	22.203	301.6	26.1	28.9	27.011	288.8	32.2	35.6	32.305
400	401.8	351.9	23.7	26.2	28.062	339.9	29.4	32.5	34.256	325.4	36.3	40.1	41.017
450	452.1	395.9	26.7	29.5	35.559	382.4	33.1	36.6	43.398	366.1	40.9	45.1	51.949
500	502.3	440.0	29.6	32.7	43.802	424.9	36.8	40.6	53.546	406.8	45.4	50.1	64.096
560	562.5	492.7	33.2	36.7	55.028	475.9	41.2	45.5	67.167	455.8	50.8	56.0	80.283
630	632.9	554.4	37.3	41.2	69.541	535.5	46.3	51.1	84.911	512.6	57.2	63.1	101.737
710	713.2	624.6	42.1	46.5	88.438	603.4	52.2	57.6	107.862				
800	803.6	703.9	47.4	52.3	112.141	680.0	58.8	64.8	136.820				
1000	1004.5	879.8	59.3	65.4	175.319								

Flow Chart

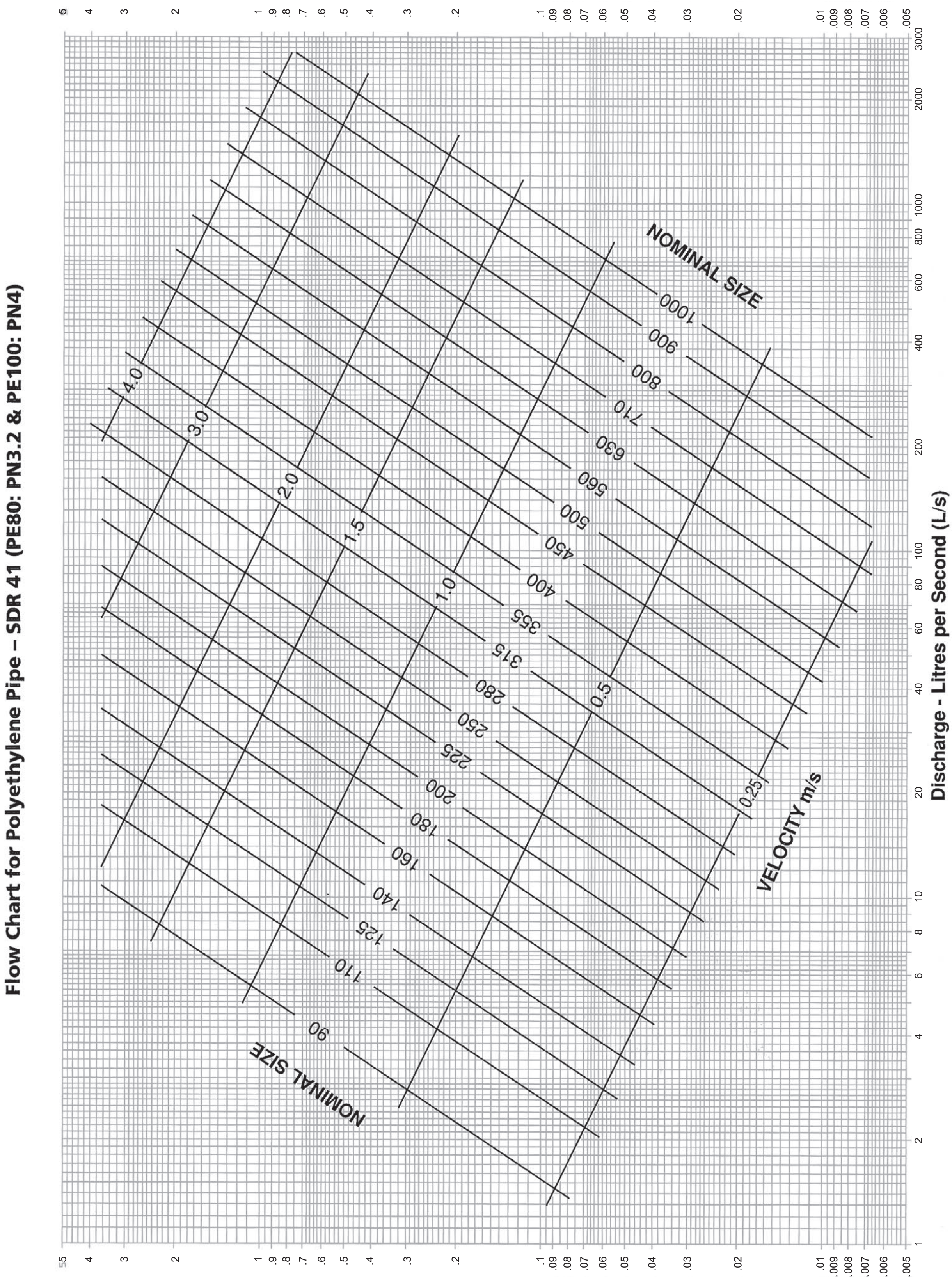
Small Bore Polyethylene Pipe - DN16 to DN75 (PE80B Material)

Use Marley Pressure Pipe Calculator for specific analysis



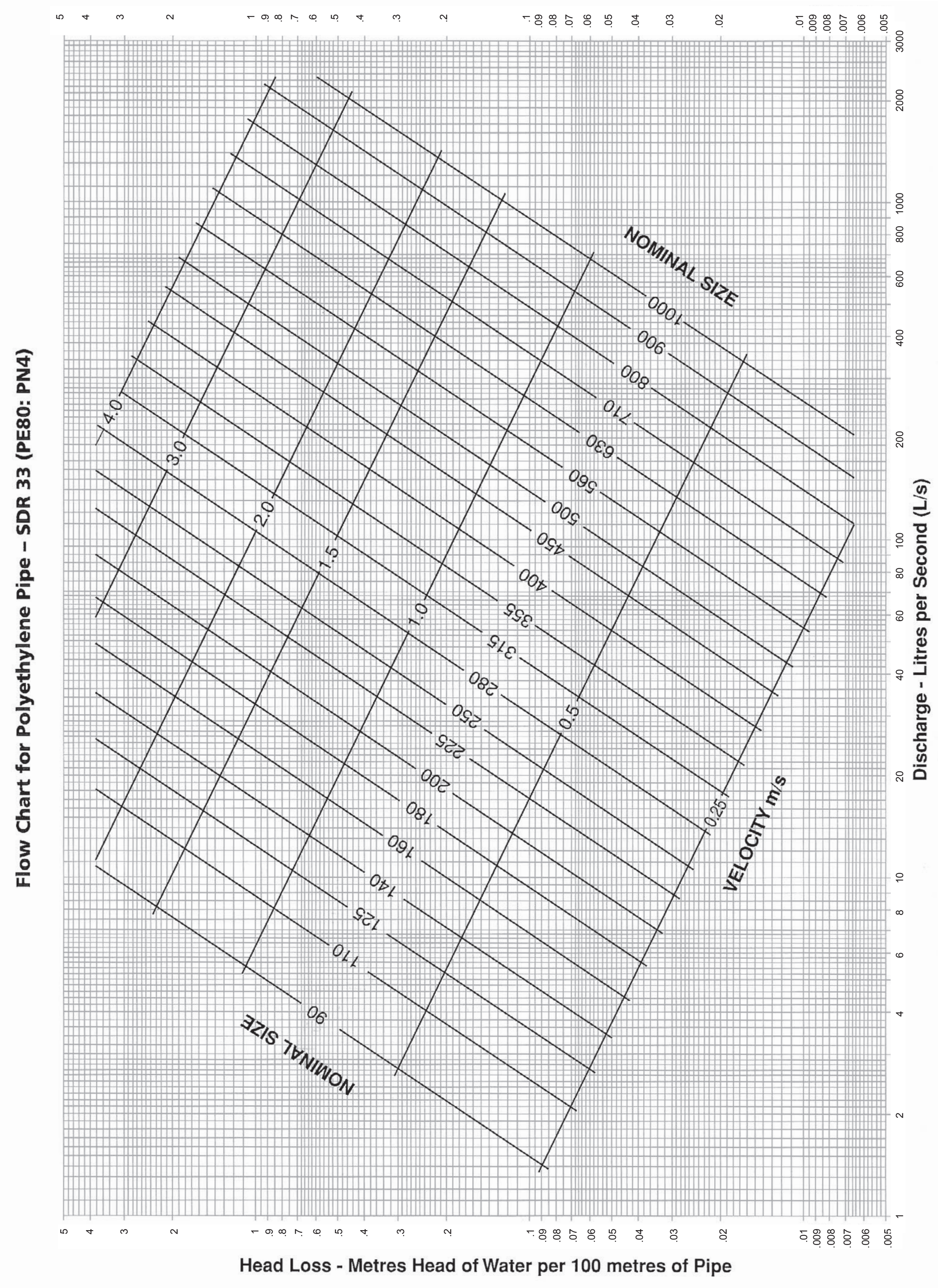
Polyethylene Pressure Pipe - SDR 41 (PE80: PN3.2 & PE100: PN4)

Use Marley Pressure Pipe Calculator for specific analysis



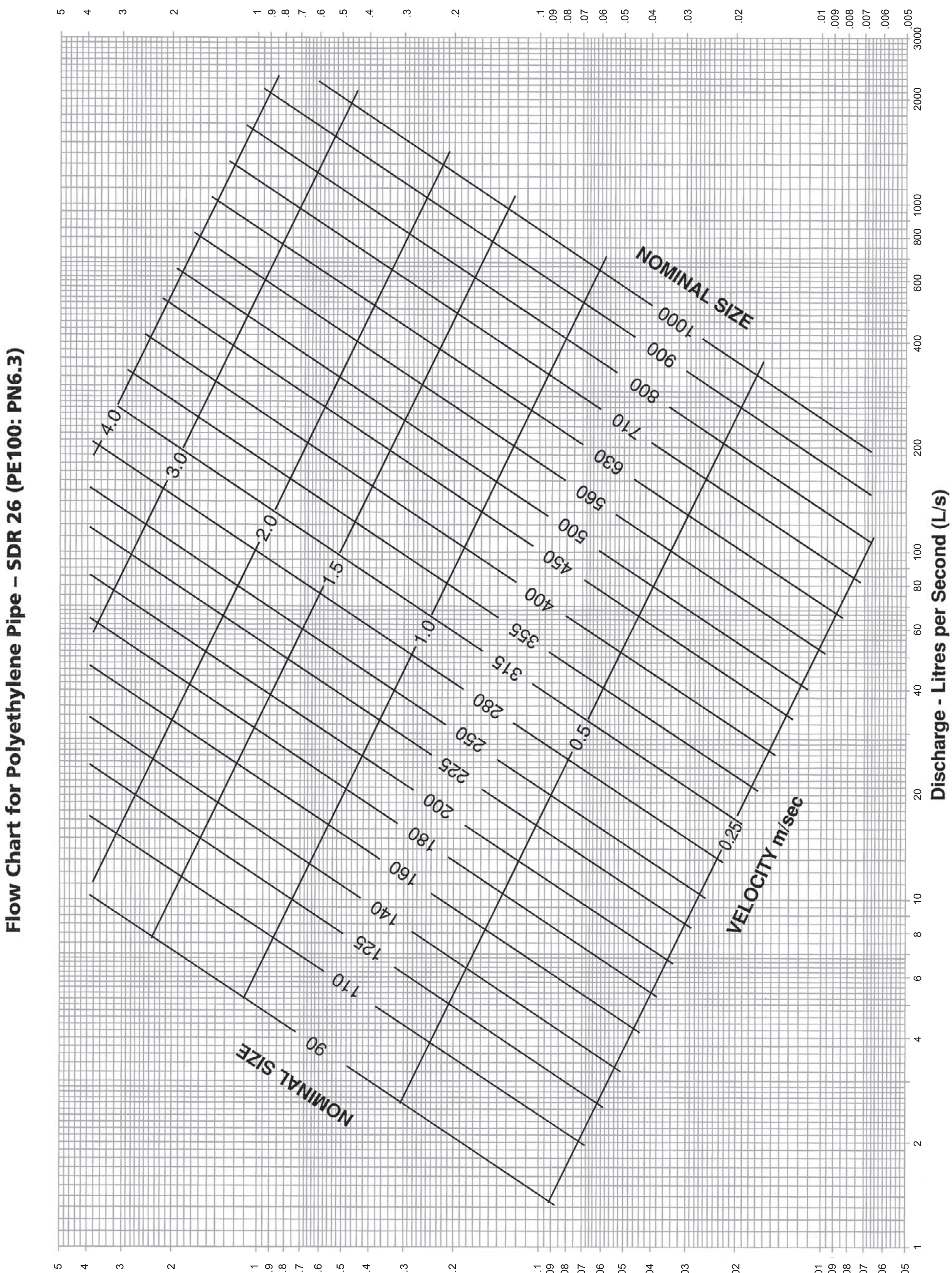
Polyethylene Pressure Pipe - SDR 33 (PE80: PN4)

Use Marley Pressure Pipe Calculator for specific analysis



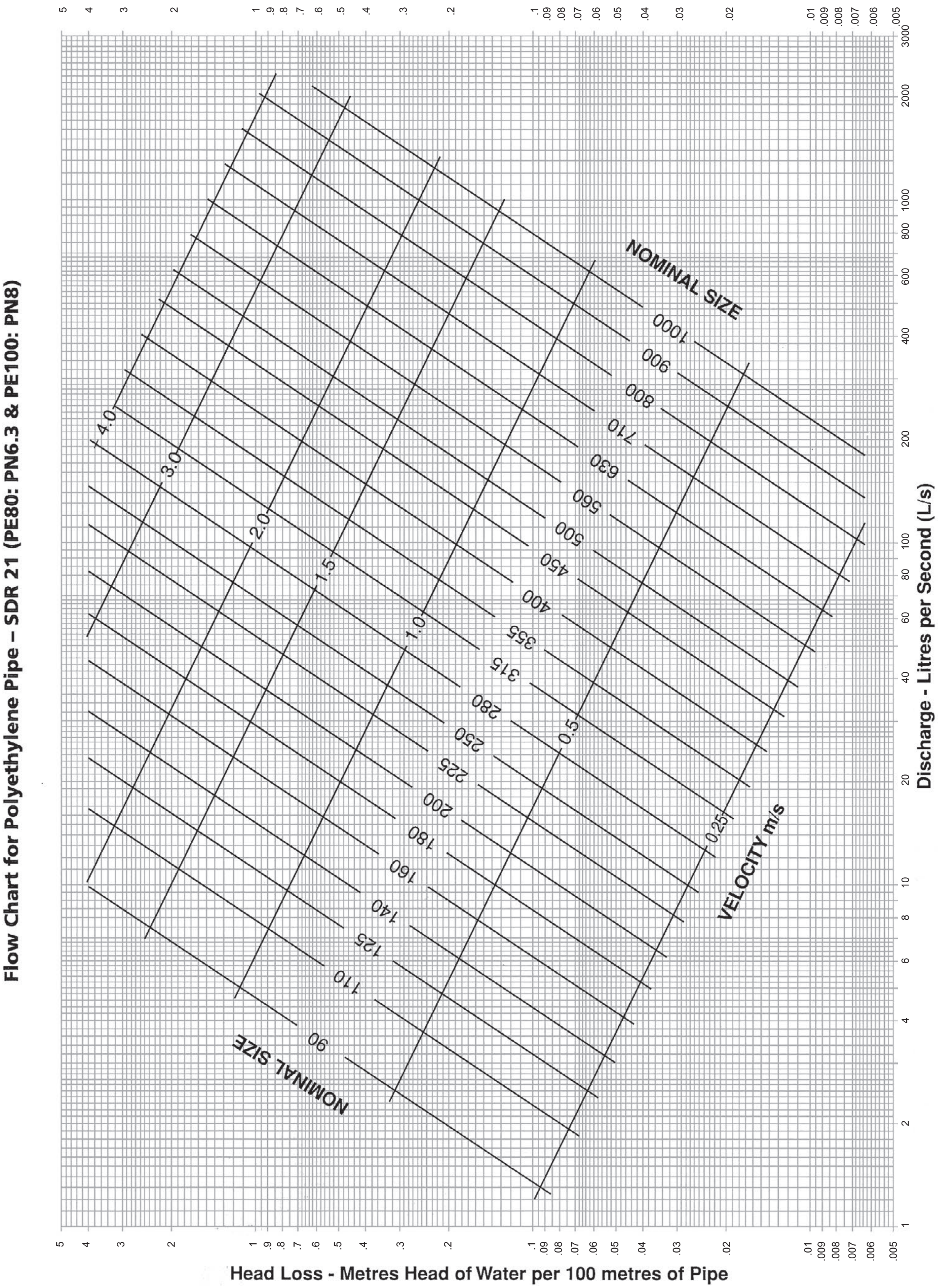
Polyethylene Pressure Pipe - SDR 26 (PE 100: PN6.3)

Use Marley Pressure Pipe Calculator for specific analysis



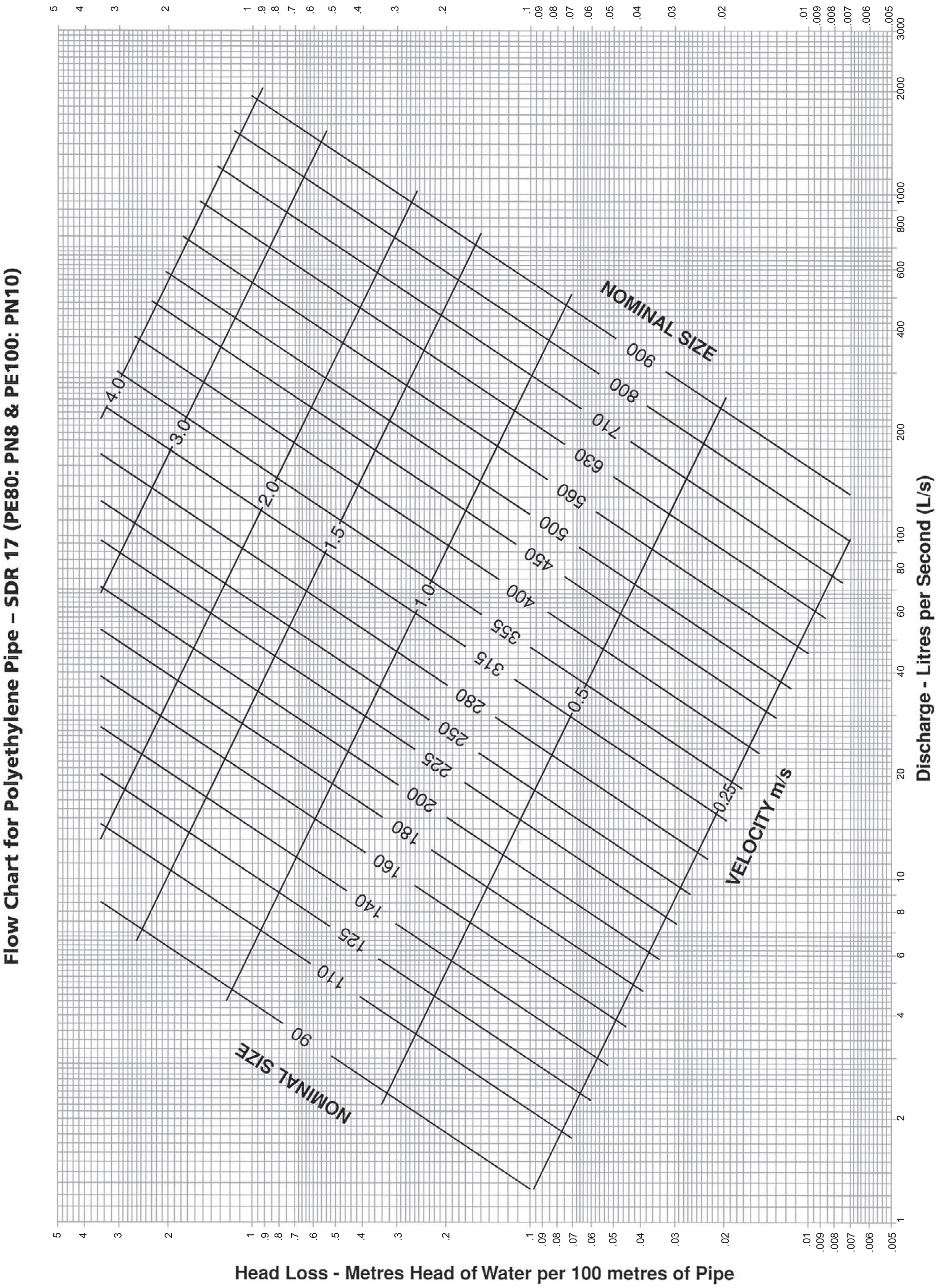
Polyethylene Pressure Pipe - SDR 21 (PE 80: PN6.3 & PE100: PN8)

Use Marley Pressure Pipe Calculator for specific analysis



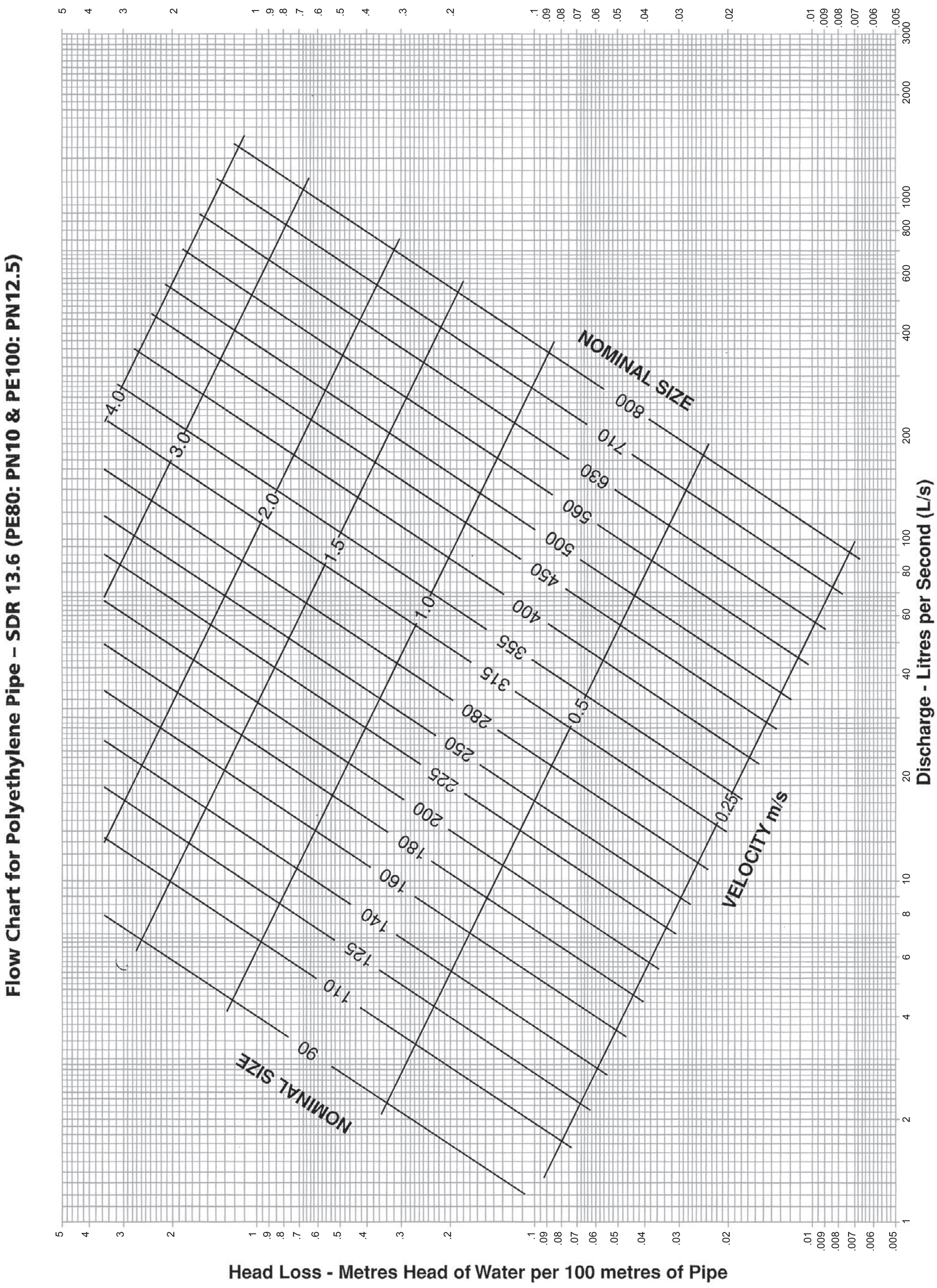
Polyethylene Pressure Pipe - SDR 17 (PE 80: PN8 & PE100: PN10)

Use Marley Pressure Pipe Calculator for specific analysis



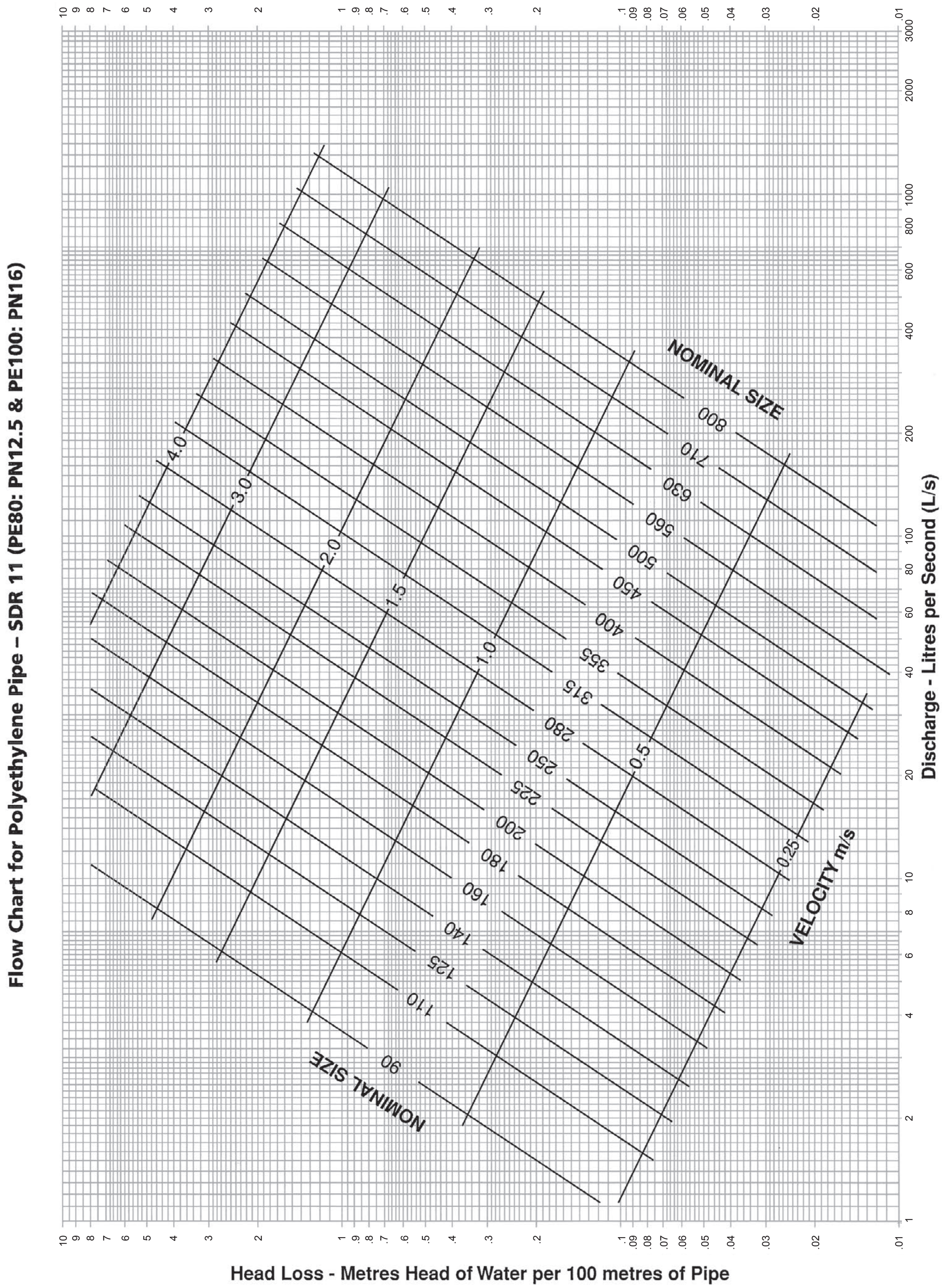
Polyethylene Pressure Pipe - SDR 13.6 (PE 80: PN10 & PE100: PN12.5)

Use Marley Pressure Pipe Calculator for specific analysis



Polyethylene Pressure Pipe - SDR 11 (PE80: PN 12.5 & PE100: PN16)

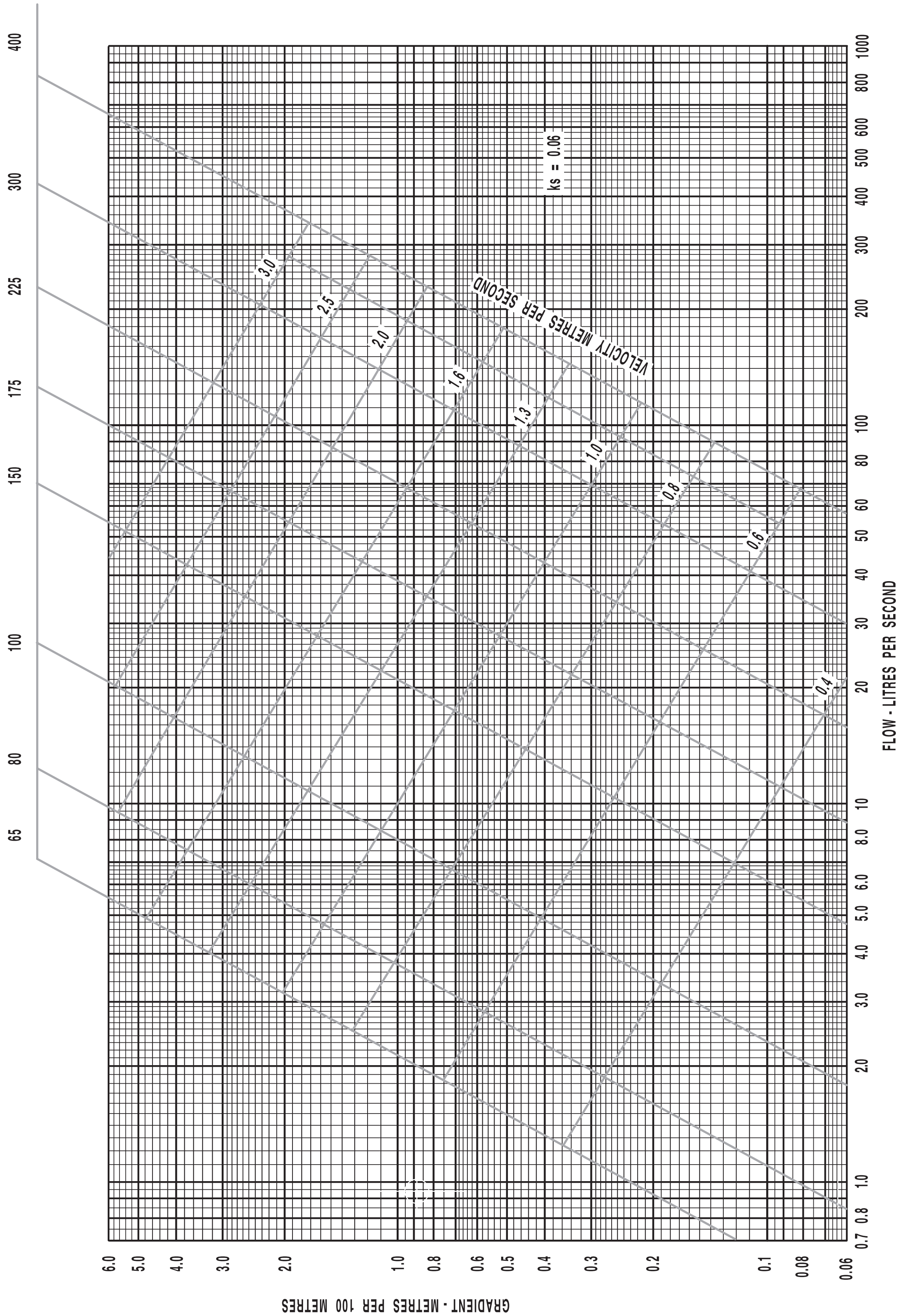
Use Marley Pressure Pipe Calculator for specific analysis



Flow Chart

Polyethylene Drain Pipe
Flow Performance Clean Sanitary Sewer or Stormwater Line

For the theoretical maximum flow condition that can be expected in the early life of a sanitary or stormwater drain with no grit or sliming a Ks of 0.06mm can be selected.



DESIGN

- Pipe Selection
- Fatigue Response
- Surge Pressure Envelopes
- Definition of Cycle Amplitude
- Effect of Surges
- Water Hammer
- Design Hints
- Effect of Temperature
- Safety Factors
- Fittings
- Wave Speed Transmission
- Celerity
- Surge Celerity
- Hydraulic Flow
- Air Valves
- Head Loss due to Friction in Pipe
- Head Loss through Fittings
- Resistance Coefficients for Valves, Fittings & changes in Pipe Cross-Section
- Negative Pressure Effects
- Expansion & Contraction
- Thermal Expansion & Contraction

PIPE SELECTION

Static Stresses

- The ratio between the diameter and the wall thickness.
- The hydrostatic design stress (Sigma value) varies for the particular pipe material used.
- The duration of applied pressure over the pipeline lifetime.
- The pipe material service temperature.

The above must all be factored when designing for hydrostatic pressure conditions using the Barlow formula as follows:

$$T = \frac{PD}{2S + P}$$

Where
T = minimum wall thickness (mm)
P = working pressure (MPa)
D = maximum mean OD (mm)
S = design hoop stress (MPa)

The Dynamic loads normally considered during operation are:

- internal cyclic loading e.g. surge associated with pumping regimes or the rapid closure of valves; the amplitude (or range of surge pressure) should be limited to one half of the maximum allowable working pressure of the pipe.
- external cyclic loadings due to traffic conditions; the total pressure should not in any case exceed the rated pressure of the pipe.

HYDROSTATIC DESIGN STRESS AND MINIMUM REQUIRED STRENGTH VALUES

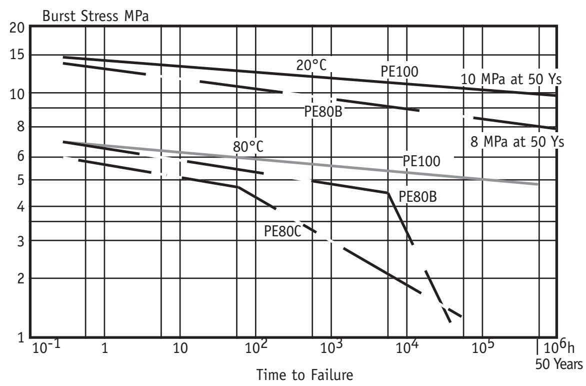
- for MDPE

Material Designation	Minimum Required Strength (MRS)MPa	Hydrostatic DesignStress (S) MPa
PE80B	8.0	6.3
PE100	10.0	8.0

Dynamic Stresses

Nominal working pressures assigned to the various classes of pressure pipes are based on the stress regression line principle for pipes subjected to constant internal pressure. It is well known that a form of failure due to material fatigue can arise if stress fluctuations of sufficient magnitude and frequency occur in any material.

Pressure pipes are capable of handling accidental events, such as pressure fluctuations due to a power cut, however, if repetitive surges are likely to exceed about 100,000 occurrences, which is equivalent to an average of one surge wave every four hours for the total life of the pipe, then fatigue is a possibility and a fatigue design should be considered. In most water supply lines this frequency of surges should never occur. If stress peaks in excess of the design stresses are present, fatigue proceeds more rapidly and failure can occur earlier. For this reason peak pressures should not be allowed to exceed maximum recommended working pressures, including water hammer.



Principal stress/time curves for PE80B and PE100 pipes at 20°C and 80°C. The standard curve for PE80C at 80°C (acc. to DIN 8075) is shown for comparison. The minimum required strength (MRS) at 20°C and 50 years is 10 MPa for PE100 and 8 MPa for PE80 giving the design stress 8 MPa and 6.3 MPa, respectively.

FATIGUE RESPONSE

Studies of fatigue response have shown that a fatigue crack initiates from some dislocation in the material matrix, usually towards the inside surface of the pipe where stress levels are highest, and propagates or grows with each stress cycle at a rate dependent on the magnitude of the stress. Ultimately the crack will penetrate the pipe wall, extending from a few millimetres to a few centimetres long in the axial direction and will produce a leak. On occasions, particularly with larger pipes containing air entrained in the line, a large surge may cause unstable crack propagation and the pipe will burst.

It is important to appreciate that the growth of a fatigue crack is primarily dependent on the stress cycle amplitude, i.e. the maximum pressure minus the minimum pressure. Therefore a pipe subjected to a pressure cycle of zero to half working pressure is as much in danger of fatigue as one subjected to a pressure cycle of half to full working pressure. Thus pipe fatigue failures occur just as frequently at high points in the system as at low points where the total pressure is greater.

Design Criteria for Fatigue

A design for fatigue must involve:

1. An estimate of the magnitude of pressure fluctuations likely to occur in the pipeline, i.e. the difference between maximum and minimum pressures.
2. An estimate of the frequency, usually expressed as cycles per day, at which fluctuations will occur.
3. A statement of the required service life needed from the pipe.

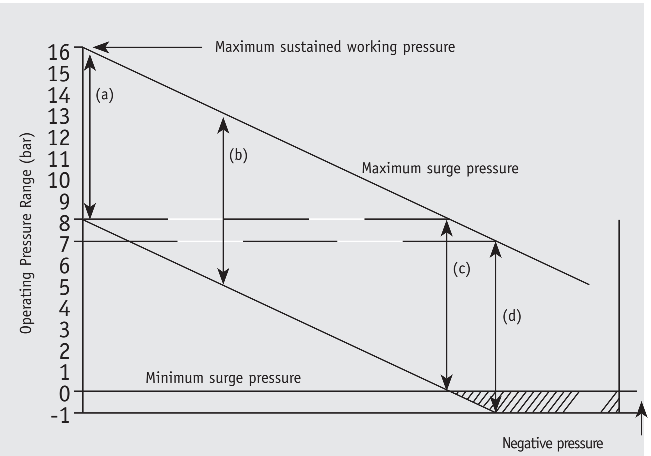
The DYNAMIC loads normally considered during operation are:

- internal cyclic loading e.g. surge associated with pumping regimes or the rapid closure of valves;
- external cyclic loadings due to traffic conditions.

In general terms and for normal use, polymer pipelines which are correctly laid, bedded and supported are capable of withstanding such imposed loadings, within these recommendations.

SURGE PRESSURE ENVELOPES

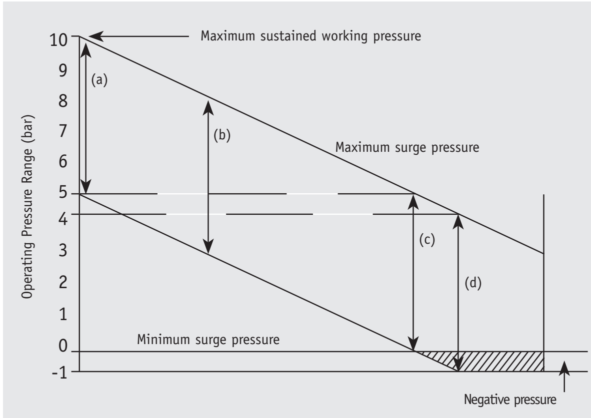
- PE PE100, SDR 11



In fluctuating pressure conditions, the pipe should operate within the pressure envelope. The vertical lines a, b, c & d illustrate that the permissible range of pressure fluctuation due to surge should not exceed 8 bar and may be, for example,between the following limits:

a) from 8 bar to 16 bar
b) from 5 bar to 13 bar
c) from 0 bar to 8 bar
d) from –1 bar to 7 bar (possible vacuum conditions which means the system can be operated at 8 bar pressure and can still work within the pressure envelope)

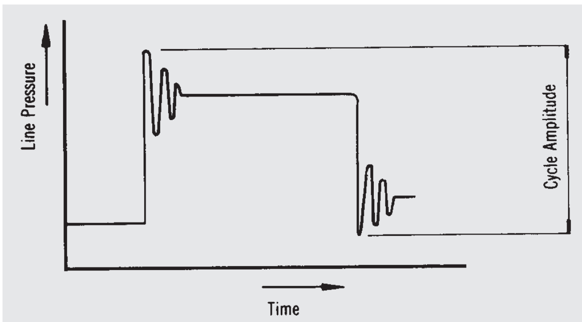
PE100 (SDR 17.6) and PE80 (SDR 11)



The vertical lines a, b, c, d illustrate that the permissable range of fluctuation in pressure should not exceed 5 bar and may be, for example, between the following limits;
(a) from 5-10 bar,
(b) from 3-8 bar,
(c) from 0-5 bar,
(d) from 1-4 bar (possible vacuum conditions).
This applies to 10 bar PE pipe, eg. PE100 pipes at SDR 17.6 and PE80 pipes at SDR 11.

DEFINITION OF CYCLE AMPLITUDE

In the simplest terms the pressure cycle amplitude is defined as the maximum pressure, minus the minimum pressure experienced by the system, including all transients, both positive and negative.
For purposes of fatigue design, transient pressures due to accidental events such as power failure may be ignored, since they are not repetitive. Only primary repetitive operational events need be considered.



EFFECT OF SURGES

Pumping systems are frequently subject to surging due to the effects of switching. The resultant pressure wave will decay exponentially and the system will then experience a number of minor pressure cycles of diminishing magnitude. In order to take this into account, the effect of each minor cycle is related to the primary cycle in terms of the number of such cycles which would produce the same crack growth as one primary cycle.

According to this technique, a typical exponentially decaying surge regime is equivalent to two primary cycles. Thus for design purposes, the primary cycle amplitude only is considered, with the frequency doubled.

WATER HAMMER

Water hammer is a temporary change in pressure in a pipeline due to a change in the velocity of flow in a pipe with respect to time, e.g. a valve opens or closes or a pump starts or stops. Accidental events such as a pipe blockage can also be a cause. The effects are exacerbated by:

- Fast closing/stopping valves/pumps
- High water velocities
- Air in the line
- Poor layout of the pipe network, positioning of pumps
- Pump start method

Note that water hammer pressure may be positive or negative. Both can be detrimental to pipe systems; not only pipes, but pumps, valves and thrust supports can be damaged. Negative pressures can cause "separation" (vacuum formation), with very high positive pressures on "rejoinder" (collapse of the vacuum). For these reasons, water hammer should be eliminated as far as possible.
Water hammer pressures can be reduced by:

- Controlling and slowing valve and pump operations
- Reducing velocities by using larger diameter pipes
- Using pipe material with lower elastic modulus
- Astute layout of network, valves, pumps & air valves
- Fast-acting pressure relief valves.

It is beyond the scope of this manual to give a complete description of water hammer analysis and mitigation.

DESIGN HINTS

To reduce the effect of dynamic fatigue in an installation, the designer can:

1. Limit the number of cycles by:
   (a) Increasing well capacity for a pumping station.
   (b) Matching pump performance to tank size to eliminate short demand cycles for an automatic pressure unit.
   (c) Using double-acting float valves or limiting starts on the pump by the use of a time clock when filling a reservoir.
2. Reduce the dynamic range by:
   (a) Eliminating excessive water hammer.
   (b) Using a larger bore pipe to reduce friction loss.

EFFECT OF TEMPERATURE

Temperature rating principles must be applied in pressure rating selection for static pressures, (ductile burst), no adjustment need be applied for dynamic design.

SAFETY FACTORS

For fatigue loading situations, the maximum pressure reached in the repetitive cycle shall not exceed the pressure rating of the pipe and fittings. Fatigue re-rating factors for PE 80B and PE 100 pipes and fittings shall be as shown in the table.
To select the appropriate pipe and fittings class for fatigue loading, the following procedure shall be adopted:
(a) Estimate the likely pressure cycle amplitude, i.e. the maximum pressure minus the minimum pressure.
(b) Estimate the frequency or number of cycles per day that are expected to occur.
(c) Determine the required life and calculate the total number of cycles that will occur in the design lifetime.
(d) From the Table determine the fatigue load factor for the number of cycles.
(e) Divide the pressure amplitude by the fatigue load factor to obtain the equivalent operating pressure.
(f) Use the equivalent operating pressure to select the class of pipe and fitting required.

FATIGUE RE-RATING FACTORS FOR PE 80B AND PE 100 PIPES AND FUSION FITTINGS

Total Cycles	Approximate No. of cycles per day for 100 year life	Factors Load Factors	
		Pipes	Fusion fittings
		PE 80B & PE 100	PE 80B & PE 100
36,500	1	1.00	1.00
100,000	3	1.00	1.00
300,000	8	1.00	1.00
500,000	14	0.95	0.95
1,000,000	27	0.88	0.88
5,000,000	137	0.74	0.74
10,000,000	274	0.68	-
50,000,000	1,370	0.57	-

FITTINGS

Complex stress patterns in fittings can "amplify" the stress cycling in the fitting. This factor is particularly prevalent in branch fittings such as tees, where amplification factors of up to four times have been observed. The condition can be aggravated by the existence of stress cycling from other sources. For example, bending stresses induced by flexing under hydraulic thrust when improperly supported, or vibration induced fatigue caused by direct connection of pipe work to pumps, e.g. flanged connections. Isolation from vibration should always be provided in the design.

WAVE SPEED TRANSMISSION

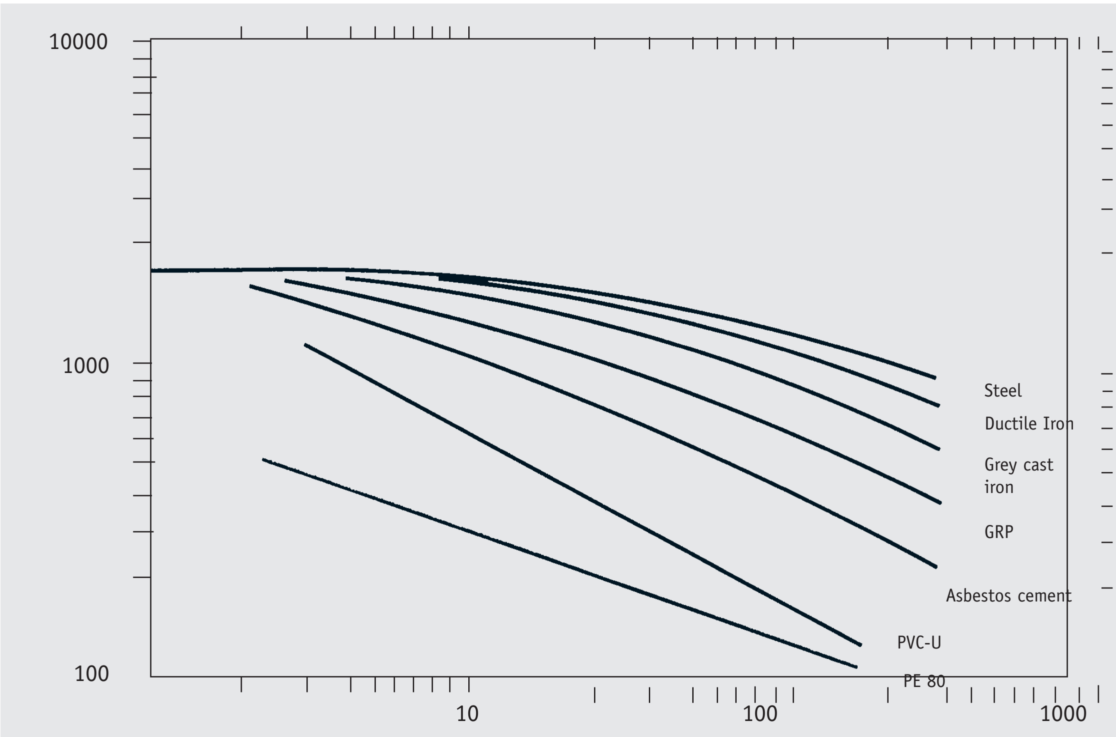
In applications where surge pressures may occur, the relatively low shock wave transmission speed in polymer pipes (compared with that of a pipe of a more rigid material), can be particularly beneficial.
The range of wave transmissions speeds in water for various pipe materials and wall thicknesses as shown below. Wave speed is approximately related to pressure change by the Joukowski formula:

$$\Delta p = W.a.\ \Delta V$$

where

Δp = pressure change (N/m^2)
W = fluid density (1000kg/m^3)
a = wave speed (m/s)
ΔV = velocity change (m/s)

Therefore for a given density and change in velocity, the surge pressure is approximately proportional to wave speed. This illustrates how, for a given surge 'event', the surge pressures generated in Marley P6 pipes will be considerably less than the magnitude of surge developed in other pipe materials.
For external dynamic loading conditions the use of PE pressure mains under major carriageways is dependent on the type of trench bedding conditions used, and the depth.
PE 80 and PE 100 pressure mains should be laid under major roads with the correct installation techniques.



Wave speeds for water in various pipes of diameter (D) and wall thickness (e)

CELERITY

The velocity of the pressure wave, referred to as celerity (C), depends on the pipe material, pipe dimensions and the liquid properties in accordance with the following relationship

$$C=\left[W\left(\frac{1}{K}+\frac{SDR}{E}\right)\right]^{-0.5} \times 10^3 \text{ m/sec}$$

where
W = liquid density (1000 kg/m^3 for water)
SDR = Standard Dimension Ratio of the pipe
K = liquid bulk modulus (2150 MPa)
E = pipe material short term modulus (MPa)

The time taken for the pressure wave to travel the length of the pipeline and return is

$$t = \frac{2L}{C}$$

where
t = time in seconds
L = length of pipeline in metres

If the valve closure time tc is less than t, the pressure rise due to the valve closure is given by:

$$P_1 = C.V$$

where
P_1 = pressure rise in kPa
V = liquid velocity in m/sec

If the valve closure time tc is greater than t, then the pressure rise is approximated by:

$$P_2 = \left[\frac{t}{t_c}\right] P_1$$

SURGE CELERITY

The surge celerity in a pipeline filled with liquid can be determined by:

$$C = \left[W\left(\frac{1}{K} + \frac{SDR}{E}\right)\right]^{-0.5} \times 10^3 \text{ m/sec}$$

where
W = liquid density (1000 kg/m^3 for water)
SDR = Standard Dimension Ratio of the pipe
K = liquid bulk modulus (2150 MPa)
E = pipe material 'instantaneous' modulus (taken as 1000 MPa for PE80B, 1200MPa for PE80C, 1500 MPa for PE100)

Dimension Ratio (SDR) and Celerity (C)

For buried pipes increase the wave celerity (Ca) by 7%.

SDR	Celerity m/s (C) MDPE (PE 80B)	HDPE (PE 100)
41	160	190
33	170	210
26	190	240
21	220	260
17	240	290
13.6	270	320
11	300	360
9	330	390
7.4	360	430

Complex Cycle Patterns

In general, a similar technique may be applied to any situation where smaller cycles exist in addition to the primary cycle. Empirically, crack growth is related to stress cycle amplitude according to $(\Delta S)^{3.2}$. Thus n secondary cycles of magnitude ΔP_1, may be deemed equivalent in effect to one primary cycle, ΔP_0.

$$\text{where } n = \left(\frac{\Delta P_1}{\Delta P_0}\right)^{3.2}$$

For example a secondary cycle of half the magnitude of the primary cycle is expressed as:

$$n = \left(\frac{2}{1}\right)^{3.2} = 9.2$$

so it would require nine secondary cycles to produce the same effect as one primary cycle. If these are occurring at the same frequency, the effective frequency of primary cycling is increased by 1.1 for the purpose of design.

HYDRAULIC FLOW

The velocity of flow in PE pipes should not normally exceed 1-2 metres per second in distribution mains. Where higher velocities are expected, consideration should be given to the effects of surge.
The hydraulically smooth bore of a PE pipe gives excellent flow characteristics which are usually retained through its operational life. The hydraulic frictional coefficients normally used in the design of continuous straight PE pipes working under pressure are:

- Colebrook-White Ks = 0.003mm
- Hazen Williams C = 144

The metric Colebrook- White formula for the velocity of water in a smooth bore pipe under laminar conditions takes the form:

$$V = -2\sqrt{2gDi} \bullet \log.\left[\frac{Ks}{3.7D} + \frac{2.51v}{D\sqrt{2gDi}}\right]$$

Depending on the nature of the surface of a pipe and the velocity of fluid that it is carrying, the flow in a pipe will either be rough turbulent, smooth turbulent or most probably somewhere in between.
The Colebrook-White transition equation incorporates the smooth turbulent and rough turbulent conditions. For smooth pipe the first term in the brackets tends to zero and the second term predominates. For a rough pipe the first term in the brackets predominates, particularly at flows with a high Reynolds Number. This equation is therefore an almost universal application to virtually any surface roughness, pipe size, fluid or velocity of flow in the turbulent range.

$$H = f\,\frac{Lv^2}{D2g}$$

Where
f = Darcy friction factor
H = head loss due to friction (m)
D = pipe internal diameter (m)
L = pipe length (metres)
v = flow velocity (m/s)
g = gravitational acceleration (9.8 m/s^2)
R = Reynolds Number

Substituting for f in the Darcy equation note that:

Q = flow velocity x pipe internal area.
Where Q = discharge (m^3/s)

This leads to the following expression upon which the flow charts are based

$$Q = \frac{\Pi D^2}{4} \bullet \sqrt{\frac{2gD\,H}{L}} \bullet \log_{10}\left[\frac{k + 2.51\nu}{3.7\;\; 2gD\sqrt{\frac{H}{L}}}\right]^2$$

Where
V = velocity in metres per second
g = gravitational acceleration (a value of 9.807 m/s^2 may be assumed)
i = hydraulic gradient
v = kinetic viscosity (a value of 1.141 x 10-6 may be assumed).
Ks = linear measure of roughness in mm = 0.003
D = mean internal diameter of pipe in metres
Q = discharge (litres/second)
H = loss of head (meters/100 metres of pipe)

Computer programs and flowcharts for pipe systems using this formula have been in operation in New Zealand for over 20 years for transmission of water.

Other Pipe Flow Formulas

a) The Manning formula

$$V = \frac{1}{n} R^{2/3} \left(\frac{H}{L}\right)^{1/2}$$

b) The Hazen-Williams formula

$$V = 0.849\, C\, R^{0.63} \left(\frac{H}{L}\right)^{0.54}$$

Where: n = Manning roughness coefficient
C = Hazen-Williams roughness coeffiecient
R = hydraulic radius (m)
(R = D/4 for a pipe flowing full)

$\frac{H}{L}$ = hydraulic gradient (m/m)

Though both formulas do not give the same accuracy as the Colebrook-White equation over a wide range of flows they are often used in hydraulics because of the comparative simplicity.

Water Temperature

The viscosity of water decreases with increasing temperature. As the temperature increases the friction head will decrease.

An approximate allowance for the effect of the variation in water temperature is as follows:

1. **Pipe diameter < 150mm**
   Increase the chart value of the hydraulic gradient by 1% for each 2°C below 20°C.
   Decrease the chart value of the hydraulic gradient by 1% for each 2°C above 20°C.

2. **Pipe diameter> 150mm**
   Increase the chart value of the hydraulic gradient by 1% for each 3°C below 20°C.
   Decrease the chart value of the hydraulic gradient by 1% for each 3°C above 20°C.

Manufacturing Diameter Tolerance

PE pressure pipe is manufactured in accordance with AS/NZS4130 which permits specific manufacturing tolerance on both its mean outside diameter and wall thickness. Hence the mean bore of a pipe is given by:

Mean bore = De - (2 • te)
De = mean OD te = mean wall thickness

The Nominal Size lines on the flow chart correspond to the mean bore of that size and class of pipe.
However, it is conceivable that a pipe could be manufactured with a maximum OD and a minimum wall thickness within approved tolerances. In this case the discharge will be more than that indicated by the charts. Similarly a pipe with a minimum OD and a maximum wall thickness will have a lower discharge than indicated.
For a given discharge the variation in friction head loss or hydraulic gradient due to this effect can be of the order of 2% to 10% depending on the pipe size and class. For pipe sizes greater than 100mm, this variation is usually limited to 6% for a PN18 pipe.

Roughness Considerations

The value of k, the roughness coefficient, has been chosen as 0.003mm for new, clean, concentrically jointed PE pressure pipe. This figure for k agrees with recommended values given in AS2200 (Design Charts for Water Supply and Sewage). It also is in line with work by Housen at the University of Texas which confirms that results for PE pipe compare favourably with accepted values for smooth pipes for flows with Reynolds' Number exceeding 104.
Roughness may vary within a pipeline for a variety of reasons. However, in water supply pipelines using clean PE pressure pipe these effects are minimised if not eliminated and k can be reliably taken as being equal to 0.003 mm.

Factors which may result in a higher k value include:

- Wear or roughness due to conveyed solids
- Growth of slime or other encrustations on the inside
- Joint irregularities and deflections in line and grade

Note: Significant additional losses can be caused by design or operational faults such as air entrapment, sedimentation, partly closed valves or other artificial restrictions. Every effort should be made to eliminate such problems. It is not recommended that k values be adjusted to compensate, since this may lead to errors of judgement concerning the true hydraulic gradient.

Engineers who wish to adopt higher values of k should take into account some of the above effects in relation to their particular circumstances. The maximum suggested value is 0.015 mm. Table 6 lists the percentage increase in the hydraulic gradient for typical k values above 0.003 mm for various flow velocities.

Percentage increase in Hydraulic Gradient for Values of k Higher than 0.003 mm.

SIZE	FLOW VELOCITY (m/s)	k = 0.006 (mm)	k = 0.015 (mm)
50	0.5	0.6%	2.3%
	1.0	1.0%	3.8%
	2.0	1.6%	6.2%
	4.0	2.7%	9.8%
100	0.5	0.5%	2.0%
	1.0	0.9%	3.3%
	2.0	1.5%	5.5%
	4.0	2.4%	8.8%
200	0.5	0.4%	1.8%
	1.0	0.8%	2.9%
	2.0	1.3%	4.9%
	4.0	2.2%	7.9%
300	0.5	0.4%	1.6%
	1.0	0.7%	2.8%
	2.0	1.2%	4.6%
	4.0	2.0%	7.4%
450	0.5	0.4%	1.5%
	1.0	0.6%	2.5%
	2.0	1.1%	4.3%
	4.0	1.9%	6.9%

Relating Roughness Coefficients

Knowing **k** the equivalent roughness coefficients n and C for the two formulas can be compared as follows:

$$\frac{1}{n} = 5.04\, D^{-1/6} \sqrt{2g}\, \log_{10} \left[\frac{D}{\dfrac{k}{3.7} + \dfrac{2.51\nu}{\sqrt{2gD\dfrac{H}{L}}}} \right]$$

$$C = 5.64\, D^{-0.13} \frac{H}{L}^{-0.04} \sqrt{2g}\, \log \left[\frac{D}{\dfrac{k}{3.7} + \dfrac{2.51\nu}{\sqrt{2gD\dfrac{H}{L}}}} \right]$$

EQUIVALENT ROUGHNESS COEFFICIENTS

ID (m)	k (m)	v (m2/s)	H/L (mm)	n	C
0.20	0.003×10^{-3}	1×10^{-6}	0.01	0.0082	154
	0.015×10^{-3}	1×10^{-6}	0.01	0.0084	154
0.45	0.003×10^{-3}	1×10^{-6}	0.01	0.0084	156
	0.015×10^{-3}	1×10^{-6}	0.01	0.0086	152

AIR VALVES

All water contains dissolved air. Normally this would be about 2% but it can vary largely depending on temperature and pressure. Air trapped in the line in pockets is continually moving in and out of solution.

Air in the line not only reduces the flow by causing a restriction but amplifies the effects of pressure surges. Air valves should be placed in the line at sufficient intervals so that air can be evacuated, or, if the line is drained, air can enter the line.

Air valves should be placed along the pipe line at all high points or significant changes in grade. On long rising grades or flat runs where there are no significant high points or grade changes, air valves should be placed at least every 500-1,000 metres at the engineer's discretion.

Recommended Air Valve Size

Size	Air Valve Size
Up to 100	25 single
100-200	50 double
200-450	80 double

HEAD LOSS DUE TO FRICTION IN PIPE

$$H = f\,\frac{Lv^2}{D2g}$$

Where

f = Darcy friction factor
H = head loss due to friction (m)
D = pipe internal diameter (m)
L = pipe length (metres)
v = flow velocity (m/s)
g = gravitational acceleration (9.8 m/s^2)
R = Reynolds Number

This is valid for the laminar flow region. However, as most pipes are likely to operate in the transition zone between smooth and full turbulence, the transition function developed by Colebrook-White is necessary to establish the relationship between f and R.

$$\frac{1}{\sqrt{f}} = -2\,\mathrm{Log}_{10} \left[\frac{K}{3.7D} + \frac{2.51}{R\sqrt{f}} \right]$$

Where

K = Colebrook-White roughness coefficient (m)

For ease of reference, typical design flow charts in this manual based upon k = 0.003mm are reproduced.

HEAD LOSS THROUGH FITTINGS

The frictional losses occasioned by flow through valves and fittings are approximately proportional to the square of the liquid velocity,

$$H = \frac{Kv^2}{2g}$$

where
H = loss of head m
v = liquid velocity m/s
g = acceleration due to gravity m/s^2
K = coefficient dependent on type of fitting

Perhaps a more convenient way of allowing for the frictional resistance of valves, fittings, obstruction, etc is to consider an equivalent straight length of pipe which would create the same frictional resistance.

Actual headloss characteristics for a range of service pipe sizes and appropriate fittings to determine overall headloss for PE pipes service installations.
The effect of the frictional resistance created by the internal beads in butt welded joints is hardly significant in normal distribution installations in smaller diameters or where the joints are frequent (e.g. for a joint once every 2 metres, an increase in the frictional resistance of about 2% should be allowed).

For practical purposes, designers of water mains for normal housing layouts may consider alternative methods to take account of all secondary and minor losses for small and medium sized developments.

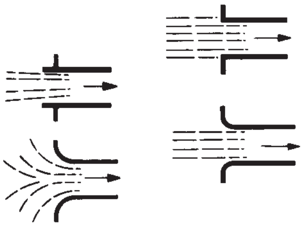
Average Headloss in Fittings and Components

	Table Fitting/Component	Size mm/"	Headloss (m) at flow rates of:				
			L/m 10	25	35	100	160
			L/s 0.16	0.42	0.58	1.66	2.66
1	Ferrule connection	20	0.1	0.9	2.0		
		25	0.1	0.7	1.5		
		32		0.2	0.4		
		63				0.5	1.5
2	Stop valves	20	0.6	3.7	9.5		
		25	0.2	1.2	1.9		
		32		0.4	0.7		
		50		0.1	0.2	0.9	2.2
		63			0.1	0.4	0.8
3	Boundary boxes	20	0.8	4.5	10.0		
	(with meter)	25	0.7	3.2	6.1		
	Boundary boxes	25	0.5	1.9	3.4		
	(without meter)						
4	Double check valves	20	1.8	4.0	6.0		
		25	1.2	2.0	2.7		
		32		1.3	1.8		
		50				2.5	
		63				0.4	0.9
5	Adaptors	20	0.4	0.5			
		25		0.1	0.1		
		32			0.1		
6	Elbows	20	0.3	1.3	2.4		
		25	0.1	0.2	0.4		
		32		0.1	0.2		
		50				0.2	
		63					0.1
7	Tees (on branch)	20	0.2	1.0			
		25		0.3	0.6		
		32		0.1	0.2		
		50				0.3	
		63					0.2

Design

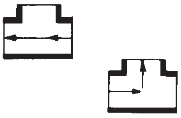
RESISTANCE COEFFICIENTS FOR VALVES, FITTINGS AND CHANGES IN PIPE CROSS-SECTION.

TYPE OF FITTING		K
PIPE ENTRY LOSSES		
Square Inlet		0.50
Re-entrant Inlet		0.80
Slightly rounded Inlet		0.25
Bellmouth Inlet		0.05

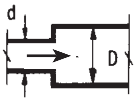


TYPE OF FITTING		K
PIPE INTERMEDIATE LOSSES		
Elbows: R/D < 0.6	45°	0.35
e.g. uPVC	90°	1.10
Long Radius Bends	11Qr °	0.05
(R/D>2)	22 Qw °	
0.10		
	45°	0.20
	90°	0.50

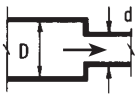
TYPE OF FITTING	K
TEES	
(a) Flow in line	0.35
(b) Line to branch flow	1.00



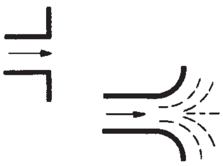
SUDDEN ENLARGEMENTS Ratio d/D	K
0.9	0.04
0.8	0.13
0.7	0.26
0.6	0.41
0.5	0.56
0.4	0.71
0.3	0.83
0.2	0.92
<0.2	1.00



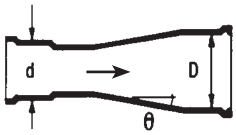
SUDDEN CONTRACTIONS Ratio d/D	K
0.9	0.10
0.8	0.18
0.7	0.26
0.6	0.32
0.5	0.38
0.4	0.42
0.3	0.46
0.2	0.48
<0.2	0.50



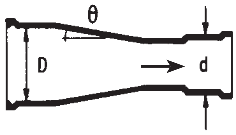
PIPE EXIT LOSSES	K
Square Outlet	1.00
Rounded Outlet	1.00



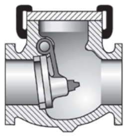
TYPE OF FITTING	K
GRADUAL ENLARGEMENTS	
Ratio d/D q = 10° typical	
0.9	0.02
0.7	0.13
0.5	0.29
0.3	0.42

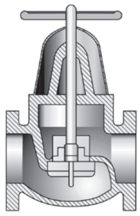


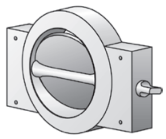
GRADUAL CONTRACTIONS	K
Ratio d/D q = 10° typical	
0.9	0.03
0.7	0.08
0.5	0.12
0.3	0.14

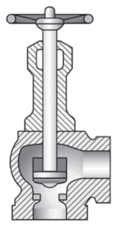


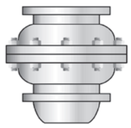
VALVES	K
Gate Valve (fully open)	0.20
Reflux Valve	2.50
Globe Valve	.0.00
Butterfly Valve (fully open)	0.20
Angle Valve	5.00
Foot Valve with strainer	
hinged disc valve	15.00
unhinged (poppet) disc valve	10.00
Air Valves	zero
Ball Valve	0.10

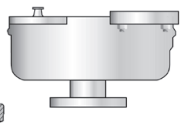


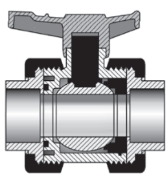












NEGATIVE PRESSURE EFFECTS

The buckling performance limit may govern the design of a flexible pipe under conditions of internal vacuum or underwater installations.
Reduced pressures can be generated in pumped mains due to sudden change in system operation. In some instances these transients can generate sub-atmospheric pressures in the pipeline. The magnitude of negative pressure conditions is limited by the vapour pressure of the fluid conveyed. For water at 20°C the vapour pressure is 2.34 kPa. As atmospheric pressure is nominally 101.3 kPa, full negative head can not exceed 99 kPa or 10 metres head. In practise, negative head is only a transient phenomenon and is also mitigated by leakage past valves and control devices.

INSTALLATION

- Design Consideration
- Loads on Pipes
- External Loading
- Deflection
- Trench Installation
- Thrust Support
- Trenched Pipelines on Steep Slopes
- Pipeline Buoyancy
- Pipeline Detection
- Bends & Bending
- Concrete Encasement
- Above Ground Installation
- Installation Considerations
- Pneumatic Design
- Trenchless Installation

DESIGN CONSIDERATION

1. Where PE Pressure Pipes are selected the designer must consider:
- the use of straight or coiled pipes
- the jointing method
- rehabilitation
- burial method – directional drilling
  – narrow trench
  – mole ploughing
  – impact moling

2. PE Pressure pipes are available either in coils or straight lengths depending upon pipe size and material selected.
   Straight pipes are usually produced in 12m lengths or to suit specific applications and MDPE coils and drums are currently available in sizes up to 160mm.

3. Trenchless techniques such as directional drilling and impact moling are specifically designed for PE systems and significantly reduce reinstatement cost. Open trench pipelines must allow for the jointing, cooling and snaking of the pipe. When using 'normal' trench widths, this can mean greater inconvenience to traffic but allows flexibility to overcome unforeseen obstructions and also ensures the ability to bed and surround the pipe properly. Narrow trenching with PE has the considerable advantages of reduced reinstatement costs and less spoil to handle. Not all subsoils are conducive to such a technique and proper laying, bedding and compaction is not always possible at the required depths of cover.

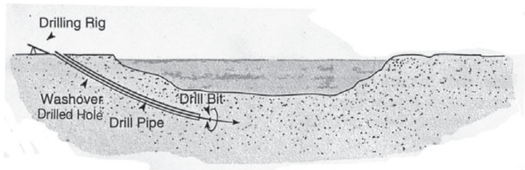
4. The flexibility of PE allows the accurate alignment of the pipeline to awkwardly contoured kerb races on housing sites. The reinstatement or replacement of pipes in established areas will minimise disruption for major cost advantages.

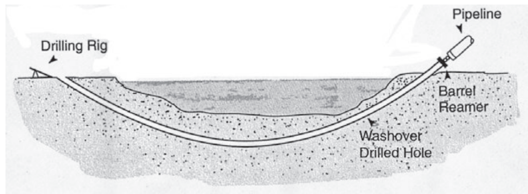
INSTALLATION

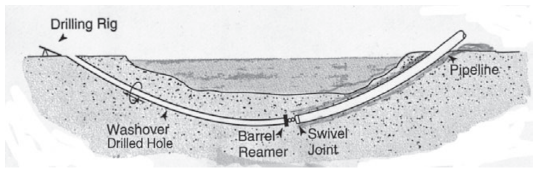
Before installation, each pipe and fitting should be inspected to see that its bore is free from foreign matter and that its outside surface has no large scores or any other damage.
Pipes of the required diameter and pressure rating should be identified and matched with their respective fittings and placed ready for installation.

Installation Techniques for Buried Pipe

Directional Drilling
The major advantage is that PE is either a continuous coil or can be butt welded into a continuous pipe string, enabling the pipe to be directional drilled. The technique was developed for the oil and gas wells. It is now increasingly important and used to limit reinstatement work in developed city and business areas, under motorways, traffic intersections, roads, rivers or other objects which can be drilled under without disturbance.
It basically involves drilling a hole, whereby the drill bit is steered by the driller using information supplied by hand held locators on the surface above the drill head. The hole is then back cut using a barrel reamer and a washover pipe or the PE pipe which is attached with a swivel to the barrel reamer to pull back the pipe. A variety of special cutting and slip fluids are used as the cut rate, the soil type and the depth need to be assessed by the driller as the removed material has to flow from the drill or relief holes. Significant pressure is created at the drill head so the appropriate SDR pipe needs to the selected to avoid the pipe being crushed or the ground disturbed.

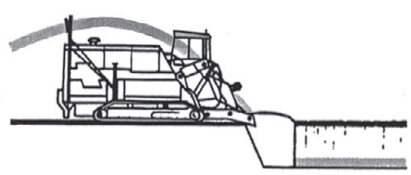






Trenching/Narrow/Chain
With the PE pipe string jointed above the ground the need to trench joint is eliminated and the width of the excavation can be minimised thus reducing labour, the amount of backfill required and reinstatement costs.

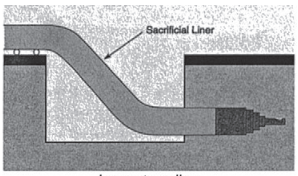
Moleploughing
Developed for laying land drainage and adapted to installation of gas and water pipes in rural areas. It enables pipe to be laid across rural landscapes with minimal disruption to the land use and the ground is reinstated virtually in prime condition.



Tabulations of the value of E´ for various combinations

Impact Moling

Moling is suitable where a pit can be dug at both the beginning and the end of the pipe line to accommodate the drilling equipment. A bore hole is launched between the two pits, leaving the ground undisturbed. A sacrificial liner is attached to the mole and the PE pipe is inserted in the liner.



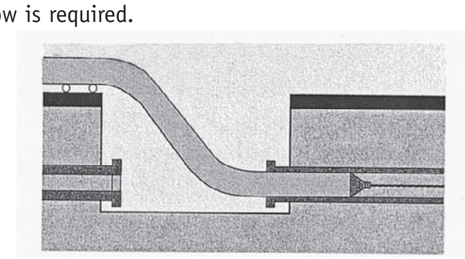
TRENCHLESS INSTALLATION

Rehabilitation

Sliplining

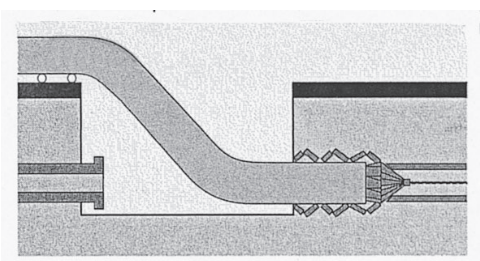
In slip lining a replacement PE pipe string of a smaller size is inserted into an existing decommissioned pipeline. Pressure grouting can enable the existing pipe to be rehabilitated structurally while reinforcing the pressure rating of the new line.

Some reduction of flow capacity is inevitable. This can be minimised with careful preparation and cleaning of the old pipeline. The average annular clearance can be approximately 5%. In pressure the reduction in capacity can often be overcome with increased pressure in the new line, or in gravity the exclusion of ground water entering the line if a significant reduction in flow is required.



Pipe Bursting

Size for size replacement, or upsizing of existing cast iron pipelines can be achieved with significant savings by the pipe bursting method. With this method an existing main is burst and the bore hole is simultaneously expanded by a mole. Modern pipe bursting mole with hydraulic expanders can crack open unserviceable pipelines even with repair collars or concrete surrounds.



LOADS ON PIPES

Soil and Traffic Loads

Loads are exerted on buried pipe due to:

- Soil pressures
- Superimposed loads
- Traffic loads

For normal water supply systems, the minimum depths of burial (cover) stipulated in AS/NZ 2033 should be observed. Under these conditions and up to a maximum of 3 metres cover, soil and traffic loadings are of little significance and design calculations are not necessary. This applies to all classes of pipe.

For depths shallower than those recommended, traffic loading may be of significance.

At greater depths, soil loadings may control selection of pipe class. In these instances, lighter pipe classes may not be suitable and specific design calculations and/or special construction techniques may be required. Wet trench conditions may also require further investigation.

For design purposes, AS/NZS 2566 Plastics Pipelaying Design sets out procedures to be adopted.

Special construction techniques can involve backfill stabilisation, load bearing overlay or slab protection.

It should be noted that cover of less than 1.5 diameters may result in flotation of empty pipes under wet conditions. Low covers may also result in pipe "jacking" (lifting at vertically deflected joints) when pressurised.

Bending Loads

Under bending stress PE Pressure pipes will bend rather than break. However, the following precautions are very important.

1. In below ground installations, the pipes must have uniform, stable support.
2. In above ground installations, proper, correctly spaced supports must be provided.
3. In above ground installations, pumps, valves and other heavy appendages must be supported independently.

External Pressure

All flexible pipe materials can be subject to buckling due to external pressure and PE pipes behave in a similar fashion to PVC and steel pipes.

For a uniform section pipe the critical buckling pressure Pc can be calculated as follows:

$$Pc = \frac{2380\ E}{(SDR - 1)^3}$$

Where

E = modulus of elasticity (Gpa)

Where pipes are buried and supported by backfill soil the additional support may be calculated from:

$$P_b = 1.15(P_c E`)^{0.5}$$

Where

E` = soil modulus from AS2566-Plastic Pipelaying Design.

of soil types and compactions are contained in AS/NZS2566.
The development of any restraint from the surrounding soil is governed by the depth of installation and for installations less than 3 pipe diameters deep, the effect should be disregarded.
The value of Pc calculated requires a factor of safety to be applied and a factor of 1.5 may be applied for those conditions where the negative pressure conditions can be accurately assessed.
Where soil support is taken into account then a factor of 3 is more appropriate.
In general terms PN9 pipe should be used as a minimum for pump suction lines or when negative pressure will be generated due to the gradient the pipe is laid to.
Where the individual installation conditions result in negative pressure conditions that are not present in operation, then regard must be paid to construction techniques. For example pipes may need to be filled with water during concrete encasement when being used as vertical or horizontal ducting.
In operation, fluid may be removed from the pipeline faster than it is supplied from the source. This can arise from valve operation, draining of the line or rupture of the line in service. Air valves must be provided at high points in the line and downstream from control valves to allow the entry of air into the line and prevent the creation of vacuum conditions. Generally, in long pipelines air valves should be provided each 250 metres along the line.

EXTERNAL LOADING

AS/NZS2566 – Plastics Pipelaying Design provides a methodology of calculating these loads operating on buried pipes under various installation conditions.
The basis of the AS/NZ2566.1 and 2566.2 is that developed by Marston in the USA and for each of the load sources listed in "Loads on Pipes" section 1,2 and 3 is as follows:

4) Earth Loads

Trench

a) Embankment
b) $W = C_e wD2$

1) Imposed Loads

Uniformly distributed load

2) Trench
$W = C_u BU$

3) Embankment
The load U is expressed as an equivalent height of fill and added to the embankment height.

$$h = \frac{U}{w}$$

4) Traffic Loads

$$W = Cp \frac{M\alpha}{I}$$

The symbols expressed in these formulate for evaluating the loads acting on the pipes are contained in AS/NZ2566 and are as follows:

W = load on pipe (kN/m)
C = load coefficient
Ω = impact factor
l = length of pipe over which concentrated load acts (m)
M = concentrated load (kN)
D = mean pipe outside diameter (m)
B = trench width (m)
U = uniformity distributed load (kPa)
w = density of fill (t/m^3)

DEFLECTION

Flexible pipes resist external loading by a combination of ring stiffness of the pipe and the soil support developed as a result of deflection of the pipe under loading.
This deflection invokes passive support and provides the major portion of the total installed pipe strength.
The amount of passive support is determined by the type of soil and the amount of compaction in the soil at the side of the pipe.
The determination of this support is contained in the various sections of AS/NZS2566 and is specific to each installation.
For flexible pipes the maximum load bearing capacity is determined by the deflection of the pipe from the original diameter.
Traditionally, in New Zealand the maximum allowable deflection has been 5% of the pipe outside the diameter and this value has been adopted AS/NZS2566. This value originally related to the limit applied to cement lined steel pipe as being the limit before the lining cracked and failed under loading.
In the case of homogeneous flexible pipes this limit has no engineering basis and may be exceeded without structural damage.
The actual maximum design value adopted may be selected by the designer taking into account the particular requirements of the installation, such as the need to pass mechanical cleaning equipment down the bore of the pipe.
For the pipe deflected at 5% of the outside diameter the hydraulic capacity of the pipe is 99.9% of the capacity of the same pipe as a perfect circle.
The calculation of the deflection of the pipe caused by the external loading is performed in AS/NZS2566 using the approach developed by Spangler in the USA at Iowa State College. A computer program is available to accurately calculate maximum depth for pipe installations and soil loads on pipe.
The major support in the installed pipeline is derived from the supporting soil and the attention of the designer is drawn to modifying the type of standard compaction as the preferred method of increasing the load resistance of the pipeline.

The standard levels of compaction contained in AS/NZS2566 and the intended usage areas are as follows:

a) Type 1
The highest level of compaction as used in highway and road pavements and requires mechanical compaction techniques.

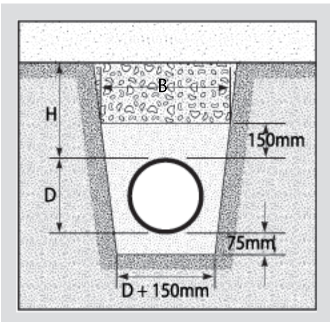
b) Type 2
The level of compaction attained by thorough hand tamping methods normally used in trench and embankment conditions for sewer and drain applications.

c) Type 3
The level of compaction attained where the sidefill is not compacted and side support arises from natural soil consolidation. Normally used in stormwater and pressure pipe applications where no additional external loads are encountered.

TRENCH INSTALLATION

Preparing the Trench

PE pipe can be damaged or deformed if the bed support is not made as uniform as possible. The trench bottom should be compacted and examined for irregularities and any hard projections removed.
The minimum trench width should allow for adequate tamping of side support material and should be not less than 150mm greater than the diameter of the pipe. In very small diameter pipes this may be reduced to a trench width of twice the pipe diameter.



The maximum trench width should be as restricted as possible depending on the soil conditions. This is necessary for both economics and to develop side support.
Where wide trenches or embankments are encountered then the pipe should be installed on a 75mm layer of tamped or compacted bedding material as shown on the cross section diagrams. Where possible a sub trench should be constructed at the base of the main trench to reduce the soil loads developed.
AS/NZS2566 provides full details for evaluating the loads developed under wide trench conditions.

Recommended Trench Widths

SIZE DN	MINIMUM (mm)	MAXIMUM (mm)
100	320	800
125	340	825
150	360	825
175	400	875
200	425	900
225	450	925
300	515	1000
375	600	1200

The width of trenches used with PE pipe may be reduced by jointing above ground in the case of butt or electrofusion welding and then feeding the jointed pipe into the trench.Similarly, small diameter pipe in coil form can be welded or mechanically jointed above ground and then fed into the trench.

Trench Depths

The recommended minimum trench depth is determined by the loads imposed on the pipe such as the mass of backfill material, the anticipated traffic loads and any other superimposed loads. The depth of the trench should be sufficient to prevent damage to the pipe when the anticipated loads are imposed upon it.

Minimum Cover for Trenches

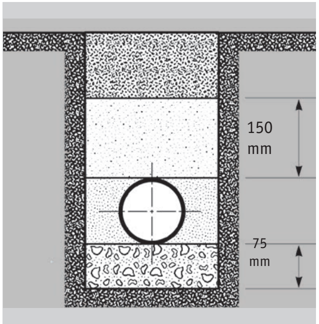
Trenches should be excavated to allow for the specified depth of bedding, the pipe diameter and the minimum recommend cover and overlay plus backfill above the pipes. Table below provides recommendations for minimum cover to pipe crown.

Minimum Cover

Loading	Cover (mm)
Roads and streets	750
Driveways and similar areas subject to traffic	600
Footpaths, gardens	500
Construction traffic	750

The above cover requirements will provide adequate protection for all pipes. Where it is necessary to use lower covers, several options are available.

- Provide additional structural load bearing bridging over the trench. Temporary steel plates may be used in the case of construction loads.
- Use a high quality granular backfill e.g. crushed gravel or road base.
- Use a higher class of pipe than required for normal pressure or other considerations.



Bedding Material

Preferred bedding materials are listed in AS/NZ2655.1 and are as follows:

a) Suitable sand, free from rock or other hard or sharp objects that would be retained on a 13.2 mm sieve.

b) Crushed rock or gravel evenly graded up to a maximum size of 20 mm.

c) The excavated material may provide a suitable pipe underlay if it is free from rock or hard matter and broken up so that it contains no soil lumps having any dimension greater than 40 mm which would prevent adequate compaction of the bedding.

The suitability of a material depends on its compactability. Granular materials (gravel or sand) containing little or no fines, or specification graded materials, requiring little or no compaction, are preferred.

Clays and sands containing fines are difficult to compact and should only be used where it can be demonstrated that appropriate compaction can be achieved.

Pipe Side Support

Material selected for pipe side support should be adequately tamped in layers of not more than 75mm for pipes up to 250mm diameter and 150mm for pipes of diameters 300mm and above. Care should be taken not to damage the exposed pipe. Tamp evenly on either side of the pipe to prevent pipe distortion and not to disturb the line or grade.
Side support and pipe overlay material used should be identical with the pipe bedding material.

Backfill

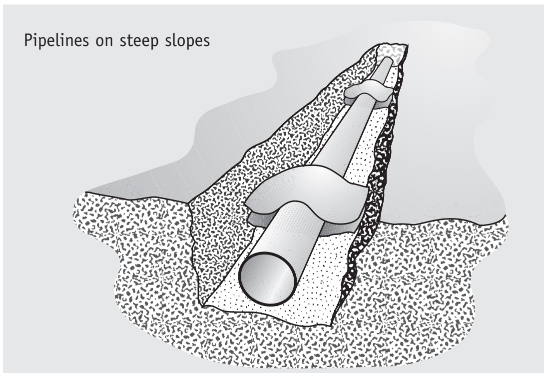
Unless otherwise specified, excavated material from the site should constitute the back fill.
Gravel and sand can be compacted by vibratory methods and clays by tamping. This is best achieved when the soils are wet.
When flooding the trench, care should be taken not to float the pipe.
All ground should be compacted back to 91-95%.The loads arise from two sources; the static or pressure force and the kinetic or velocity force.

THRUST SUPPORT

A major advantage of PE is that the length of pipe can be butt or electrofusion jointed to form a continuous string of pipe and there is normally no need for thrust blocks.
It is advisable to ensure that soil support or bracketing will sustain pipe movement due to thrust loads.
Valves and pumping equipment should be appropriately mounted to sustain thrust loads. This, together with the material's inherent flexibility, makes polyethylene suited to a wide range of pressure and nonpressure application and innovative installation techniques.

TRENCHED PIPELINES ON STEEP SLOPES

When pipes are trenched on steep slopes, i.e. slopes steeper than 20% (1:5), trenched backfill around the pipe may be scoured out by water movement. Clay stops or sandbags should be placed at appropriate intervals above and below the pipe to stop erosion of the backfill.
Directional drilling is recommended on steep slopes to maintain environment.



PIPELINE BUOYANCY

Pipe under wet conditions can become buoyant in the trench. Marley pipes should be covered with sufficient overlay and backfill material to prevent inadvertent flotation and movement. A depth of cover over the pipe of 1.5 times the diameter is usually adequate.

PIPELINE DETECTION

Marley pipes are electrically non-conductive and cannot be detected by metallic detection devices in underground installations.
Several techniques are available to detect buried pipelines.

Metal Detector Tapes

Foil based tapes may be located in the trench on top of the pipe overlay material (150-300mm above the pipe crown). These tapes can be detected at depths up to 600mm by metal detection equipment operating in the 4-20MHz frequency range.
The tape backs may also be colour coded and printed in order to provide early warning of the presence of the pipeline during later excavation.

Tracer Wires

Pipes installed deeper than 600mm may be detected by the use of tracer wires placed on, or taped to,the top of the pipes.
Application of a suppressed current allows the detection of pipes up to a depth of three metres. However, both ends of the tracer wire must be accessible, and a complete electrical circuit present over the entire length of the pipeline.

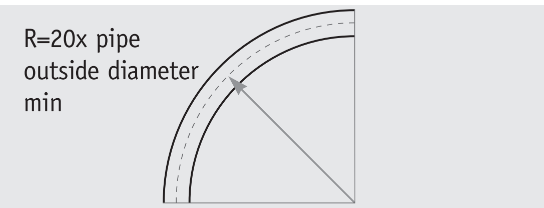
Audio Detection

Acoustic, ultrasonic or Ground Penetrating Radar noise detection devices are available which use either the noise from water flowing in the pipes, or an introduced noise signal, to detect the presence of buried pipelines.

BENDS AND BENDING

Bending MDPE Pipes

1. The bending of PE pipe is permissible and the properties of fusion jointed systems enable changes of direction without recourse to the provision of special bends or anchor blocks. SDR11 and 17 PE pipe can normally be cold bent to a radius 20 times the outside diameter of the pipe, increasing to 30 in very cold conditions. For SDR26 these values need to be increased by 50%. No joints or tappings should occur on the bend.
2. A full range of standard preformed bends are available



and are preferable for the larger sizes. Special configurations are similarly available upon request.

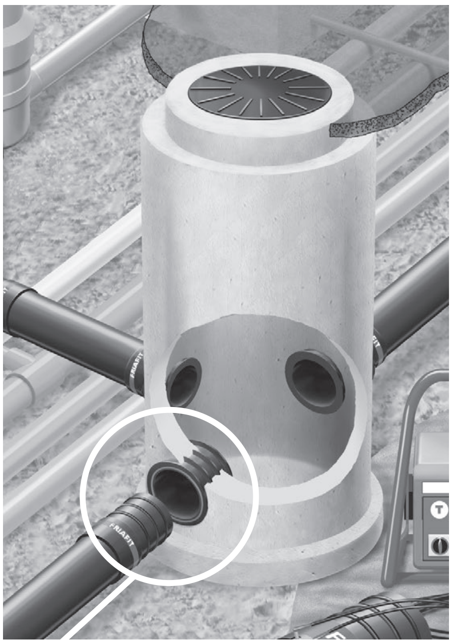
CONCRETE ENCASEMENT

Pipe Entry Into Structures

1. Wherever pipework meets or passes through rigid structures, careful consideration should be given to:

- the need to effect a watertight seal at the pipe/structure interface;
- the extent to which the structure itself is required to withstand forces transmitted from the pipe;
- where there is rigid connection between pipe and structure, whether the adaptation of standard fittings influence the degree to which compressive, tensile, bending and shear forces are generated;
- where differential settlement may occur, the extent to which the pipe and fittings flexibility can normally be relied upon to withstand the bending and shear stresses set up.
- an annular space of not less than 6mm should be left around the pipe or fitting. This clearance should be maintained and sealed with a flexible sealant such as loosely packed felt, a rubber convolute sleeve or other suitable flexible sealing material.
- if the pipeline has to pass through a fire rated wall, advice on suitable fire stop methods is available from our Product Manager.

2. Where pipe is to be connected to a large rigid structure, movement and bending will occur and can be accommodated by using a Friafit manhole connector.



Friafit manhole connector

ABOVE GROUND INSTALLATION

Pipes may be stored above ground for pressure and non pressure applications in both direct sunlight and protected conditions.

Black PE pipes made to AS/NZS 4130 requirements may be used in direct sunlight sunlight conditions without any additional protection. However, special attention is required to the pipe ends before welding. Where PE pipes of colours other than black are used in exposed conditions, then the pipes may need to be protected from sunlight. Localised temperature build up conditions such as proximity to steam lines, radiators or exhaust stacks must be avoided unless the pipes are suitably protected. Where lagging materials are used, these must be suitable for external exposure applications.
For above ground pipework anchoring and support is essential.

Support Spacing

The spacing of supports for a PE pipeline depends on factors such as the diameter of the pipe, the density of the fluid being conveyed and the maximum temperature likely to be reached by the pipe material.
Table below, shows the support spacing in metres for PE pipe carrying water at 20°C. These spacings do not allow for additional extraneous loading.

Recommended Support Spacing
for MDPE pipes

Nominal Pipe OD (mm)	Maximum Recommended Spacing (m)
16	0.25
20	0.30
25	0.35
32	0.38
40	0.43
50	0.45
63	0.50
75	0.60
90	0.67
125	0.75
140	0.85
160	1.00
200	1.10
225	1.15
250	1.25
280	1.30
355	1.50

If temperatures are in excess of 20°C the horizontal spacing should be reduced by 25% for every 10°C. At 60°C , continuous horizontal support is required.

Vertical Installation

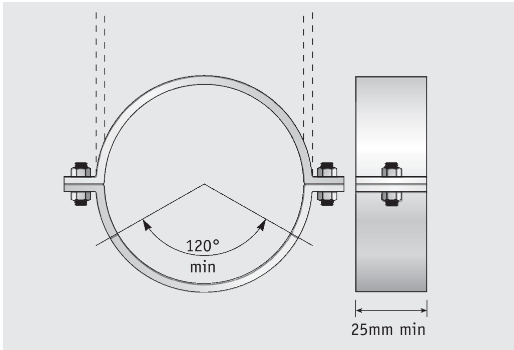
Generally, vertical runs are supported by spring hangers and guided with rings or long U-bolts which restrict movement of the rise to one plane. It is sometimes helpful to support a long riser with a saddle at the bottom.

Brackets and Clips

For either free or fixed pipelines supports using brackets or clips, the bearing surface should provide continuous support for at least 120° of the circumference.

Straps

Metal straps used as supports should be at least 25mm wide, preferably plastic coated with no sharp edges or burrs. If a strap is fastened around a pipe, it should not distort the pipe in any way.



Location and type of support must take into account provision for thermal movement, if required. If the supports are to resist thermal movement, an assessment of the stress induced in pipes, fittings and supports may need to be made.

Free Support

A free support allows the pipe to move without restraint along its axis while still being supported. Prevent the support from scuffing or damaging the pipe as it expands and contracts. Lag with a layer of PE pipe material or Marley Hippolon sheet.

Fixed Support

A fixed support rigidly connects the pipeline to a structure totally restricting movement in a least two planes of direction. Such a support can be used to absorb moments and thrusts.

Placement of Support

Careful consideration should be given to the layout of piping and its support system. Even for non pressure lines the effects of thermal expansion and contraction have to be taken into account. In particular, the layout should ensure that thermal and other movements do not induce significant bending moments at rigid connections to fixed equipment or at bends or tees.

INSTALLATION CONSIDERATIONS

Expansion and Contraction

PE Pipe will expand or contract if it is installed during very hot or very cold weather, so it is recommended that the final pipe connections be made when the temperature of the pipe is stabilized at a temperature close to that of the backfilled trench.
PE lines can be laid directly on the natural surface by snaking the pipe during installation and allowing the pipe to move freely in service. Where the final joint connections are made in high ambient temperature, sufficient pipe length must be allowed to permit the pipe to cool, and hence contract, without pulling out of non end load bearing joints.

Heat sources

Pipes and fittings should be protected from external heat sources which would bring the continuous pipe material service temperature above 60°C.
Where the pipes are installed above ground, the protection system used must be resistant to ultra violet radiation and the effects of weathering. Pipes running across roofing should be supported above the roof sheeting in order to prevent temperature build up.
Due to heat being generated by continuously running pumps under load, the pipe's pressure rating needs to be appropriate.

Vibration

Direct connection to sources of high frequency vibration should be avoided. All fabricated fittings manufactured by cutting and welding techniques must be isolated from vibration.
Where high frequency vibration sources exist in the pipeline, the sections should be connected using a wire reinforced rubber bellows joint.

Conductivity

Marley pipes are non-conductive and cannot be used for electrical earthing purposes or dissipating static electricity charges.
When pipes are used to replace existing metal water pipes, the designer must consider any existing systems used for earthing. In these cases the appropriate electrician must be consulted to determine the requirements.

Fire Rating

Marley PE pipe systems will support combustion and as such are not suitable for use in fire rated zones in buildings without suitable protection.

PNEUMATIC DESIGN

Pneumatic Flow

Marley PE pipe systems are ideal for the transmission of gases both in the high and low pressure range.
The use of compressible fluids in PE pipes requires a number of specific design considerations as distinct from the techniques adopted for fluids such as water.

In particular:

Safety factor for different gases should be considered in any design.

Natural gas 2.0
Compressed air 2.0.

- Compressed air may be at a higher temperature than the ambient air and PE pipes require temperature re-rating accordingly, especially at source.

  For air cooled compressors the air temperature averages 15°C above the surrounding air temperature.

  For water cooled compressors the air temperature averages 10°C above the cooling water temperature.
- For underground applications the surrounding temperature may reach 30°C and the pipe properties require adjustment accordingly.
- High pressure lines must be protected from damage, especially in exposed installations.
- Valve closing speed must be reduced to prevent a build up of pressure waves in the compressible gas flow.
- Where gaseous fuels such as propane, natural gas or mixtures are carried the gas must be dry and free from liquid contamination which may cause stress cracking in the PE pipe walls.
- MDPE pipes should not be connected directly to compressor outlets or air receivers. A 20 metre length of metal pipe should be inserted between the air receiver and the start of the PE pipe to allow for cooling of the compressed air.
- Dry gases and gas/solids mixtures may generate static electrical charges and these must be dissipated to prevent the possibility of explosion.
- Compressed air must be dry and filters installed in the line to prevent stress cracking in the PE pipe.
- The fitting systems used must be pressure compatible with the pipe and where metal couplings and shouldered ends are used, the maximum pressure is limited to 0.6MPa.

Several empirical flow formulae are in widespread use and any of these e.g. Weymouth, Spitzglass or Harris, may be used to calculate the flow of gas through PE pipes.

Compressed Air Formula

It is customary to determine the required inside diameter of the pipe by using formulas such as that shown below. The formulas used are generally for approximation purposes only, surmising that the temperature of the compressed air corresponds roughly to the induction temperature. You will obtain an acceptable approximation through the following equation.

$$di = \sqrt[5]{\frac{450.l.\dfrac{dV^{1.85}}{dt}}{\Delta p.p}}$$

Where

Δp = pressure decrease (bar)
p = working pressure (bar)
V = volumetric flowrate (l/s)
dV/dt = atmosphere (l/s)
l = pipe length (m)
di = inside diameter (mm)

The values are specific to each fluid type and the properties should be available from testing.

JOINTING SYSTEMS

- Electrofusion
- Butt Welding
- Mechanical Joints
- Tapping Systems

ELECTROFUSION

Jointing using electrofusion is simple, quick and efficient. Successful joints can be consistently reproduced after suitable training and effectively following the cleaning, preparation and process procedures.

Preparation

All electrofusion processes must be carried out inside a suitable shelter to prevent dirt and dust contamination of the pipes, couplings and power leads.

The pipes must be aligned so the same centreline height of the coupling clamps and supported evenly support the pipe on both sides of the joint. The pipes should be leveled to prevent any movement or pulling away from the coupling joint during welding, or allowing water or dirt inside the pipe to contaminate the weld zone.
An inbuilt resistor is contained within the terminal pin. The resistor pins are colour coded and require the correct colour coded lead to be connected to the resistor.

Fusion Welding Equipment Preparation, Control Systems

Ensure that the generator is operating correctly and that the power output conforms to the control box requirements. Excessive fluctuations in the power source, outside +10%, -10% from a nominal 240 volt, may cause the control box to shut down using a safety cut out device.
Both the fusion and cooling times are entered manually or entered by a bar code reader into the control box by the operator.
Care needs to be taken to ensure that the pins are compatible with the control box being used.
Position the welding cables so as to prevent their weight from twisting the welding socket during the welding process.

Fusion Welding Pipe Spigot Ends

Successful electrofusion jointing depends upon correct gap alignment between the end of the pipe spigot and the coupling. Pipes which are oval must be rerounded and clamped. Pipes should not be forced into the coupling as this can damage the coupling and misplace the heating element wires.
Where pipe ends have a “toe in”, diameter reduction at the end, or flats from storage this can affect the strength of the joint and lead to peel strength reduction. The spigot ends must be recut square to remove the imperfections.
The pipe ends must be aligned evenly along the centreline of the coupling and pipes, especially coiled pipe, must be held in clamps to prevent movement and stressing during the fusion process.
All jointing surfaces must be clean and free from all contamination.
This includes dirt, dust and oil films. Surfaces must not be handled after cleaning. If the sections are contaminated they must be cleaned with a clean cloth and isopropanol alcohol.
All jointing faces must be dry before being assembled.
Mark the end of the pipe at a distance equal to half the length of the coupling and scrape the outside diameter of the pipe over this distance to remove all oxidation layers on the pipe surface. **This should be in the order of a layer of 0.3mm and removed with a sharp peeling tool.**
All rough edges and swarf from the pipe ends must be removed.

Fusion Welding Fusion Cycle

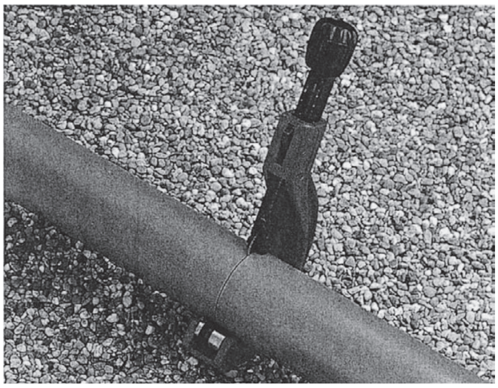
Only the recommended fusion and cooling times recommended by the manufacturer of the fitting must be used. Where any doubt exists that the proper cycle has taken place, the coupling should be cut out of the line and discarded.
No attempt must be made to rerun the fusion cycle as this will lead to overheating of the PE and degradation.
The full cooling times must be allowed. No attempt must be made to accelerate the rate of cooling. See cooling time in Butt welding section before allowing pressure testing.
Large SDR11 PN16 couplings have a preheat which aids gap reduction, to improve welding performance.

Fusion Welding Coupling Storage

Couplings, saddles and electrofusion fittings must be stored in the original containers until actual use. Where fittings are sealed in plastic bags, the bags must not be perforated before the couplings are used.
Saddles may be protected with a cardboard insert wrapped around the heating element and fitted over the terminal posts. These should only be removed immediately prior to use.
Terminals may have a plastic cap fitted over the terminal post and these should be left in place until connecting the control box leads.
Couplings should be stored under cover to prevent any oxidation of the fitting materials in the element zone.
The fusion surfaces must not be handled after they are cleaned and prepared for welding.

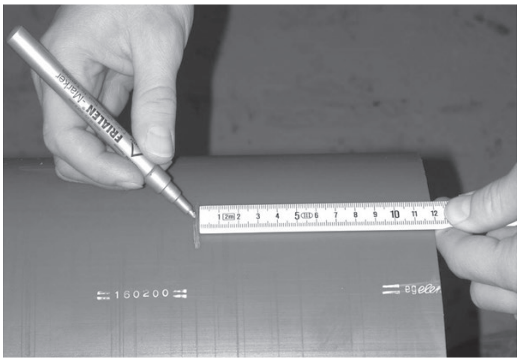
ELECTROFUSION JOINTING PROCEDURES

1. Cut the pipe square and remove burrs.

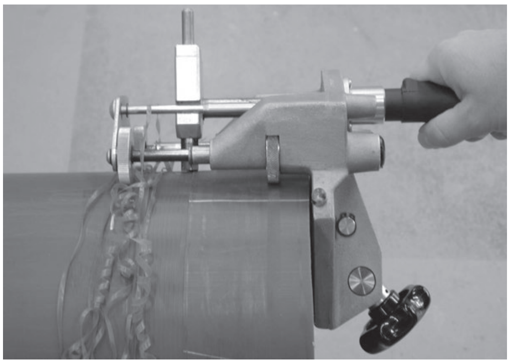


2. Wipe loose dirt from pipe ends and clean pipe surface to be welded with isopropanol.

3. Without removing the protective wrap, place the centre of the electrofusion fitting alongside the pipe end and mark the pipe around the circumference, approximately 15mm beyond the extremity of the socket depth, using a felt tip pen.



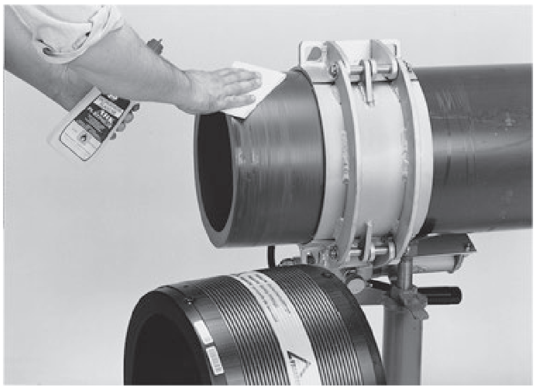
4. Using the pipe end preparation tool, remove the entire surface of the pipe over the marked area, preferably as a continuous ribbon or strip.



Note: The use of mechanical end preparation tools is preferred to hand scraping which is seldom carried out correctly as it requires great care and can be time consuming especially on larger diameter pipes.

It is essential that material is removed by scraping or peeling; scratching or abrading is not sufficient.

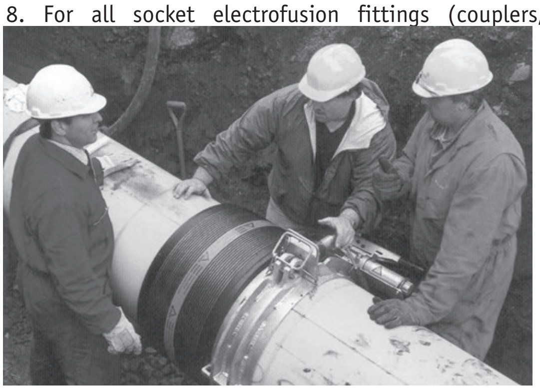
5. Remove the fitting from its packaging and check that the bore of the fitting is clean and dry.



6. Clean the scraped area of the pipe with clean isopropanol wipes.

7. Insert the pipe ends into the fitting so that they are in contact with the centre stop. Check the clearance and pipe ovality and use rerounding tools if necessary.

8. For all socket electrofusion fittings (couplers, reducers, elbows and tees) clamps must be used. The clamps must be adjusted to suit the particular size and type of fitting being welded so the pipes cannot move during the fusion cycle.
If possible, rotate the fitting to check that the pipe ends are correctly aligned.



9. Remove the terminal protection caps from the terminal shrouds.

10. Connect the ECU output leads to the fitting terminals.
Note: It does not matter which lead is connected to each terminal. (The connections are not live and neutral.) Check the correct leads are used.

11. Check that there is sufficient fuel in the generator to complete the joint. Start the generator and check for correct operation. Fumes from the generator should be well clean of the pipe and couplers.

12. Operate the ECU according to the instructions, which should have been thoroughly read and understood prior to any welding operations. The ECU will either have some form of automatic operating system or require manual operation. Whichever system the ECU uses, all fittings are marked with both fusion and cool times in seconds plus the necessary input voltage.

13. If the fitting has melt indicators check that they have risen. The molten material should have risen to a point just above, or just below, the surface of the fitting. (Fittings size 63mm and below do not have melt indicators. Couplers 355mm and 400mm have heat sensitive labels to indicate that sufficient heat has been generated.)

14. The joint must be left in the clamps for the cooling time specified on the fitting, although the terminal leads may be removed carefully without disturbing the joint.
If the fusion cycle terminates before completion of the countdown, check for faults as indicated by the ECU display. Check that there is adequate fuel in the generator. Once the fault has been rectified the welding process can be recommenced, but the timer has to be reset to zero.

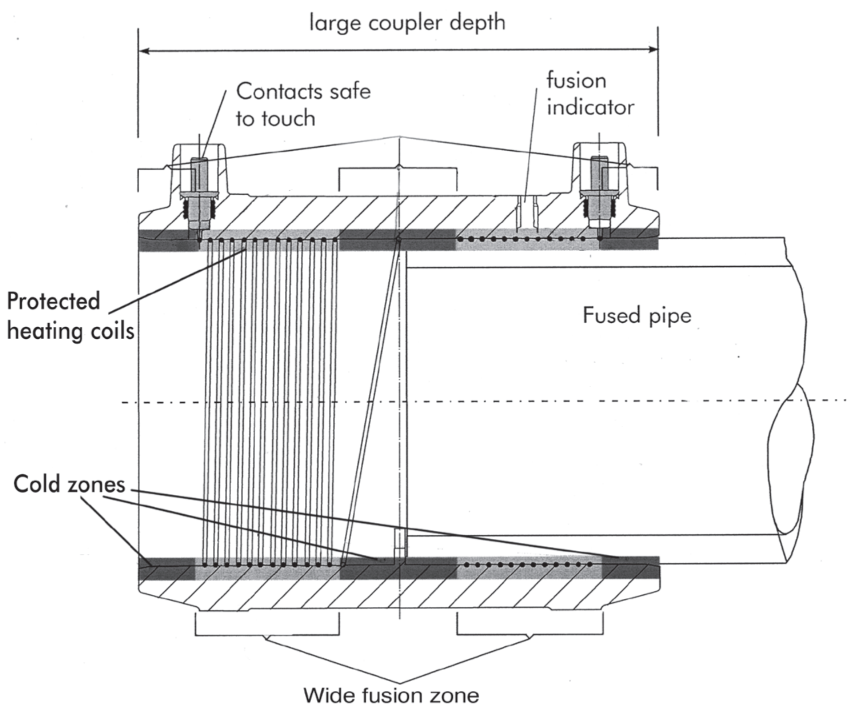
If using a transformed supply, make sure that the supply lead to the ECU is not of excessive length. **NEVER** extend the length of the leads from the ECU to the fitting.
Do not pressurise the system until the joints have cooled to ambient temperatures.

15. Note fusion details on pipe after completing joint.

Electrofusion Jointing of Coiled Pipe

i) Up to 63 diameter.
Clamps must be used which align and restrain the pipes.
ii) Greater than 63mm diameter:
To electrofuse coiled pipe with a diameter greater than 63mm, the pipe must be rerounded.
See the Ancillary Equipment section for details of rerounders.

Electrofusion Coupling Section

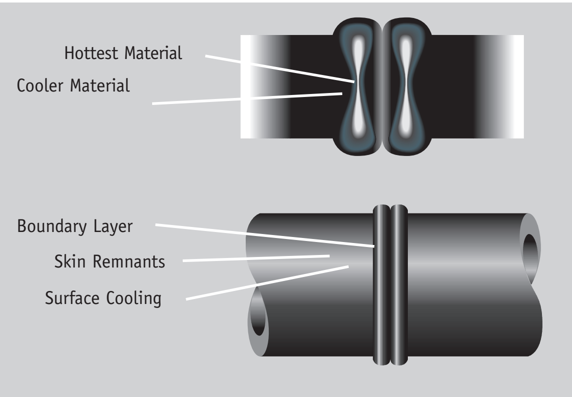


BUTT WELDING

Introduction Thermal Welding

All thermal welding joint systems require the PE materials to be heated and raised well above the crystalline melt temperature of nominally 130°C, creating a melt pool of the PE material, placing that melt pool under steady pressure, and then allowing the PE melt zones to cool down to ambient temperature.
After the heat source is removed, the temperature will drop and as the cooling continues, the crystalline structure of the MDPE will gradually develop. PE is a poor conductor of heat and the internal pipe sections will remain considerably hotter than the outer surfaces. Accelerated cooling of the melt zone must not be attempted in any type of thermally welded joint. This will lead to smaller crystalline structures and decrease impact strength of the joint.

Temperature Distribution Through Pipe Wall At Final Weld Stage



Introduction Butt Welding

Butt welding is normally only used in pipe size from 90mm to 1000mm for jointing pipe and fittings. Butt fusion brings the molten surfaces together under precise temperature pressure and time to provide a homogeneous material which has the same properties as the original pipe. Butt Fusion is a precise operation and must be carried out with equipment which is well maintained and calibrated by qualified staff in an appropriate working environment. Clean, dry working conditions are imperative as is consistency in the procedure and process.

Butt Weld Detail Environment

The working environment is important that the pipe are correctly aligned and that the machinery can accommodate the pipe drag.
The welding equipment needs to be suitably sited so dirt, dust ,water, rain, oil or drafts will not prevent proper weld strength developing.
All welding must be performed under controlled environmental conditions. Field welding must be carried out in shelters to prevent dust and water contamination. Pipe ends must be blocked off to prevent wind chill and dirt contamination.

Butt Weld Detail Heater Plates

The heater plate **surface** temperature should be set at 230°C with an evenly distributed tolerance of **plus/ minus** 10°C.
Temperatures **above** this will lead to possible failure due to thermal degradation.
Temperatures **below** this may be adopted, as it may be necessary to adopt these values for thick wall pipes to prevent overheating, or for PE materials with a high Melt Flow Index.
Only plates in good order should be used and they need to be kept scrupulously clean.

Butt Weld Detail Interface Pressure

The gauge pressure adopted **must have drag pressures added** to any calculated values.

Butt Weld Detail Pipe Alignment

Any misalignment between pipe outside diameter and the ends will reduce the strength of the completed weld. Pipe and fitting must be accurately aligned in the welding machine before the ends are faced. The alignment of the welding machine also needs to be checked after the trimming procedure has been completed.

Misalignment arises from:

- Ovality of pipes
- Eccentric wall thickness around the circumference of the pipe.
- Pipes not being properly aligned in support rollers on either side of the welding machine.
- Pipe spigot end diameter reduction due to in built stresses in the pipes.
- Bent, or misaligned, welding machine frames.

Pipes should be supported on free running rollers on either side of the welding machine and the height and alignment of these rollers should be adjusted to ensure that the pipe centrelines are level with the welding machine.
The alignment should be checked after the pipe ends are trimmed and brought together. The outside diameters should be even around the circumference of the pipes and any offsets adjusted using the adjusting clamps in the welding machine (when fitted).

The **maximum** offsets at the **outside diameter** between abutting pipe ends should not exceed 5 – 10% of the pipe wall thickness when measured at any cross-section.

Butt Welding Procedure

Precise adherence to the procedure, set-up and cleanliness is critical for consistent welding and long-term pipe performance.
The current PIPA (Plastic Industry Pipe Association) procedures are aligned to ISO procedures. These procedures have been confirmed by long-term testing from in-field tests and the resin suppliers.
Welding procedures are detailed at www.pipa.com.au or www.pe100plus.net under ISO Standards.

Butt Weld Welding Times

The times adopted for each section of the weld process must be adhered to and care needs to be taken to recognize the units in seconds or minutes as appropriate.
When the welding process has been completed, the pipe joint **must** be held **under compression** for the full period of the cooling time. The interface pressure can be backed off from the welding pressure, however, the pressure **must** be **above** the drag pressure.
Any attempt to shorten the cooling times will damage the final joint.
Each joint needs to be numbered and the identifiable records as shown in the **pipe weld record** sheets must be completed and signed by the welding operator. A copy of the records should be held by the contractor and an additional copy submitted to the client as part of the Quality Assurance program for each installation.

Weld Parameters: Sample Calculation

Machine Type:	Dixon HF 225
Cylinder Area:	753 mm^2
Pipe Details:	160 PN10 PE80B
	D = 160.0mm
	t = 11.8mm
Weld Procedure:	Single Phase

$$\text{Pipe Area} = \frac{22}{7} \times (160.0 - 11.8)11.8$$

$$= 5496\text{mm}^2$$

Pressure Calculations

(As per PIPA - Industry guidelines for Butt Fusion parameters POP 003/2000)

i) Weld Pressure P1 and P3. (180kPa (0.18 MPa)

$$= \frac{5496}{753} \times 0.18 = 1.31 \text{ MPa + DRAG}$$

ii) Soak Pressure P2 (5 kPa (0.005 MPa)

$$= \frac{549}{753} \times 0.005 = 0.036 \text{ MPa + DRAG}$$

Time Calculations

i) T1 (Until weld bead established)

ii) T2 Heat Soak
= 15 x 11.8 = 177 seconds

iii) T3 Changeover
= (160 x 0.01) + 3 = 4.6 seconds (**maximum**)

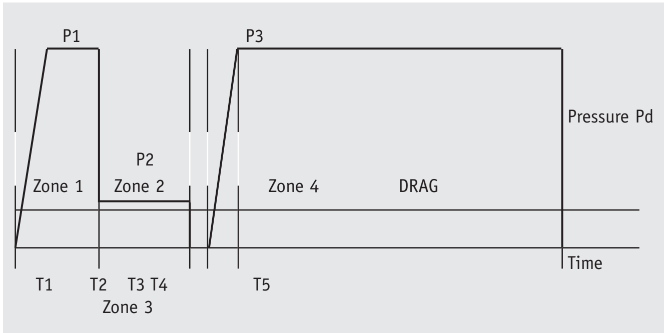
iv) T4 Pressure Rise
= (160 x 0.03) + 3 = 7.8 seconds

v) Weld Time & Cooling Time (t<15mm)
= 10 + (0.5 x 11.8) = 15.9 minutes

Recording for both Butt and Fusion Weld Conditions

The welding conditions actually applied must be recorded for each weld joint made.
Each joint needs to be numbered and the identifiable records as shown in the pipe weld record sheets must be completed and signed by the welding operator. A copy of the records should be held by the contractor and an additional copy submitted to the client as part of the Quality Assurance program for each installation.

Butt Weld Detail Welding Parameters



The **maximum gap** between the **faces** when brought together under slight pressure should be no more than shown in the following table:

Pipe Diameter DN mm	Maximum Gap mm
Up to 225	0.3
280 to 450	0.5
500 to 630	0.6
710 to 900	0.7
1000 and above	1.0

Where finished gaps exceed these values, the pipe ends should be re trimmed, or the pipes rotated in the in the welding machine frame.

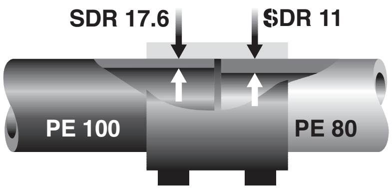
Butt Fusion Parameter		Units	Value
Heater plate temperature		°C	220 ± 15
Pressure value: Bead up	P1	kPa	175 ± 25
Approx. bead width after bead up		mm	0.5 + 0.1t
Bead up time	T1	second	Approx. 6t
Pressure value: Heat soak	P2	kPa	Drag only
Heat soak time	T2	second	15t
Max changeover time	T3	second	3 + 0.01D
Maximum time to achieve welding pressure	T4	second	3 + 0.03D
Pressure value: Welding & Cooling	P3	kPa	175 ± 25
Welding & cooling time: t<15mm	T5	minute	10 + 0.5t
Welding & cooling time: t>15mm	T5	minute	1.5t
Min bead width after cooling		mm	3 + 0.5t
Max bead width after cooling		mm	5 + 0.75t

* Drag Pressure measured for each joint must be added to give the final applied pressure, eg. P = Pi + Pd. P = Pinterface + Pdrag

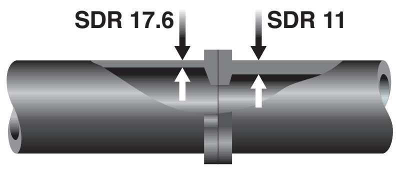
Polyethylene Fusion Jointing Compatibility

CORRECT

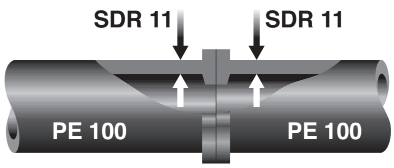
WRONG



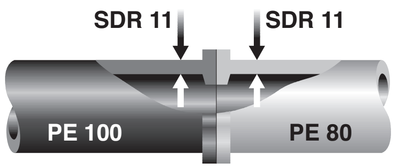
(a) Dissimilar materials and dissimilar wall thicknesses can be jointed by electrofusion coupler



(d) Dissimilar wall thicknesses must not be jointed by butt fusion



(b) Only similar materials and wall thicknesses may be jointed by butt fusion

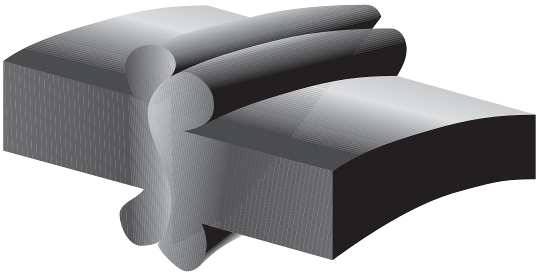


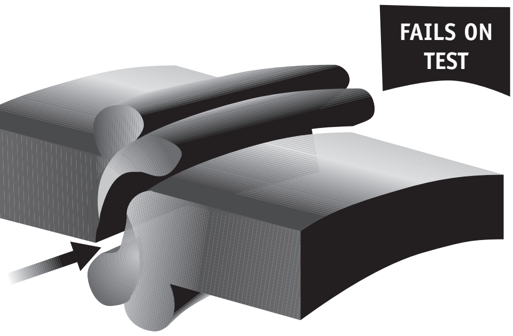
(c) Dissimilar materials may be jointed by butt fusion. However, care is required to ensure a ductile weld is produced.

Jointing Systems

Pipe Misalignment

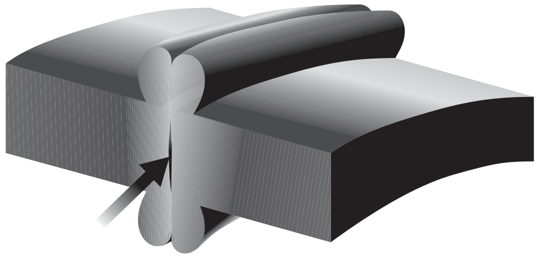
Pipe misalignment

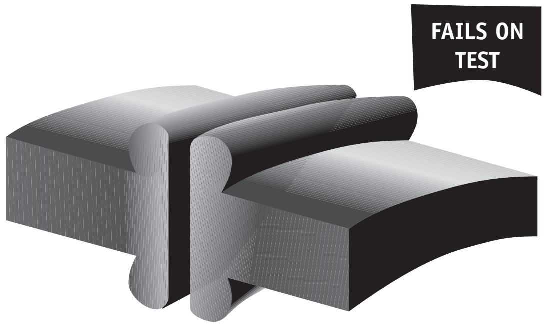




Pipe misalignment, combined with high fusion pressure, creates an excessively sharp weld bead notch. This can cause premature stress crack failure and reduced impact resistance. Bead removal will reveal the offset.

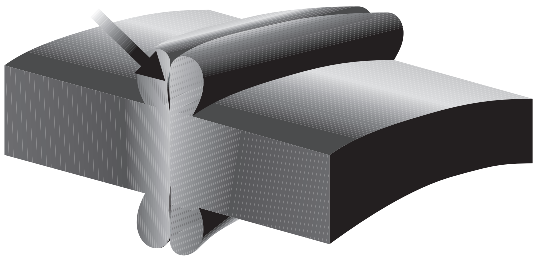
Melt cooling

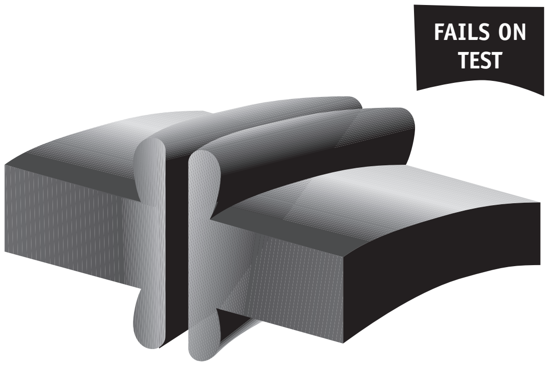




Re-crystallisation of melt surface, due to excess cooling after fusion gives a low bond strength brittle region at the interface. The weld bead interface can be good, but the weld bead may be small. This causes a joint with poor impact strength and brittleness in bending. Stress crack resistance may be adequate.

Interface contamination





In an otherwise well-made joint, contamination (eg. from a dusty hotplate) may be retained at the interface. Butt fusion is **not** fully self-cleaning. Weld bead removal will reveal a slit defect. The weld bead interface is weak. This causes very poor properties in bending or impact when the very sharp slit crack can grow. Pressure tests may fail to detect poor stress crack resistance.

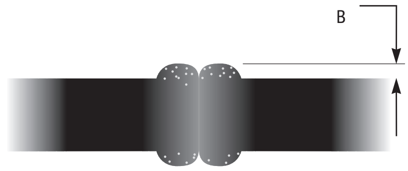
Butt Weld Bead Appearance

The size, shape and surface appearance of the completed weld bead is a good first order guide to the quality of the weld.

The weld beads should be evenly formed around the circumference of the pipe and be evenly sized on both sides of the weld line.

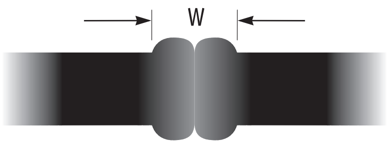
The weld bead must project above the outside diameter of the pipe at all times and be smooth and free from all voids and pitting.

Where pitting or bubbling is observed on the weld bead surfaces, **the welding procedure must be immediately stopped**. This appearance is due to moisture or volatiles being present in the weld face due to moisture in the pipe materials or the heater plate surfaces.



B = 0.5 + 0.1t

As a general guide the minimum set-up bead height should be 1mm with a maximum set-up bead height of 5mm.



MIN W = 3 + 0.5t
MAX W = 5 + 0.75t

a) The weld width should not exceed 40mm for any pipe size.
b) These are general guidelines and the weld bead dimensions may vary with different PE materials.
c) The size and appearance applies to the outside diameter weld bead only, as the residual stress left in the pipe may result in a different shaped internal bead section.

Butt Weld QA Recording

All jointing procedures performed on site must be recorded and identified for each of the numbered joints. The procedures which have been demonstrated as being suitable before field construction should be used. To complete this requirement, pilot welds should be made using the equipment, operators and procedures proposed for use with the particular pipeline system and the resultant joints tested for compliance with the specified requirements.

Butt Weld Testing

There are several methods currently adopted to evaluate the strength of the completed weld.

Current research shows that none of these methods alone will fully evaluate a joint and that they need to be used in combination. The requirements for a joint will depend on the end application of the pipeline.

The strength of a butt weld will be less than that of a plain pipe section due to the interruption of the wall section because of differences in wall thickness, slight misalignment of the diameters and the effect on the pipe material structure due to the welding process.

For pipe to pipe welding with equal wall sections, a minimum weld strength factor of 90% can be assumed (Dedrich and Dempe Kunststoffe 1980).

a) Hydrostatic Pressure Testing

Pressure testing the completed pipeline is routinely adopted to detect leaks at assemblies or joints.

For PE Pressure pipelines, this is commonly performed at a nominal test pressure of 1.5 times the maximum working pressure in the line, for a period of 15 minutes.

A hydrostatic pressure test of 1.5WP will only detect a weld with a strength of **less than 70%**. A pipe tested to the maximum pressure class rating will **pass a weld with a strength of 50%** of the pipe strength.

Welds of these strength levels are regarded as reject.

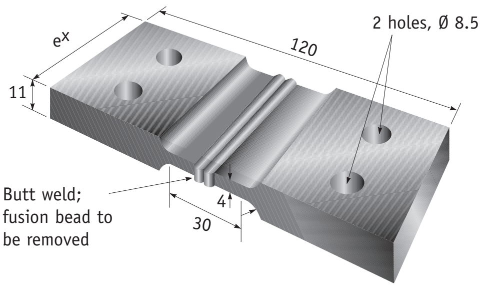
Hydrostatic pressure testing does not adequately evaluate of weld strength.

Minimum Cooling Time Before Applying Pressure Test Minutes

Diameter	Test Pressure Range	
	≤ 0.60 MPa	≤ 2.0 MPa
20 – 63	10	30
75 – 110	20	60
125 – 160	30	75
180 – 225	45	90
250 – 315	60	150

b) Tensile Testing

Tensile test specimens taken along the length of the pipe with the weld zone at the mid point of the specimen have been extensively used as a standard method of test using the standard 'dog bone' specimen shape as detailed in AS1145 – Determination of tensile properties of plastics materials.



Short term tensile testing to ISO 18953 using crosshead speeds around 5mm per minute, are useful to detect low strength welds.

$$\% = \frac{\text{weld strength}}{\text{pipe strength}}$$

c) Tensile Fracture Testing

Any testing needs to concentrate the stress at the weld plane, in order to obtain an understanding of the strength of the weld, and by forcing the stress into the weld plane enables an evaluation of any contamination in the weld material
This enables a comparison to be made with the parent pipe material and a short term weld strength factor as a percentage to be calculated.
Weld specimens should fracture in ductile manner, with yield being evident in the weld zone material. However, once the pipe wall thickness increases beyond a particular level (typically 20mm for PE80B materials) then the samples need special evaluation.

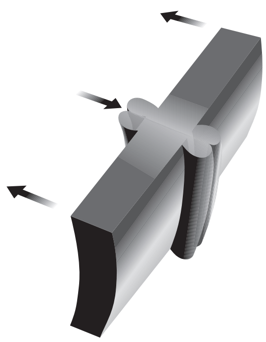
No evidence of contamination, or dislocations should be present on the weld plane fracture surfaces. Any such appearance is sufficient to reject the welds.

d) Long Term Creep Testing

The long term behavior of the weld strength may be evaluated by constant load creep testing at an elevated temperature using an accelerating medium. Typically this means using a tensile specimen immersed in a water/detergent mixture around 5% concentration and applying a static load.
The test proceeds until the specimen fractures and the elapsed time is recorded.

e) Flexural Beam Testing

Welded PE pipelines are subject to flexural stressing during installation when lifted, or lowered into the trench and under these conditions the welded joints are placed in bending with tensile and compression stresses on opposite faces of the pipe wall. Any misalignment of the butting wall sections will increase localised stresses in the weld joint.



MECHANICAL JOINTS

Mechanical jointing utilises compression of elastomeric seals with the pipe being restrained with a gripper ring, locked by a mechanical locking nut wedging onto the pipe. They are available for use with pipe diameters from 20mm to 110mm. The fittings are all demountable. The elastomeric seal ring material requires consideration. The temperature and the environment must be taken into account. Sealing rings supplied are produced in nitrile rubber.

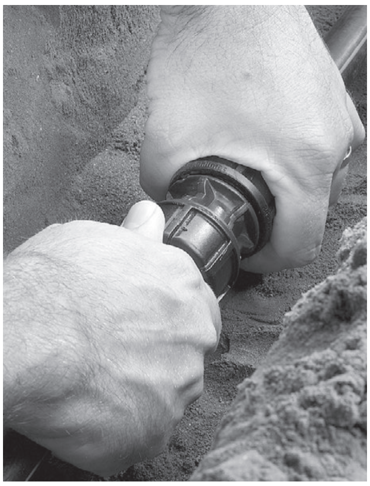
Only tighten by hand, strap wrench or specialised assembly spanner. Serrated teeth spanners or wrenches must not be used.

Philmac 3G Compression Fittings Installation Guide

1. Cut Pipe Square
Cut the pipe square. There is no need to prepare the pipe end. Chamfering or lubrication is not required.

2. Ready to Use Position
The fitting is pre-assembled and ready to use, however always ensure the nut is fully relaxed and 2 threads are showing before inserting the pipe.

3. Pipe Insertion
Insert the pipe until the stop is felt.



4. Nut Tightening
The nut should be tightened by hand and then firmly with a wrench. Tighten the nut all the way to the flange on the body of the fitting.

5. Fully Installed
Fitting is now fully installed.

6. Disassembly
To disassemble the fitting simply loosen the nut using a wrench until 2 threads are showing. Pipe will be released and can simply be pulled out of the fitting.

Note: Philmac recommends the use of PTFE tape on BSP threads to ensure a positive seal.

Universal Transition Fittings Installation Guide

1. Cut pipe to length
Cut pipe square and to length using the flange on the central body as a guide. Ensure end of connecting pipe is undamaged and clean.

2. Ready to use position
The fitting is pre-assembled and ready to use, however always ensure the nut is backed off and 3 threads are showing. Pipes at the top end of the fitting tolerance may require 5 threads showing.

3. Pipe insertion
To ensure adequate insertion depth, witness mark the pipe to the back of the flange. If conditions permit a marker pen can be used or alternatively use of a thumb is suitable. Then insert pipe to the correct depth.

4. Nut Tightening
Tighten nut firmly with a wrench. Nut will not butt against the body flange when the pipe size is at the top end of the fitting tolerance.

5. Fully Installed
The fitting is fully installed when the nut cannot be tightened any further with reasonable force.

* For the PE end of a transition fitting please refer to the Philmac 3G installation instructions.

Flange Ends

Flange ends are adopted for connections between PE pipes and valves, fitting or other materials such as ductile iron, PVC, or FRP pipes

The flange method of jointing PE pipes consists of a PE stub end which is connected to the PE pipe by butt welding or electrofusion. The sealing is carried out with an appropriate elastomeric gasket being compressed within the mating surfaces. Metal backing plates are moulded into the fittings.
The guidelines contained within AS/NZS2129 need to be followed.
The suitability of the gasket sealing materials needs to be checked in terms of the fluids being carried in the pipeline and the external groundwater surrounding the pipeline.
The tightening of the bolts must be carried out evenly around the flange to permit an even seal in the gasket material. A torque wrench should be used to prevent over tightening of the bolts.
In corrosive soil conditions, the metal backing up plates and bolts need to have appropriate protection, sacrificial anodes or coatings.

Repair Joints
Repairs to PE pipelines is carried out using electrofusion joints with no centre register. Special care with cleaning or re-rounding is required.

Threaded Joints
Where threaded joints are used in PE pipelines, only moulded thread forms should be used.
Direct cut threads must not be used.
Threaded fittings must only be assembled by hand, strap wrench, flat face tools. Serrated jaw spanners, or wrenches must not be used as damage to the moulding can easily occur.
Only inert PTFE tape, or PTFE compounds should be used to seal threaded joints. Sealing compounds can stress crack either PE or other plastics used in the fittings and must be avoided.

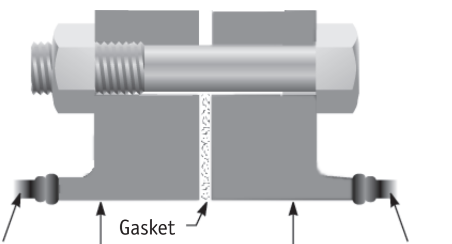
TAPPING SYSTEMS

General Considerations
PE pipelines may be tapped using specialist tapping saddles or tees connected to the PE main by either electrofusion welding methods or compression metric fittings.
Tapping systems are limited to the size of the off take pipe diameter compared to the main line pipe diameter and the pressure classes of the PE pipes used in both the service and main lines.

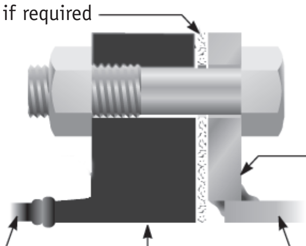
PE pipes must not be direct tapped using ferrules threaded into the PE pipe wall section.
Tapping saddles rely on compression of a rubber seal ring to complete the seal. Ensure that the fitting is assembled and locked onto the pipe in the required position before drilling the service outlet hole with an appropriate hole saw.
Multiple Tapping Saddles may be use on a service line but these should not be installed closer than 5 times the pipe diameter.
All tapping activities and service connections in PE pipes should be made where practical before backfilling is completed, so the service line is not stressed in its alignment to the tapping band. Where the tapping takes place at a predetermined location on the allotment boundary, then the tapping can be carried out before the PE pipe is placed into the trench.
Where tapping and service connections are performed in hot weather conditions, then care needs to be exercised to allow for any thermal expansion/contraction in the PE pipes so that the final service connection pipe sits evenly into the side trench and does not bear against the side wall of the trench.
Where electrofusion tapping saddles or tees are used, tapping must not take place until the welded joints have fully cooled. Any attempt at tapping before this occurs may cause the joint area to leak at the tapping point.
Where PE pipes are tapped, the tapping system should contain a cutter which removes the tapping plug material from the PE main pipe as a single piece and either retains the plug in the cutter or allows the plug to be removed.

Stub Flanges and Backup Plates

(a) Polyethylene to Polyethylene



(b) Polyethylene to Steel

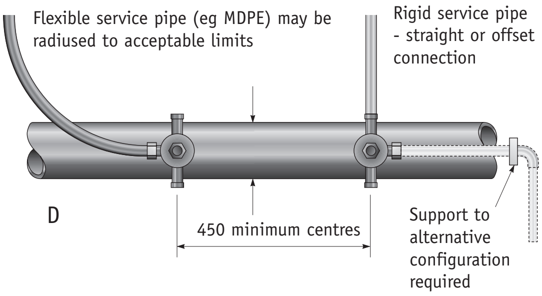


Mechanical Jointing and Service Connections

Tapping Saddles
Only tapping saddles designed for use with PE pipe should be used. These saddles should:
- Be contoured to fit around the pipe and not have lugs or sharp edges that dig in.
- Have a positive stop to avoid overtightening of the saddle around the pipe.

The maximum hole size that should be drilled in a PE pipe for tapping purposes is 50mm, or 1/3 the pipe diameter, whichever is smaller.
This does not prevent the connection of larger branch lines via tapping saddles, provided the hydraulic loss through the restricted hole size is acceptable.
For larger branches a tee is preferred.

Holes should not be drilled into PE pipe:
- Closer than 450 mm to another hole on a common parallel line.
- Where significant bending stress is applied to the pipe.



NOTE: Straight connections are considered the norm in most cases

Live Tapping
Live tapping of a line using a specially designed range of tapping bands, or drilling machines can be used.
The tapping band should be fitted to the pipe and correctly tightened. A specially adapted main cock for live tapping should be fitted to the tapping saddle using PTFE tape and a drilling machine fitted with a “shell” cutter or hole saw only. The hole is drilled and the tapping flushed. The hole saw is then withdrawn and the main cock sealed. The tapping machine is removed along with the hole cut out and the main cock plunger or cap is then fitted.

Direct Tapping
Marley does not recommend direct tapping (threading of the pipe wall) for PE pressure lines.

Self Tapping Ferrule
Live mains may be tapped for service connections using the self tapping ferrule, available with 20mm male outlet.

HANDLING AND STORAGE

- General Principals
- Coiled Pipes
- Loading and Off-Loading
- Storage

Handling and Storage

GENERAL PRINCIPLES

Polyethylene is a tough resilient material which is relatively light and easy to handle although it is prone to damage through scoring by sharp objects. Therefore careful handling is always required and the dragging of straight pipe and coils should be avoided.

1. The maximum allowable depth of scoring of the external surface of the pipe is 10% of the wall thickness. Pipes and fittings showing obvious defects or excessive scoring should be withdrawn, clearly identified as unsuitable and, where appropriate, returned to the source of supply.
2. The general properties of polyethylene are unaffected by low ambient temperatures but having very smooth surfaces, the pipes and fittings become slippery in wet or frosty weather. Particular attention should be given to effective securing and storage under such conditions.

The rules on handling and storage
Never

- Drag or roll individual pipes or bundles.
- Throw/drop pipe/fittings from delivery vehicles.
- Use metal slings, hooks or chains when handling.
- Expose pipe/fittings to prolonged sunlight. (Protect with opaque sheeting or tarpaulin).
- Stack more than three metres or three bundles high.
- Place pipes or fittings in contact with lubricating or hydraulic oils, gasoline, solvents or other aggressive materials.

Always

- Store pipes on flat, firm ground, able to withstand the weight of pipe/fittings and lifting apparatus.
- Keep pipe/fittings well away from sharp objects, such as flints.
- Use wide non-metallic slings (eg. nylon or polypropylene).
- Exercise special care when handling pipes in wet or frosty conditions, since they may become slippery.
- Keep protective packaging (battens, shrinkwrap, pallets, strapping, etc.) intact until pipes/fittings are required for use.
- Keep pipes/fittings away from intense heat, except when jointing.
- Allow for some bending deflection when pipes are loaded and unloaded. Lifting points should be evenly spaced.

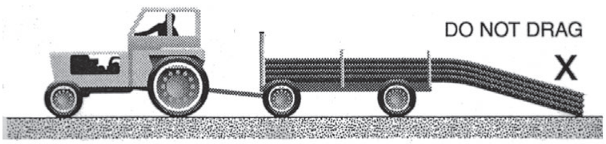
Coiled Pipes

Pipe sized >63mm should be moved and uncoiled using an approved dispensing trailer.
Before unstrapping pipe from the coil or drum, both pipe ends must be firmly mechanically restrained. The band securing the outer end of the pipe should be removed first and the movement of the free end carefully controlled. This removal should be followed with those securing successive layers. No more bands should be removed than necessary to release the length of pipe immediately required.
When removed from the coil or drum, the pipe will be oval and curved. The extend of the ovality and curvature will depend upon the temperature, SDR rating, pipe diameter, coil diameter and material type. Although both ovality and curvature will reduce naturally with time, special re-rounding tools are available to facilitate handling and jointing.

Loading and Off-loading

Lengths and bundles

A flat-bed vehicle, free from sharp objects and projections should be used for transportation of pipe systems. When lifting pipe bundles by crane, wideband slings must be used; do not use chains, hooks or wire slings. Do not drag pipe across truck deck or the ground. For lengths greater than six metres, load spreading beams should be inserted at equal distances apart.
Care should be taken to avoid positioning pipes and



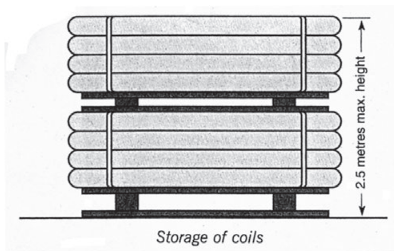
On-site transport

fittings near or adjacent to exhaust systems or other head sources and to avoid possible contamination from materials such as diesel oil.

Any product over 25 kilos needs to be lifted mechanically.

Storage

All pipes and fittings should be inspected prior to storage and any damaged items isolated and removed from stock. The supplier should be notified immediately of any defective product.
As PE pipes are date stamped at the time of manufacture, stocks should be arranged so that the earliest date production is used first in installation. The same procedure should be followed with fittings, where the packaging indicates a date of manufacture.
Where pipes are stored on site, the ground should be flat, and free from all rocks. Pipes must not be stored near high temperature sources and must be kept away from combustible materials and potential contaminants. Under no circumstance should coils be stored higher than 2.5m.



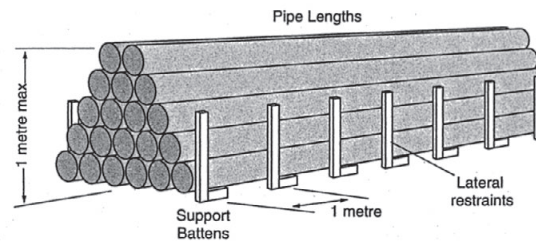
Storage of coils

Fittings

Electrofusion fittings should be stored under cover in dry conditions, preferably on racking. They should be kept in their boxes and packaging until ready for use. Butt fusion and spigotted fittings may be stored outdoors, as long as they are protected against damage and prolonged direct sunlight. Electrofusion fittings should be retained in their plastic bags until used.

Lengths

Pipe lengths stored individually should be stacked in a pyramid not more than one metre high, with the bottom layer fully restrained by wedges. Where possible, the bottom layer of pipes should be laid on timber battens at one-metre centres. On site, pipes may be laid out individually in strings. (Where appropriate, protective barriers should be placed with adequate warning signs and lamps.)



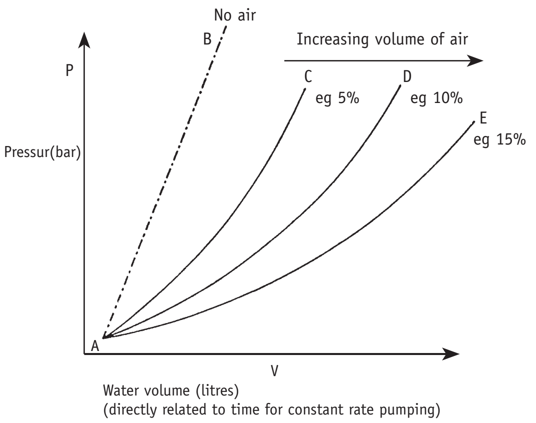
TESTING & COMMISSIONING

- Introduction
- Pre Test Considerations
- Pressure Pipeline Testing
- Gas Pipe Testing
- Pressure Test - large bore commissioning
- Pressure Test Analysis - three point
- Pressure Test Analysis - predicted pressure
- Commissioning
- Pipeline Location, Marking, Recording and Detection

POLYETHYLENE PIPELINE TESTING

INTRODUCTION

All completed PE pipelines should be tested to ensure that all joints, fittings, anchorage blocks are installed correctly and that there are no leakages or loss of fluid. The actual testing procedures to be adopted will vary on the actual application of each pipeline and the specific requirements laid down by the relevant Local Authority in tender contract documents.
The local authority specifications must be followed at all times.



Typical Pressure/volume characteristic during pressurisation

The introduction of the PE63, PE80B and PE100 rating systems in AS/SNZ 4130 and the modification to the applied design factor applied to calculate each of the pressure class wall thicknesses, has resulted in reduced pipe wall section thicknesses, when compared to the previous AS1159. This means that the hydrostatic test pressure applied for pressure pipes must also be adjusted from the previous values applied to AS 1159 pipes.
All PE materials listed in AS/NZS 4130 behave in an elastic manner when internally pressure tested and this shows up as an apparent pressure loss, or lead on the test recording gauge due to the increase in pipe volume as the pipeline expands. This means that, as distinct from rigid pipeline materials, a makeup volume of water may be needed to be added to the pipeline during the test period to maintain a constant pressure reading. PE pipelines subjected to extended periods of high test pressure, or temperature which should be below 28°C, will also creep over the test period and this may show up as a drop in the pressure readings.
Neither of these observations means that a leak is present in the pipeline.
The test is the installation. Ensure all valves are closed, seal correctly and all air is removed from the lines.

PRE TESTING CONSIDERATIONS

Prior to carrying out any testing activities, a number of precautions need to be observed.

- All facilities must be available and sufficient notice given to the relevant Local Authority to allow compliance inspection prior to any testing being carried out.
- All residential construction materials must be removed from the trench or embankment, alignments so that no additional materials are in direct contact with the PE pipes or fittings.
  There should be no point loading on fittings.
- PE pipelines must be supported by either backfilling with soil or loaded with sandbags to prevent movement and possible mechanical seal joint displacement.
- Where cast insitu concrete thrust blocks are used, a minimum period of 7 days should be allowed before testing. Where timber or moulded blocks are used then testing can start as soon as required. All blanked off ends, including valves, must be fully supported.
- All intermediate valves should be opened to allow full venting of entrapped air from the PE pipeline.
- Where water is used as the test fluid, then PE pipeline testing should not be performed in wet weather, unless any potential leakage can be readily observed on site.
- Where thermal fusion joints are used in the PE pipeline, no testing should proceed until the last joint made has completely cooled to ambient temperature.

PRESSURE PIPELINE TESTING

PE pipelines may be tested as a single section for lengths up to 800 metres, depending on the size of the pipe and the availability of test water. Beyond this length, the pipeline should be progressively tested in sections.
The test section must be swabbed and flushed clean before introducing test water. The test water should be introduced at the lowest available point to assist air venting and all air vent valves opened.

Testing and Commissioning

As PE pipes are subject to thermal expansion and contraction the testing should take place at ambient temperature and the water should be introduced and the pipeline kept full of water (but **not under pressure**) for 12 hours where elevated temperatures are encountered. Where pipes are at ambient temperature testing may commence as soon as required.

Pressure test gauges or recording devices should be placed at the lowest elevation point accessible in the pipeline.

The test water should be fed into the pipeline evenly and without pulsation up to the nominated test pressure value. The actual test pressures adopted may vary depending on the Local Authority requirements and these must be adhered to at all times.

For **small** diameter PE80B PE pipelines (up to 110mm diameter) a test pressure of a **maximum of 1.2 WP** (working pressure) may be applied for a period of 15 minutes or for sufficient time to allow the pipeline to be inspected for leakage at all joints. The same procedures may be adopted for small length additions to existing pipelines. The pressure gauge reading should not drop once the pressure has stabilised.

For PE pipe property service connections using PN16 class PE100 PE pipe, a standard test pressure of 1.5 MPa may be applied uniformly for all applications.

For **large** diameter PE pipelines and for pipeline lengths up to 1000 metres, the volume change in the pipes under the action of the test pressure needs to be evaluated. Pipes should be brought up to test pressure and the pressure stabilised by introducing make up water.

A test pressure of a maximum of 1.25 times WP (working pressure) may be applied for a period of up to 8 hours, or for sufficient time to inspect all joints and connections for signs of leakage. Pressure gauge readings should be taken at regular time intervals during the test period to ensure that leakage does not take place.

High pressure testing using air must not be carried out.

The following are identified as contributing factors to variations in the pressure test results:

- length of the test section
- diameter of the pipe
- temperature changes
- range of test pressure imposed
- rate of pressure loading
- presence of air in the pipeline
- presence of air in the water
- relative movement of 'mechanical' fittings
- efficiency of the bedding and compacted surround to resist pipe movement.
- accuracy and efficiency of testing apparatus.

Air Testing

All openings must be sealed prior to testing.

Air should be pumped slowly into the PE pipeline until a test pressure of 50 KPa is reached on a recording gauge fitted to the pipeline. The test pressure of 50 KPa must be maintained for a minimum time of 3 minutes and if no leaks are detected or pressure loss is observed on the gauge, then the air supply control valve should be turned off.

The pressure should be held for a minimum time of 1 minute and if the gauge pressure reading has not fallen below 35 KPa after this time then the test pressure should be released.

When the test pressure drops below 35 KPa after 1 minute, then the pressure should be returned to 50 KPa and this pressure maintained until a full inspection of the PE pipeline has been completed. All joints and connections need to be individually inspected for leakage and a solution of water and detergent should be poured over any suspect joint. If a leak is present, it will cause the detergent solution to bubble and foam.

The test must be accepted by the relevant Local Authority representative before completing the testing.

Deflection Testing

PE drainage pipelines are designed to support external loading within the acceptable limits of diameter deflection (or ovality) for hydraulic or structural reasons. Where this is a critical feature of the installation, then the effectiveness of the backfill compaction may require testing.

In these cases a presized plug, or proving tool can be pulled through the pipeline between manholes or other entry points.

For flanged, electrofusion or mechanically jointed PE pipelines without any protrusions into the pipe bore, the plug can be sized to the minimum diameter reduction allowed in the design.

For butt welded PE pipes the size is based on if the internal beads are removed.

In either case, the plug should be able to be pulled completely through the PE pipeline.

GAS PIPE TESTING

For gas pipe installations, testing should not proceed until the last completed fusion joint has had adequate time to fully cool to ambient temperature.

Hydrostatic pressure testing may be carried out using inert liquid (such as water), air or an inert gas approved by the utility.

Test pressure such as TP = 1.10 x WP may be applied for pipelines provided that the test pressure is not less than 100 KPa and does not exceed 1.5 times the design pressure of the pipeline system.

For larger diameter or longer pipelines, progressive testing may be applied such that:

Test Device	TestPressure	Test Duration
Dial gauge	700 KPa	Overnight
Differential leak tester	700 KPa	30 mins stability then 5 mins test

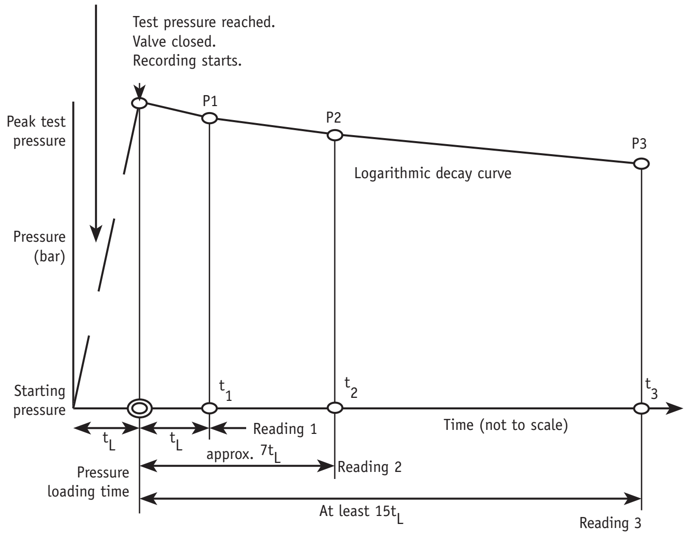
Final testing may be applied or required by the utility after progressive testing in the form of:

Test Device	Test Pressure	Test Duration
Dial gauge	700 KPa	24 hours, no drop
Recorder	700 KPa	24 hours, no drop

PRESSURE TEST

Large Bore Commissioning

On reaching the test pressure and satisfying the condition for minimal air entrapment, the pipeline is isolated and the pressure allowed to decay. The pressure decay readings (tL) to achieve test pressure is used as a reference. The natural pressure decay readings at predetermined times are then recorded in minutes from the moment of valve closure.
The analysis will be more comprehensive with larger numbers of readings being taken throughout the test.
Since the pipeline begins to relax within the period of pressurisation, a correction factor has to be applied to allow for this. Experience suggests that this correction should be 0.4tL.
A typical sequence of readings is illustrated below.



PRESSURE TEST ANALYSIS
- Three Point Analysis

To demonstrate that the PE pipeline is sound, an analysis of the pressure test is carried out as follows:

As the pressure decay is of exponential form, the use of logarithms is necessary when comparing readings taken during the test but the use of pocket calculator is all that is required for 'on site' calculations.

1.0
Take a first reading of pressure P1 at t1, where t1 is equal to the pressure loading time (tL).

2.0
Take a second reading of Pressure P2, at a time approximately 7tL; Let this be t2.

To allow for the stress relaxation behavior of PE pipelines, calculate the corrected values of t1 and t2.

- calculate corrected t_1
  $t_{1c} = t_1 + 0.4t_L$
- calculate corrected t_2
  $t_{2c} = t_2 + 0.4t_L$

3.0
The measure of the slope of the pressure decay curve between t1 and t2 is then calculated as the ratio n1.

Calculate $n_1 = \dfrac{\log P_1 - \log P_2}{\log t_{2c} - \log t_{1c}}$

For a sound main, experience suggests that the ratio n_1 should be;

a) 0.08 – 0.10 for pipes without constraint
(eg sliplined or not backfilled).
b) 0.07 for pipes with compacted backfill.

Bearing in mind the identified compaction , if the values are significantly less than the minimum identified, then there is too great a volume of air in the main. This air will have to be removed before a satisfactory test can be performed.

4.0
Take a further reading of pressure P3 at a decay time not less than 15tL. Let this be t3. Again to allow for the stress relaxation behavior of PE pipelines, calculate the correct value for t3.

$T_{3c} = t_3 + 0.4t_L$

5.0
The measure of the slope of the pressure decay curve between t2 and t3 is then calculated as the ratio of n2.

Calculate $n_2 = \dfrac{\log P_2 - \log P_3}{\log t_{3c} - \log t_{2c}}$

For a pipe system with no leakage and bearing in mind the identified compaction, then the ratio of n2 should be:

a) 0.08 – 0.10 for pipes without soil constraint,

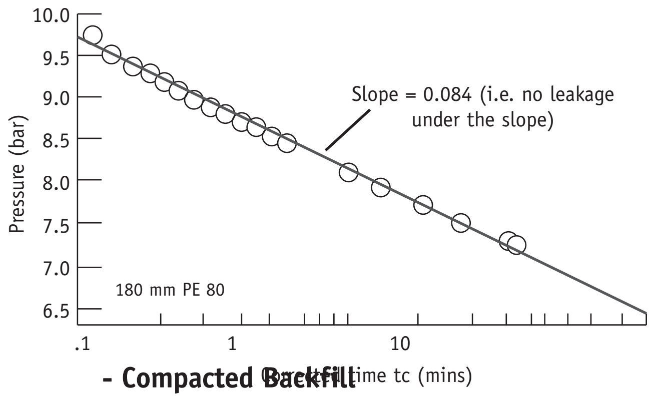
b) 0.04 – 0.05 for pipes in compacted backfill.

The following figure shows the results of test (using graphical analysis with multiple results from a data logger) on mains without leaks in unconstrained and constrained situations respectively.
The sensitivity of the test can be increased by extending the value of t3 ie extending the test duration.

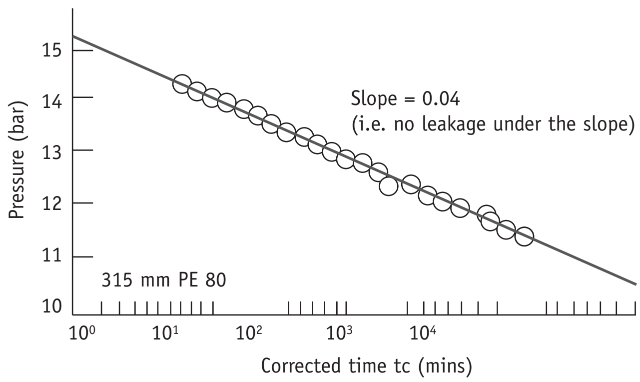
6.0
The procedure detailed above identifies the principle. However it is strongly advised that the slopes n1 and n2 are obtained from more than three points.

PRESSURE REGRESSION

- Unrestrained



- Compacted Backfill



PRESSURE TEST ANALYSIS

- Predicted Pressures

To allow an early indication of problems such as leakage or air entrapment, a supplementary analysis can be carried out during the pressure test. This necessitates comparing the recorded pressure at any point in time with the predicted pressure since the logarithmic plot of pressure decay in an ideal PE pipeline system should be linear. Any deviation from linearity indicates the possibility of leakage or air entrapment.

The predicted pressure can be calculated from

$$P = P_L\left[2.5\left(\frac{t}{t_L}\right)+1\right]^{-n}$$

Where
P = predicted pressure at time t
P_L = test pressure (at start of test when the test pressure is first reached)
t = time (from reaching the test pressure)
t_L = loading time

From experience it has been shown that:

For pipes installed in compacted soil n = 0.04
For pipes installed without support n = 0.10

If the actual pressure recorded was found to differ significantly from the predicted value, then a formal slope analysis using all the data collected so far could be conducted.
The data should be plotted on log paper or converted to logs prior to plotting on normal paper. If the graph shows an increasing slope with time (A – C) (ie the actual recorded pressures were less than the predicted values), this indicates leakage. If the graph shows a decreasing slope with time (A – B), ie the actual recorded pressure were greater than the predicted values), this indicates air entrapment.
If the slope is linear but between the slopes identified (ie 0.04 – 0.05 and 0.08 – 0.1) this probably indicates poor backfill compaction, but not a failed test.

Note: It is possible to predict leakage rates as a function of water volume added.

If at any stage during the pressure test an unacceptable leak is indicated, it is advisable to check all mechanical fittings before visually inspecting the fusion joints. Any defect in the installation revealed by the test should be rectified and the test repeated.
For smaller pipelines, <500m in length and/or >80mm diameter and <200 metres in length, the test pressure of 700 KPa may be reduced to a test time of 5 minutes duration after allowing the pipe pressure to act for 30 minutes without any observed pressure drop on the guage.
In all instances, where bubble testing is carried out using a soft soap solution, no leakage shall be permitted at any tested point.

COMMISSIONING

PE pipelines should be commissioned following the standard practices adopted by the relevant Local Authority.
This applies for both pressure and non pressure applications.
In the case of potable water applications, the standard flushing and disinfection procedures must be followed. PE pipes made to AS/NZ 4130 do not impart additional water quality flushing or disinfection requirements due to corrosion products, heavy metal update, or pH change, and where these aspects have been included in standard commissioning procedures, then consideration should be given to the need for these elements.

PIPELINE LOCATION, MARKING, RECORDING AND DETECTION

PE pipes are electrically non conductive and as such cannot be detected by magnetic detection devices.
However, where it is desired to detect buried pipelines, several techniques are available.

Metal Detector Tapes

Custom tapes may be located on top of the PE pipe cover material (150 – 300mm above the top of the pipe) and can be detected by metal detection equipment operating in the 4-20 MHz range at depths up to 600mm.
The tapes also offer colour coded identification and early warning of the presence of the pipeline during later excavations.

Trace Wires

Pipes deeper than 600mm may be detected by the use of tracer wires placed underneath the pipeline.
Application of a suppressed current allows the detection of pipes up to 3 metres depth. However, both ends of the wire must be accessible and a complete circuit must be available without breakage of the wire over the length of the pipeline.

Audio Detection

Several types of acoustic detectors are available using either the sound of turbulence from flow in the line or by the introduction of an outside sound source.

CHEMICAL RESISTANCE

CHEMICAL RESISTANCE

Three different classes of chemical resistance degree are conventionally used in this guide ie:

Class 1: High Resistance (Corrosion-proof) - all materials belonging to this class are completely or almost completely corrosion-proof against the conveyed fluid, according to the specified operating conditions.

Class 2: Limited Resistance - the materials belonging to this class are partially attacked by the conveyor chemical compound. The average life of the material is therefore shorter, and it is advisable to use a higher safety factor by selecting a higher SN rating pipe.

Class 3: No Resistance - all materials belonging to this class are subject to corrosion by the conveyed fluid and they should therefore not be used.

The absence of any class indication means that no data are available concerning the chemical resistance of the material in respect of the conveyed fluid.

ABBREVIATIONS

sat = saturated solution at 20°C **nd** = undefined concentration

deb = weak concentration **comm** = commercial solution **dil** = diluted solution

	FORMULA	CONC %	TEMP (°C)	PVC	PE
ACETALDEHYDE	CH_3CHO	100	25	3	1
			60	3	
- AQUEOUS SOLUTION		40	25	3	1
			60	3	2
ACETIC ACID	CH_3COOH	≤ 25	25	1	1
			60	2	1
		30	25	1	1
			60	2	1
		60	25	1	1
			60	2	1
		80	25	1	1
			60	2	
- GLACIAL		100	25	2	1
			60	3	2
ACETIC ANHYDRIDE	$(CH_3CO)_2O$	100	25	3	2
			60	3	2
ACETONE (DIMETHYL KETONE)	CH_3COCH_3	10	25	3	1
			60	3	
		100	25	3	2
			60	3	2
ACETOPHENONE (ACETYLBENZENE OR PHENYL METHYL KETONE)	$CH_3COC_6H_5$	nd	25		
			60		
ACRYLONITRILE (ACRYLONITRILE OR VINYL CYANIDE)	CH_2CHCN	technically pure	25		1
			60	3	1
ADIPIC ACID AQUEOUS SOLUTION	$(CH_2CH_2CO_2H)_2$	sat.	25	1	1
			60	2	1
ALLYL ALCOHOL	CH_2CHCH_2OH	96	25	2	1
			60	3	2
ALUM AQUEOUS SOLUTION (POTASH ALUM.SOL.)	$Al_2(SO_4)_3K_2SO_4nH_2O$	dil	25	1	1
		dil	60	2	1
		sat.	60	2	1
ALUMINIUM - CHLORIDE	$AlCl_3$	all	25	1	1
			60	1	1
- FLORIDE	AlF_3	100	25	1	1
			60	1	1
- HYDROXIDE	$Al(OH)_3$	all	25	1	
			60	1	-
NITRATE	$Al(NO_2)_3$	nd	25	1	
			60	1	-
SULFATE	$Al(SO_4)_3$	deb	25	1	
			60	1	1
		sat	25	1	1
			60	1	1
AMMONIA - AQUEOUS SOLUTION	NH_3	deb	25	1	1
			60	2	1
		sat	25	1	
			60	2	
- DRY GAS		100	25	1	1
			60	1	1
- LIQUID		100	25	2	1
			60	3	1
AMMONIUM - ACETATE	CH_3COONH_4	sat	25	-	1
			60	2	1
- CARBONATE	$(NH_4)_2CO_3$	all	25	1	1
			60	2	1

	FORMULA	CONC %	TEMP (°C)	PVC	PE
- FLUORIDE	NH_4F	25	25	1	1
			60	2	1
- HYDROXIDE	NH_4OH	28	25	-	1
			60	2	1
- NITRATE	NH_4NO_3	sat	25	1	1
			60	1	1
- PHOSPHATE DIBASIC	$NH_4(HPO_4)_2$	all	25	1	1
			60	1	1
- PHOSPHAT META	$(NH_4)_4P_4O_{12}$	all	25	1	
			60	1	
- PHOSPHATE TRI	$(NH_4)_2HPO_4$	all	25	1	
			60	1	
- PERSULFATE	$(NH_4)_2S_2O_8$	all	25	1	
			60	1	
- SULFIDE	$(NH_4)_2S$	deb	25	1	1
			60	2	1
		sat	25	1	1
			60	1	1
- SULFHYDRATE	NH_4OHSO_4	dil	25	1	1
			60	2	1
		sat	25	1	1
			60	1	1
AMYLACETATE (PENTYL ACETATE)	$CH_3CO_2CH_2(CH_2)_3CH_3$	100	25	3	1
			60	3	2
AMYLALCOHOL	$CH_3(CH_2)_3CH_2OH$	nd	25	1	1
			60	2	1
ALNILINE (PHENYLAMINE OR AMINOBENZENE)	$C_6H_5HN_2$	all	25	3	2
			60	3	2
- CHLORHYDRATE (ANILINE HYDROCHLORIDE)	$CH_6H_5NH_2HCl$	nd	25	2	2
			60	3	2
ANTIMONY - TRICHLORIDE	$SbCl_3$	100	25	1	1
			60	1	1
ANTHRAQUINONE (SULFONIC ACID)	suspension	25	1	1	
			60	2	-
AQUA REGIA	$HCl+HNO_3$	100	25	2	3
			60	2	3
ARSENIC ACID	H_3ASO_4	deb	25	1	1
			60	2	1
		80	25	1	1
			60	2	1
BARIUM CARBONATE	$BACO_3$	all	25	1	1
			60	1	1
- CHLORIDE	$BaCl_2$	10	25	1	1
			60	1	1
- HYDROXIDE	$Ba(OH)_2$	all	25	1	1
			60	1	1
- SULFATE	$BaSO_4$	nb	25	1	1
			60	1	1
- SULFIDE	BaS	sat	25	1	
			60	1	
BEER		comm	25	1	1
			60	1	
BENZALDEHYDE	C_6H_5CHO	nd	25	3	2
			60	3	2

Chemical Resistance

	FORMULA	CONC %	TEMP (°C)	PVC	PE
BENZENE (BENZOL)	C_6H_6	100	25	3	3
			60	3	
- + LIGROIN		20/80	25	3	
			60	3	
- MONOCHLORINE	C_6H_3Cl	technically pure	25	3	2
			60		
BENZOIC ACID	C_6H_5COOH	sat	25	1	1
			60	2	1
BENZYL ALCOHOL	$C_6H_5CH_2OH$	100	25	1	
			60	2	
BORIC ACID (BORACIC ACID)	H_3BO_3	deb	25	1	1
			60	2	1
		sat	25	1	1
			60	2	1
BRINE		comm	25	1	
			60	1	
BROMIC ACID	$HBrO_3$	10	25	1	1
			60	1	1
BROMINE - LIQUID	Br_2	100	25	3	3
			60	3	3
- VAPOURS		low	25	2	3
			60		3
BUTADIENE	C_4H_6	100	25	1	
			60	1	3
BUTANEDIOL AQUEOUS	$CH_3CH_2CHOHCH_2OH$	10	25	1	
			60	3	
		concentrated	25	2	2
			60	3	3
BUTANE GAS	C_4H_{10}	10	25	1	1
			60		1
BUTYL - ACETATE (BUTANATE)	$CH_3CO_2CH_2CH_2CH_2 CH_3$	100	25	3	3
			60	3	3
- ALCOHOL (BUTANOL)	C_4H_9OH		25	1	1
			60	2	1
- PHENOL	$C_4H_9C_6H_4OH$	100	25	2	3
			60	2	3
BUTYLENE GLYCOL	$C_4H_6(OH)_2$	100	25		1
			60	2	1
BUTYRIC ACID (BUTANOIC ACID)	$C_2H_5CH_2COOH$	20	25	1	1
			60	2	2
		concentrated	25	3	3
			60	3	3
CALCIUM - BISULFITE	$Ca(HSO3)_2$	nd	25	1	1
			60	1	1
- CARBONATE	$CaCO_3$	all	25	1	1
			60	1	1
-CHLORATE	CaHCl	nd	25	1	1
			60	1	1
- CHLORIDE	$CaCl_2$	all	25	1	1
			60	2	1
- HYDROXIDE	$Ca(OH)_2$	all	25	1	
			60	1	
- HYPOCHLORITE	$Ca(OHI)_2$	sat	25		1
			60	2	1
- NITRATE	$Ca(NO_3)_2$	50	25	1	1
			60	1	
- SULFATE	$CaSO_4$	nd	25	1	1
			60	1	1
- SULFIDE	CaS	sat	25	1	2
			60	1	2
CAMPHOR OIL		nd	25	1	3
			60		3
CARBON - DIOXIDE AQUEOUS SOLUTION	CO_2	-	25	1	1
			60	2	1
- GAS		100	25	1	1
			60	1	1
- DISULFIDE	CS_2	100	25	2	2
			60	3	
- MONOXIDE	CO	100	25	1	1
			60	1	1
- TETRACHLORIDE	CCl_4	100	25	2	2
			60	3	3
CARBONIC ACID - AQUEOUS SOLUTION	H_2CO_3	sat	25	1	
			60	1	
- DRY		100	25	1	
			60	1	
- WET		all	25	1	
			60	2	
CARBON OIL		comm	25	1	
			60	1	

	FORMULA	CONC %	TEMP (°C)	PVC	PE
CHLORAMINE	NH_2Cl	dil	25	1	1
			60		
CHLORIC ACID	$HClO_3$	20	25	1	1
			60	2	3
CHLORINE	Cl_2	sat	25	2	
			60	3	
- DRY GAS		10	25	1	
			60	2	
		100	25	2	
			60	3	
- WET GAS		5 g/m3	25	1	
			60	3	
		10 g/m3	25	2	2
			60	2	
		66 g/m3	25	2	2
			60	2	
- LIQUID		100	25	3	3
			60		
CHLOROACETIC ACID	$ClCH_2COH$	85	25	1	2
			60	2	3
		100	25	1	3
			60	2	3
CHLOROBENZENE	C_6H_5Cl	all	25	3	
			60	3	
CHLOROFORM	$CHCl_3$	all	25	3	2
			60	3	
CHLOROSULPHONIC ACID	$ClHSO_3$	100	25	2	3
			60	3	3
CHROME ALUM	$KCr(SO_4)_2$	nd	25	1	1
			60	2	1
CHROMIC ACID	CrO_3+H_2O	10	25	1	2
			60	2	3
		30	25	1	2
			60	2	3
		50	25	1	2
			60	2	3
CHROMIC SOLUTION	$CrO_3+H_2O+H_2SO_4$	50/35/15	25	1	3
			60	2	3
CITRIC ACID AQ.SOL.min.	$C_3H_4(OH)(CO_2H)_3$	50	25	1	1
			60	1	1
COPPER - CHLORIDE	$CuCl_2$	sat	25	1	1
			60	1	1
- CYANIDE	$CuCN_2$	all	25	3	
			60	3	
- FLUORIDE	CuF_2	all	25	1	1
			60	1	1
- NITRATE	$Cu(NO_3)_2$	nd	25	1	1
			60	2	1
- SULFATE	$CuSO_4$	dil	25	1	1
			60	1	1
		sat	25	1	1
			60	1	1
COTTONSEED OIL		comm	25	1	
			60	1	
CRESOL (HYDROXY TOLUENE)	$CH_3C_6H_4OH$	≤90	25	2	1
			60	3	
		≥90	25	3	
			60	3	
CRESYLIC ACID	$CH_3CH_6H_4COOH$	50	25	2	
			60	3	
CYCLOHEXANE	C_6H_{12}	all	25	3	1
			60	3	
CYCLOHEXANONE	$C_6H_{10}O$	all	25	3	1
			60	3	
DECAHYDRONAFTALENE	$C_{10}H_{18}$	nd	25	1	1
			60	1	2
DEMINERALIZED WATER		100	25	1	1
			60	1	1
DIBUTYPATHALATE	$C_6H_4(CO_2C_4H_9)_2$	100	25	3	3
			60	3	
DICHLORO-ACETIC ACID	$Cl_2CHCOOH$	100	25	1	1
			60	2	2
DICHLOROETHANE (ETHYLENE DICHLORIDE)	CH_2ClCH_2Cl	100	25	3	3
			60	3	3
DICHLOROETHYLENE	$Cl(CH)_2Cl$	100	25	3	3
			60	3	3
DIETHYL ETHER	$C_2H_5OC_2H_5$	100	25	3	3
			60	3	3
DIGLYCOLIC ACID	$(CH_2)_2O(CO_2H)_2$	18	25	1	1
			60	2	1
DIMETHYLAMINE	$(CH_3)_2NH$	100	25	2	
			60	3	2

	FORMULA	CONC %	TEMP (°C)	PVC	PE
DIOCTYLPHTHALATE		all	25	3	1
			60	3	2
DISTILLED WATER		100	25	1	1
			60	1	1
DRINKING WATER		100	25	1	1
			60	1	1
ETHERS		all	25	3	
			60	3	
ETHYL - ACETATE (ACETIC ETHER)	$CH_3CO_2C_2H_5$	100	25	3	1
			60	3	3
- ALCOHOL		CH_3CH_2OH	nd	25	1
1		60	2	2	
(ETHANOL)	CH_3CH_2Cl	all	25	3	2
- CHLORIDE			60	3	
- ETHER	$CH_3CH_2OCH_2CH_3$	all	25	3	
			60	3	
ETHYLENE	$ClCH_2CH_2OH$	100	25	3	
- CHLOROHYDRIN			60	3	
- GLYCOL	$HOCH_2CH_2OH$	comm	25	1	1
			60	1	3
(ETHANEDIOL OR GLYCOL)			nd	25	1
FATTY ACIDS			60	1	
FERRIC	$FeCl_3$	10	25	1	
- CHLORIDE			60	2	
		sat	25	1	1
			60	1	1
- NITRATE	$Fe(NO_3)_3$	nd	25	1	1
			60	1	1
- DEXTRINE (BRITISH GUM	$C_6H_{12}OCH_2O$	nd	25	1	1
			60	2	1
OR STARCH GUM)	$Fe(SO_4)_3$	nd	25	1	1
- SULFATE		60	1	1	
FERROUS	$FeCl_2$	sat	25	1	1
- CHLORIDE			60	1	1
- SULFATE	$FeSO_4$	nd	25	1	1
			60	1	1
FERTILIZER		≤ 10	25	1	1
			60	1	1
		sat	25	1	1
			60	1	1
FLUORINE GAS	F_2	100	25	2	2
			60	3	3
DRY FLUROSILICIC ACID	H_2SiF_6	32	25	1	1
			60	1	1
FORMALDEHYDE	HCOH	-	25	1	1
			60	2	1
FORMIC ACID	HCOOH	50	25	1	1
			60	2	1
		100	25	1	1
			60	3	1
FRUIT PULP AND JUICE		comm	25	1	1
			60	1	
FUEL OIL		100	25	1	
			60	1	
		comm	25	1	-
			60	1	2
FURFUROLE	$C_5H_3OCH_2OH$	nd	25	3	2
			60	3	2
ALCOHOL GAS EXHAUST		all	25	1	
- ACID			60	1	
- WITH NITROUS		traces	25	1	1
- VAPOURS			60	1	1
GAS PHOSGENE	ClCOCl	100	25	1	2
			60	2	2
GELATINE		100	25	1	1
			60	1	-
GLUCOSE (DEXTROSE)	$C_6H_{12}O_6$	all	25	1	1
			60	2	1
GLYCERINE AQ.SOL(GLYCEROL)	$HOCH_2CHOHCH_2OH$	all	25	1	1
			60	1	1
GLYCOGLUE		10	25	1	1
		60	1	1	
AQUEOUS GLYCOLIC ACID	$HOCH_2COOH$	37	25	1	1
			60	1	1
HEPTANE	C_7H_{16}	100	25	1	1
			60	2	3
HEXANE	C_6H_{14}	100	25	1	1
			60	2	2
HYDROBROMIC ACID	HBr	≤10	25	1	1
			60	2	1
		48	25	1	1
			60	2	1

	FORMULA	CONC %	TEMP (°C)	PVC	PE
HYDROCHLORIC ACID (MURIATIC ACID)	HCl	≤25	25	1	1
			60	2	1
		≤ 37	25	1	1
			60	1	2
HYDROCYANIC ACID (PRUSSIC ACID OR	HCN	deb	25	1	1
			60	1	1
HYDROGEN CYANIDE) HYDROFLUORIC ACID	HF	10	25	1	1
			60	2	1
HYDROGEN	H_2	all	25		
			60		
HYDROGEN - PEROXIDE (BLEACH)	H_2O_2	30	25	1	1
			60	1	1
		50	25	1	2
			60	1	-
- SULFIDE DRY		sat	25	1	1
			60	2	1
- SULFIDE WET		sat	25	1	1
			60	2	1
HYDROSUPHITE		≤10	25	1	
			60	2	
HYDROXYLAMINE SULPHATE	$(H_2NOH)_2H_2SO_4$	12	25	1	1
			60	1	
ILLUMINATING GAS		100	25	1	1
			60		
IODINE	I_2	3	25	2	
- DRY AND WET			60	3	
- TINCTURE		≤3	25	2	2
			60	3	3
ISOCTANE	C_8H_{18}	100	25	1	2
			60		
ISO-OCTANE	$(CH_3)_3CCH_2(CH_3)_2$				
ISOPROPYL -ETHER	$(CH_3)_2CHOCH(CH_3)_2$	100	25	2	2
			60	3	3
- ALCOHOL (ISOPROPANOL)		$(CH_3)_2CHOH$	100	25	
			60	2	
LACTIC ACID	$CH_3COHCOOH$	≤28	25	1	1
			60	2	1
LANOLINE		nd	25	1	
			60	2	1
LEAD ACETATE	$Pb(CH_3COO)_2$	sat	25	1	1
			60	1	-
LINSEED OIL		comm	25	1	
			60	2	2
LUBRICATING OILS		comm	25	1	3
			60	1	
MAGNESIUM - CARBONATE	$MgCO_3$	all	25	1	
			60	1	
- CHLORIDE	$MgCl_2$	sat	25	1	1
			60	1	1
- HYDROXIDE	$Mg(OH)_2$	all	25	1	
			60	1	
-NITRATE	$MgNO_3$	nd	25	1	1
			60	1	1
- SULFATE	$MgSO_4$	dil	25	1	1
			60	1	1
		sat	25	1	1
			60	1	1
MALEIC ACID	COOHCHCHCOOH	nd	25	1	1
			60	1	1
MALIC ACID (HYDROXYSUCCINIC ACID)	$CH_2CHOH(COOH)_2$	nd	25	1	1
			60	-	-
MERCURIC	$HgCl_2$	sat	25	1	1
- CHLORIDE			60	1	1
- CYANIDE	$HgCN_2$	all	25	1	
			60	1	
MERCUROUS NITRATE	$HgNO_3$	nd	25	1	1
			60	1	1
MERCURY	Hg	100	25	1	1
			60	2	1
METHYL	CH_3COOCH_3	100	25	-	-
- ACETATE			60	-	-
- ALCOHOL (METHANOL OR WOODSPIRIT)	CH_3OH	nd	25	1	
			60	1	1
- BROMIDE (BROMOMETHANE)	CH_3Br	100	25	3	3
			60		
- CHORIDE (CHLOROMETHANE)	CH_3Cl	100	25	3	1
			60	3	
- ETHYLKETONE	$CH_3COCH_2CH_3$	all	25	3	1
			60	3	2
METHYLAMINE	CH_3NH_2	32	25	2	1
			60	3	2

Chemical Resistance

	FORMULA	CONC %	TEMP (°C)	PVC	PE
METHYLENE CHLORIDE	CH_2Cl_2	100	25	3	3
(DICHLOROMETHANE)			60	3	
METHYL SULPHORIC ACID	CH_3COOSO_4	50	25	1	2
			60	2	2
		100	25	1	3
			60	2	3
MILK		100	25	1	1
			60	1	
MINERAL ACIDOULOUS		nd	25	1	1
WATER			60	1	1
MOLASSES		comm	25	1	1
			60	2	2
NAPHTA		100	25	2	2
			60	3	3
NAPHTALINE		100	25	1	1
			60	2	
NICKEL					
- CHLORIDE	$NiCl_3$	all	25	1	1
			60	1	1
- NITRATE	$Ni(NO_3)_2$	nd	25	1	1
			60	1	1
- SULFATE	$NiSO_4$	dil	25	1	1
			60	1	2
		sat	25	1	1
			60	1	1
NITRIC ACID	HNO_3	anhydrous	25	3	
			60	3	
		20	25	1	1
			60	2	2
		40	25	1	-
			60	1	2
		60	25	1	3
			60	2	3
		98	25	3	3
			60	3	3
NITROBENZENE	$C_6H_5NO_2$	all	25	3	
			60	3	2
OLEIC ACID	$C_8H_{17}CHCH(CH_2)_7CO_2H$	comm	25	1	-
			60	1	2
OLEUM (FUMING SULPHURIC) ACID OR PYROSULPHURIC ACID)	$H_2S_2O_7$	nd	25	3	
			60	3	3
- VAPOURS		low	25	3	
			60	3	
		high	25	3	
			60	3	
OLIVE OIL	comm	25			
			60	2	3
OXALIC ACID	HO_2CCO_2H	10	25	1	1
			60	2	1
		sat	25	1	1
			60	1	1
OXYGEN	O_2	all	25	1	1
			60	1	2
OZONE	O_3	nd	25	1	2
			60	2	3
PALMITIC ACID	$CH_3(CH_2)_{14}COOH$	10	25	1	-
			60	1	
		70	25	1	-
			60	1	
PARAFFIN (ALKANE)		nd	25		
			60	2	2
- EMULSION		comm	25	1	2
			60	1	2
- OIL (KEROSENE)		nd	25	1	
			60	1	
PERCHLORIC ACID	$HClO_4$	100	25	1	1
			60	2	1
		70	25	1	1
			60	2	2
PETROL					
- REFINED		100	25	1	
			60	1	
- UNREFINED		100	25	1	
			60	1	
PHENOL					
- AQUEOUS SOLUTION	C_6H_5OH	1	25	1	1
			60		
(CARBOLIC ACID)		≤90	25	2	1
			60	3	
PHENYL HYDRAZINE	$C_6H_5NHNH_2$	all	25	3	2
			60	3	2
- CHLORHYDRATE	$C_6H_5NHNH_3Cl$	sat	25	1	1
			60	3	3
PHOSPHORIC					
- ACID	H_3PO_4	≤ 25	25	1	1
			60	2	1
		≤50	25	1	1
			60		

	FORMULA	CONC %	TEMP (°C)	PVC	PE
		≤85	25	1	1
			60	1	2
- ANHYDRIDE	P_2O_5	nd	25	1	1
			60	2	1
PHOSPHORUS TRICHLORIDE	PCl_3	100	25	3	1
			60	3	
PHOTOGRAPHIC					
- DEVELOPER		comm	25	1	
			60	1	
- EMULSION		comm	25	1	1
			60	1	
PHTHALIC ACID	$C_6H_4(CO_2H)_2$	50	25	-	1
			60	3	1
PICRIC ACID	$HOC_6H_2(NO_2)_3$	1	25	1	1
			60	1	-
(2,4,6 TRINITROPENOL)		≥1	25	3	1
			60	3	
POTASSIUM					
- BICHROMATE (POTASSIUM HYDROGENCARBONATE)	$K_2Cr_2O_7$	40	25	1	1
			60	1	
- BORATE	K_3BO_3	sat	25	1	
			60	2	
- BROMATE	$KBrO_3$	nd	25	1	
			60	2	
- BROMIDEKBr		sat	25	1	1
			60	1	
- CARBONATE (POTASH)	K_2CO_3	sat	25	1	1
			60	1	1
- CHROLIDE (POTASSIUM MURIATE)	KCl	sat	25	1	1
			60	1	1
- CHROMATE	K_2CrO_4	40	25	1	1
			60	1	1
- CYANIDE	KCN	sat	25	1	1
			60	1	1
- FERROCYANIDE	$K_4Fe(CN)_{63}H_2O$	100	25	1	1
			60	1	1
- FLUORIDE	KF	sat	25	1	
			60	1	
- HYDROXIDE (CAUSTIC POTASH)	KOH	≤60	25	1	1
			60	2	1
- NITRATE KNO_3 (NITRE, SALTPETRE)	sat	25	1	1	
			60	1	1
- PERBORATE	KBO_3	all	25	1	
			60	1	
- PERBORATE	KBO_3	all	25	1	
			60		
- PERMANGANATE (PERMANGANATE OF POTASH)	$KMnO_4$	10	25	1	1
			60	1	1
- PERSULFATE	$K_2S_2O_8$	nd	25	1	1
			60	2	1
- SULFATE	K_2SO_4	sat	25	1	1
			60	2	1
PROPANE					
- GAS	C_3H_8	100	25	1	1
			60		
- LIQUID		100	25	1	2
			60		
PROPYL ALCOHOL (PROPANOL)	C_3H_7OH	100	25	1	1
			60	2	1
PYRIDINE	$CH(CHCH)_2N$	nd	25	3	1
			60	3	2
RAIN WATER		100	25	1	1
			60	1	1
SEA WATER		100	25	1	1
			60	1	1
SILICIC ACID	H_2SiO_3	all	25	1	1
			60	1	1
SILICONE OIL		nd	25	1	1
			60	3	2
SILVER					
- CYANIDE	AgCN	all	25	1	
			60	1	
- NITRATE	$AgNO_3$	nd	25	1	1
			60	2	1
- PLATING SOLUTION		comm	25	1	
			60	1	
SOAP - AQUEOUS SOLUTION		high	25	1	
			60	2	
SODIC LYE		≤60	25	1	
			60	1	
SODIUM					
- ACETATE	CH_3COONa	100	25	1	1
			60	1	1

	FORMULA	CONC %	TEMP (°C)	PVC	PE
- BICARBONATE (SODIUM HYDROGEN CARBONATE)	$NaHCO_3$	nd	25	1	1
		60	1	1	
- BISULFITE	$NaHSO_3$	100	25	1	1
			60	1	1
- BROMIDE	NaBr	sat	25	1	
			60	1	
- CARBONATE	Na_2CO_3	sat	25	1	1
			60	1	1
- CHLORATE	$NaClO_3$	nd	25	1	1
			60	2	1
- CHLORIDE	NaCl	dil	25	1	1
			60	2	1
		sat	25	1	1
			60	1	1
- CYANIDE	NaCN	all	25	1	
			60	1	
- FERROCYANIDE	$Na_4Fe(CN)_6$	sat	25	1	1
			60	1	1
- FLUORIDE	NaF	all	25	1	1
			60	1	1
- HYDROXIDE	NaOH	60	25	1	1
			60	1	1
- HYPOCHLORITE	NaOCl	deb	25	1	1
			60	2	
- HYPOSULFITE	$Na_2S_3O_3$	nd	25	1	
			60	1	
- NITRATE	$NaNO_3$	nd	25	1	1
			60	1	1
- PERBORATE	$NaBO_3H_2O$	all	25	1	
			60	1	
- PHOSPHATE di	Na_2HPO_4	all	25	1	
			60	1	
- PHOSPHATE tri	Na_3PO_4	all	25	1	1
			60	1	1
- SULPHATE	Na_2SO_4	dil	25	1	
			60	1	
		sat	25	1	1
			60	1	1
- SULFIDE	Na_2S	dil	25	1	1
			60	2	1
		sat	25	1	1
			60	1	1
- SULFITE	$NaSO_3$	sat	25	1	
			60	1	
STANNIC CHLORIDE	$SnCl_4$	sat	25	1	1
			60	1	1
STANNOUS CHLORIDE	$SnCl_2$	dil	25	1	1
			60	1	1
STEARIC ACID	$CH_3(CH_2)_{16}CO_2H$	100	25	1	
			60	1	2
SUGAR SYRUP		high	25	1	1
			60	2	1
SULPHUR	S	100	25	1	
			60	2	
- DIOXIDE AQUEOUS	SO_2	sat	25	1	1
			60	2	
- DIOXIDE DRY		all	25	1	1
			60	1	1
- DIOXIDE LIQUID		100	25	2	1
			60	3	2
- TRIOXIDE	SO_3	100	25	2	3
			60	2	3
SULPHURIC ACID	H_2SO_4	≤ 10	25	1	1
			60	1	1
		≤75	25	1	1
			60	2	2
		≤90	25	1	2
			60	2	2
		≤96	25	2	2

	FORMULA	CONC %	TEMP (°C)	PVC	PE
		60	3	2	
- FUMING (OLEUM)		all	25	2	
			60	3	
- NITRIC AQUEOUS SOLUTION	$H_2SO_4+HNO_3+H_2O$	48/49/3	25	1	3
			60	2	3
		50/50/0	25	2	3
			60	3	3
		10/20/70	25	1	2
			60	1	2
TALLOW EMULSION		comm	25	1	1
			60	1	2
TANNIC ACID	$C_{14}H_{10}O_9$	10	25	1	1
			60	1	1
TARTARIC ACID	$HOOC(CHOH)_2COOH$	all	25	1	1
			60	2	1
TETRACHLORO - ETHANE	$CHCl_2CHCl_2$	nd	25	3	2
			60	3	3
- ETHYLENE (PERCHLOROETHYLENE)	CCl_2CCl_2	nd	25	3	2
			60	3	3
TETRAETHYLLEAD	$Pb(C_2H_5)_4$	100	25	1	1
			60	2	
TETRAHYDROFURAN	C_4H_8O	all	25	3	2
			60	3	3
THIONYL CHLORIDE	$SOCl_3$	-	25	3	3
			60		
THIOPHENE	C_4H_4S	100	25	3	2
			60	3	2
TOLUENE	$C_6H_5CH_3$	100	25	3	2
			60	3	3
TRANSFORMER OIL		nd	25	1	1
			60	2	2
TRICHLORO-ACETIC ACID	CCl_3COOH	≤50	25	1	1
			60	3	2
TRICHLOROETHYLENE	Cl_2CCHCl	100	25	3	2
			60	3	2
TRIETHANOLAMINE	$N(CH_2CH_2OH)_2$	100	25	2	1
			60	3	
TURPENTINE		100	25	2	2
			60	2	3
UREA AQUEOUS SOLUTION	$CO(NH_2)_2$	≤ 10	25	1	1
			60	2	1
		33	25	1	1
			60	2	1
URINE		nd	25	1	1
			60	2	1
URIC ACID	$C_5H_4N_4O_3$	10	25	1	
			60	2	
VASELINE OIL		100	25	1	1
			60	3	2
VINYL ACETATE	$CH_3CO_2CHCH_2$	100	25	3	
			60	3	
WHISKEY		comm	25	1	
			60	1	
WINES		comm	25	1	1
			60	1	
WINE VINEGAR		comm	25	1	1
			60	2	1
ZINC - CHLORIDE	$ZnCl_2$	dil	25	1	1
			60	1	1
		sat	25	1	1
			60		
- CHROMATE	$ZnCrO_4$	all	25	1	
			60	1	
- CYANIDE	$Zn(CN)_2$	all	25	1	
			60		
- NITRATE	$Zn(NO_3)_2$	nd	25	1	
			60	1	
- SULFATE	$ZnSO_4$	dil	25	1	1
			60	1	1
		sat	25	1	1

Sustainable Manufacturing

Marley is committed to creating environmentally sustainable processes and products and was the first plastics manufacturer in New Zealand to achieve ISO14001 registration. We are also Best Environmental Practice certified for our entire range of manufactured uPVC systems. This means we get our raw materials from sustainable and responsible sources, continuously work on our manufacturing processes to reduce our environmental footprint and accept our products back at the end of their useful life for recycling.

FOLLOW US @MARLEYNEWZEALAND

MAR3526 March 2019

OUR PARTNERS

For more information: **0800 MARLEY (0800 627539)** | www.marley.co.nz