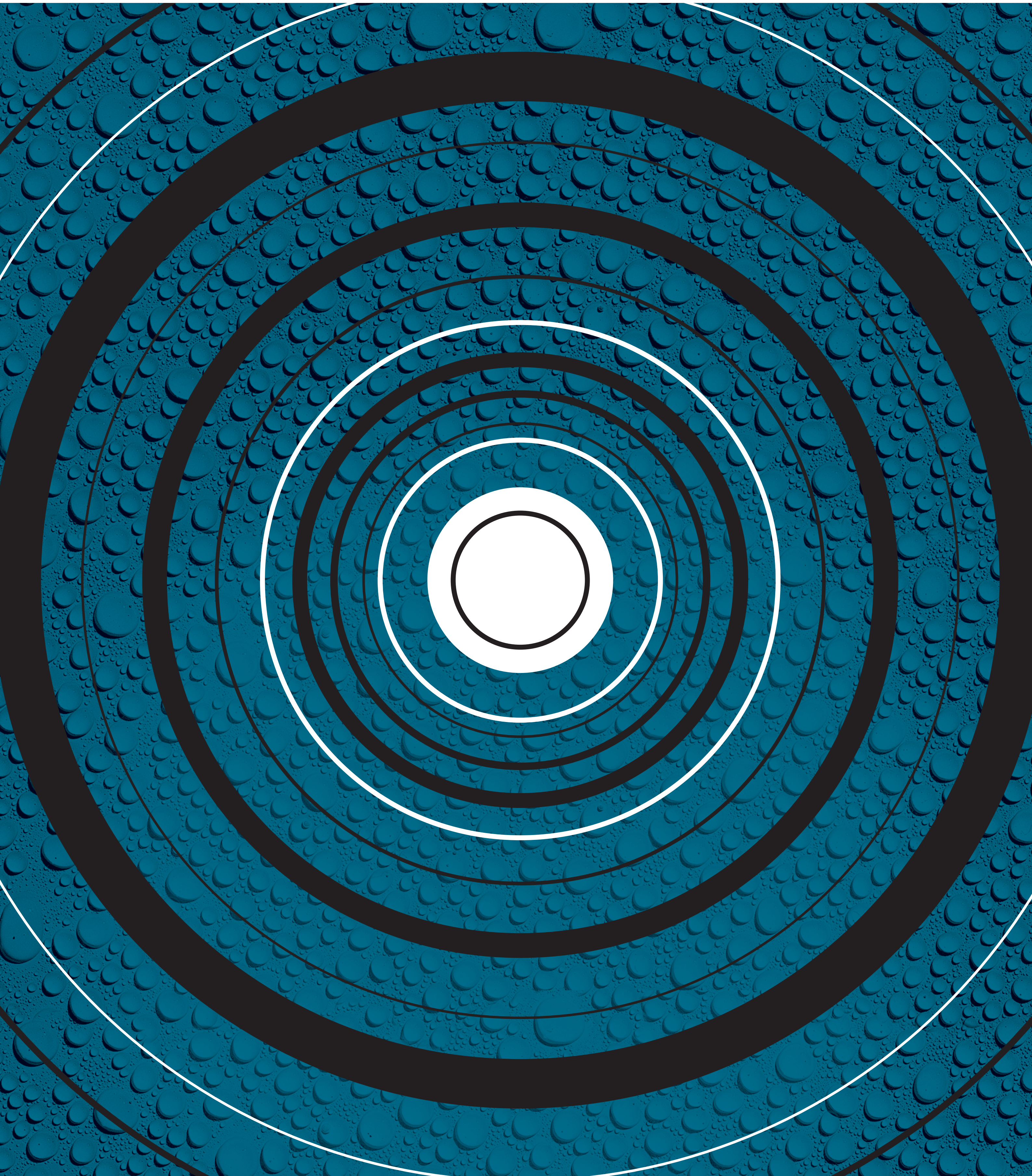
Pressure Technical Manual

For PVC and polyethylene pipe systems



Civil and Infastructure Solutions

MARLEY

by aliaxis

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- GENERAL

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PLASTICS PIPES FOR PRESSURE APPLICATIONS

This manual has been designed to detail the properties, design and installation requirements for the plastics pipe systems produced by Marley New Zealand Limited. These plastics pipes are made from PVC and MDPE and where comments are made that are relevant to both systems the term “plastics” is used. For specific details relevant to a particular material type the generic term (ie, PVC or MDPE) is.

PVC (POLYVINYL CHLORIDE)

PVC is produced from the polymerisation of VCM (Vinyl Chloride Monomer) which is made from sodium chloride (common salt) and hydrocarbons from natural gas. PVC requires the addition of certain additives including heat stabilisers and lubricants to enable it to be processed into finished products.
The addition of plasticisers results in flexible PVC which is commonly used for hoses, shoe soles, flooring and upholstery materials.
Rigid PVC pressure pipes do not contain plasticisers and are commonly referred to as uPVC or PVC-u pipes indicating that they are unplasticised.
PVC can also be made more ductile with the use of impact modifiers and these pipes are referred to as mPVC or PVC-m pipes.
In this manual PVC is used to refer to both PVC-u and PVC-m pipes and where a specific property may differ it is referenced by its full name.

MEDIUM DENSITY PE (MDPE)

MDPE materials are produced by low pressure polymerisation methods and have densities in the range of 0.93 - 0.94 kg/m3.
The current range of materials referred to as MDPE are classified as PE 100, PE 80B materials which are specialised polyethylene polymers.
MDPE materials generally have improved properties in elongation and crack propagation compared to HDPE materials.
Applications include any water reticulation, sewer and waste water ducts, gas pipe, elevated temperature applications such as artesian bore water reticulation, travelling irrigator coils and rural water reticulation due to the nature of the piping.

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 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 a hydrostatic pressure test 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 MDPE. 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:

PVC-u	2.14 - AS/NZ - 1477 • 1999
PVC-m	1.42 - AS/NZ - 4765
PE80	1.25 - AS/NZ - 4130 • 1997

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.
Where the particular application departs from the AS/NZS4130 design criteria, which is based on 50 years, in that a shorter lifetime is required, then the pressure rating of the pipe may be adjusted.
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 are appropriate.

THE STRESS REGRESSION LINE FOR HOOP STRESS

The traditional method for portraying the tensile strength of plastics 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 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

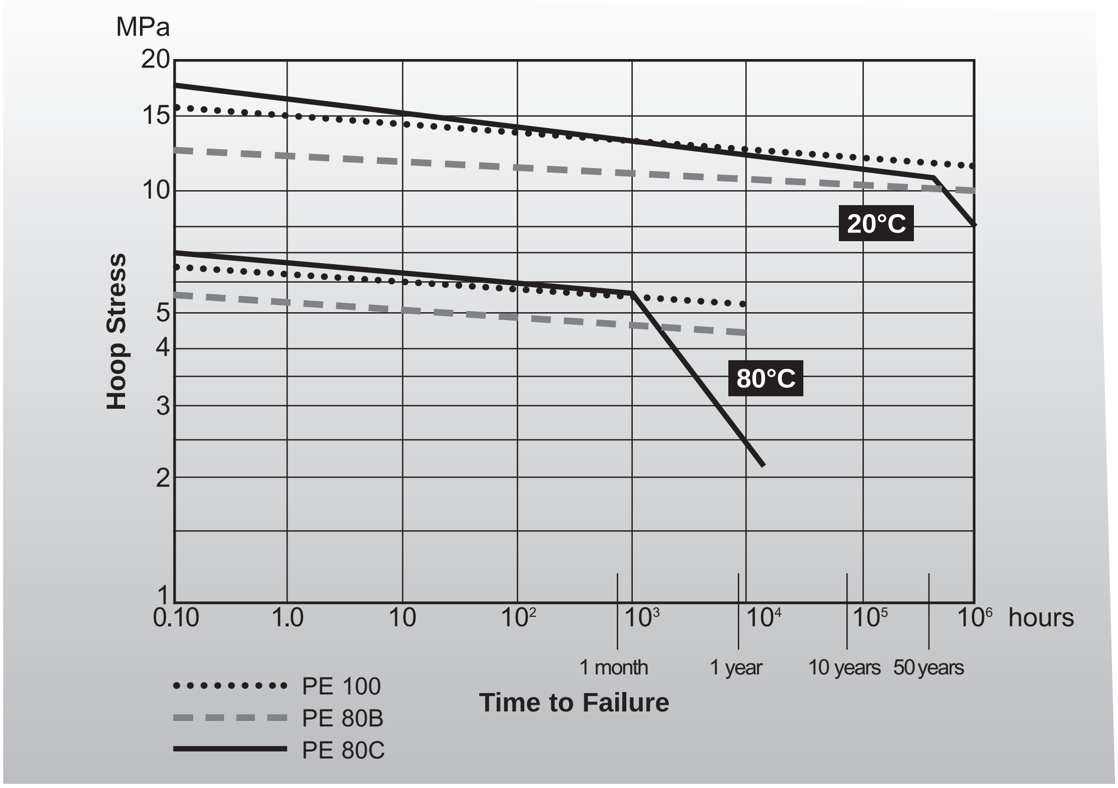
With MDPE which exhibits a knee in the regression line testing is also done at elevated to determine the position of the knee. This stress regression which is used to define the knee is used only as a design basis and does not predict the system life which has been shown to be significantly greater than the conservative predictions.

For specification purposes the design points adopted for PVC-u pipes is the 50 year line with an ultimate stress of 23.6 MPa (26.0 MPa for pipes 175mm and above) giving a safety factor of 2.1. It can be seen that the safety factor at 100 years is only slightly lower. For PVC-m the ultimate stress is 17.5 MPa.
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 MDPE manufactured to AS/NZ4130 are established by use of the Barlow formula as follows:

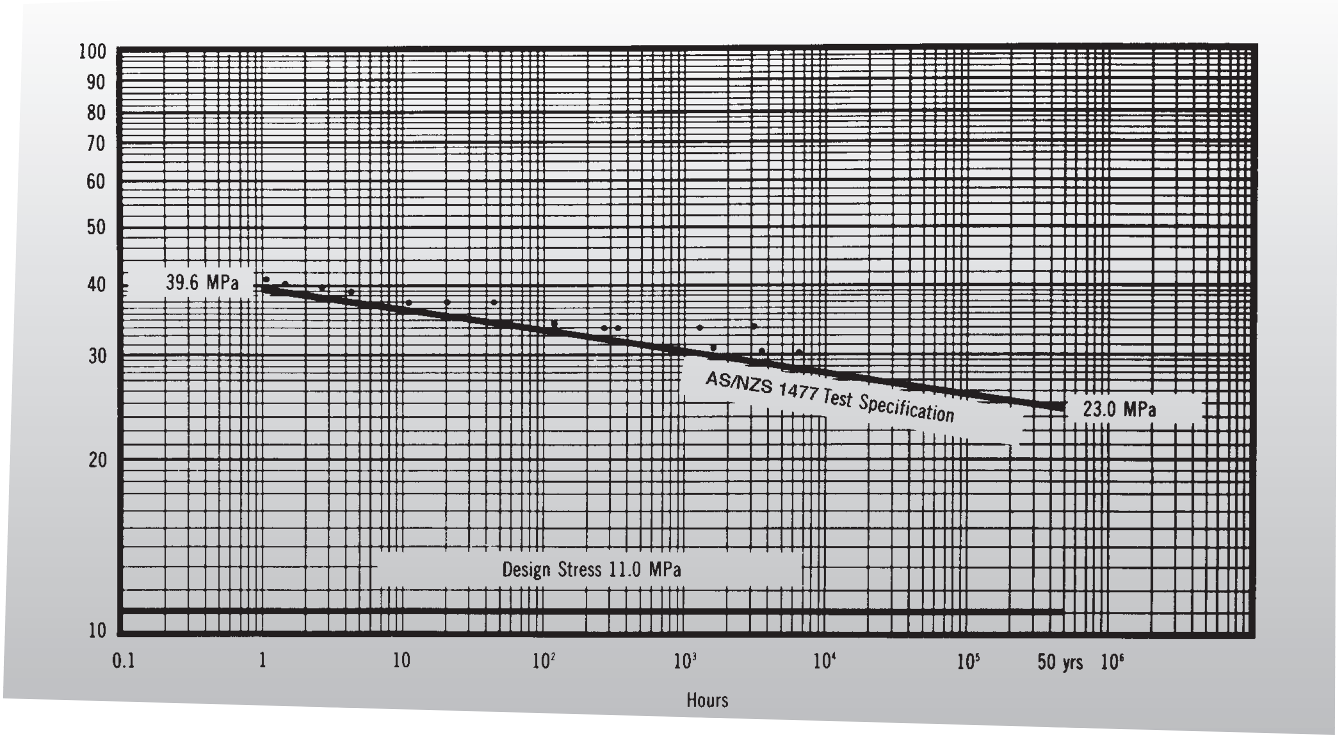
$$T = \frac{PD}{2S + P} \qquad \text{and} \qquad S = MRS/C$$

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



TYPICAL STRESS REGRESSION CURVES FOR PVC



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 particular impact when using fusion jointing techniques and leads to recommendations for the scraping of the surface of the material prior to jointing.
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.
Natural PVC is degraded by prolonged exposure to UV unless it is afforded some protection. Marley PVC pipes are stabilised with Ti02 to provide suitable protection for up to 50 years exposure.
UV degradation will result in micro crazing of the surface which results in a reduction of impact strength. Tests have shown however that the hoop stress of the pipe is not compromised when such degradation occurs. Marley recommend that pipes that are to be installed in situations where they are directly exposed to UV should be protected by painting with a light coloured acrylic paint or covered.

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 distorted, 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 plastic 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

uPVC Pipes

Temp °C	PN6	PN9	PN12	PN15
20	0.60	0.90	1.20	1.50
30	0.48	0.72	0.96	1.20
40	0.36	0.54	0.72	0.90
50	0.24	0.36	0.48	0.60
60	0.12	0.18	0.24	0.30

PE80B Material

Maximum Working Pressure (Metres Head)						
Temp °C	**PN4**	**PN6.3**	**PN8**	**PN10**	**PN12.5**	**PN16**
20	40	63	80	100	125	160
25	39	61	78	97	122	156
30	37	59	75	94	112	156
35	35	55	70	87	109	140
40	32	51	65	81	102	130
45	30	47	60	75	94	120
50	26	41	52	65	81	104

PE100 Material

Maximum Working Pressure (Metres Head)						
Temp ºC	**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 the relationship:

$$P_T = P_{20} \frac{(70 - T)}{50}$$

where:

P_T = maximum working pressure at T°C
P_{20} = maximum working pressure at 20°C
T = material temperature °C

This is equivalent to a reduction in working pressure of 2% per 1°C rise in temperature above 20°C. Pressure ratings for pipes of other classes may be computed from these relationships.
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:

$$T_m = T_1L_1 + T_2L_2 + ... + T_nL_n$$

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 lager 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 20°C. The December-February average is 25°C. Although diurnal variations occur with air temperatures up to 40°C during heatwave period, water temperatures and ground temperatures at pipe depth do not exceed the mean of 27°C. A 50 year life is required at basic factor of safety 2.145.

Weighted average temperature:

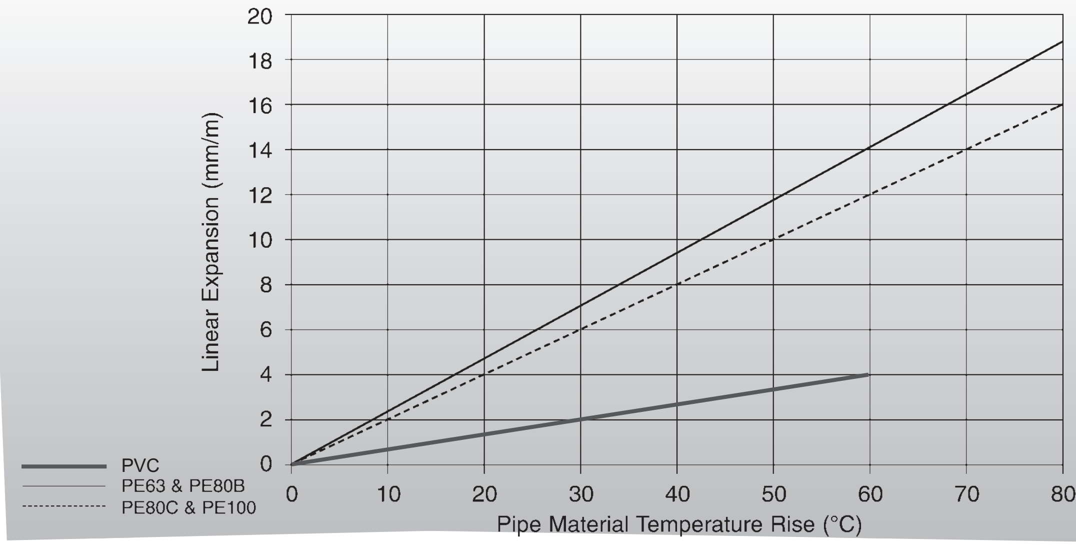
Tm = 25(3/12) + 20.5(6/12) + 15(3/12)
= 6.25 + 10.25 + 3.75 = 20.25°C

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

EXPANSION AND CONTRACTION

All materials expand and contract with changes in temperature and uPVC has a relatively high rate of change.
The coefficient of thermal expansion for PVC is 7×10^{-5}/°C.
A handy rule is 7 mm change in length for every 10 metres for every 10°C change in temperature.
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 shouldbe 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.
Where rubber ring jointed (Z joint) pipe is used for buried urban water supply, the thermal movement caused by seasonal changes in temperature can be absorbed by the rubber ring rocking in the recess. The joint is not able to absorb the gross movement caused on occasions by the severe temperature drop at the time of laying.
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.
Values and heavy components must be independently supported so that no stresses are imposed on the pipeline.

THERMAL LINEAR EXPANSION OF PLASTICS PIPE



TOUGHNESS

General

In practice it is recognised that plastics 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 PVC and MDPE pipe in the water industry confirms this confidence.

Abrasion

Plastics 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 therefore required 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 plastics 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:

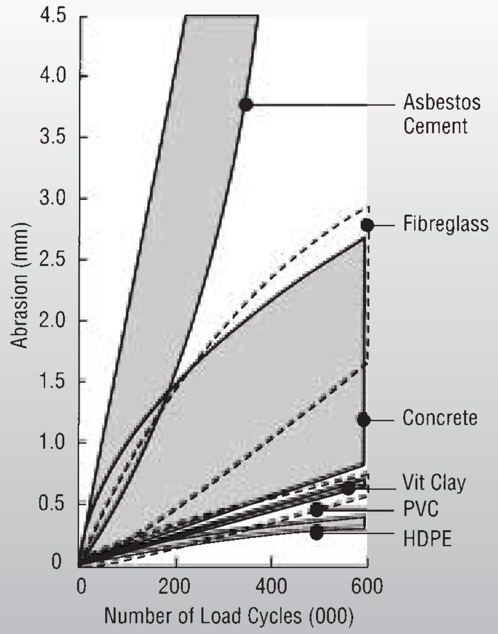
- the specific gravity of the solids
- the solids content in the slurry
- solid particle shape, hardness and size
- fluid velocity
- pipe material

In general terms plastics 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 and PVC.

Conductivity

Plastics pipes are poor conductors. At all times PE pipe should be protected against radiant heat that could raise its surface temperature above 60C.
Plastics 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 plastics 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 plastics 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.
PVC pipe systems may support combustion but are self-extinguishing when the source of ignition is removed.

CHEMICAL RESISTANCE AND STABILITY

Corrosion Resistance

For all practical purposes, plastics 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

Plastics pipes have a good resistance to a wide range of chemicals. In the water supply context, 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, cracking agents and certain solvents as shown in 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) the use of PVC or MDPE is NOT recommended unless suitability sleeved, although it is noted leakage of this nature is not acceptable under the Environment Act.

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

Chemical Attack

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

1. Swelling of the plastic occurs but the plastic returns to its original condition if the chemical is removed. However, if the plastic has a compounding ingredient that is soluble in the chemical, the plastic may be changed because of the removal of this ingredient and the chemical itself will be contaminated.
2. The base resin or polymer molecules are changed by crosslinking, oxidation, substitution reactions or chain scission. In these situations the plastic cannot be restored by the removal of the chemical. Examples of this type of attack on uPVC are aqua regia at 20^{o}C and wet chlorine gas.

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 plastics under stress can undergo higher rates of attack. In general uPVC is considered relatively insensitive to “stress corrosion”.

Considerations for Plastics Pipe

For normal water supply work, plastics 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. Table 2 gives guidance in this context.
For applications characterised as food conveyance or storage, health regulations should be observed. Specific advice should be obtained on the use of plastics pipes.

PERMEABILITY

Plastics pipes can be shown to be permeable to certain gases and liquids under extreme conditions, 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.

Chemicals Potentially Harmful to Plastics Pipes

Group	Generalised Examples	Effect on MDPE	Effect on PVC
Oxidisers	Very strong acids	Degradation.	Generally no degradation
Cracking agents	Concentrated Detergents	No degradation. (Under high temperatures, accelerates cracking under stress in brittle manner).	No degradation
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.	Can swell and soften PVC causing reduction in hoop strength and possible taste problems.
Alkaline Solutions	Strong Alkalines	No degradation	Generally no degradation but Chloride Solution needs to be given special attention.

Note: For detailed information refer to Chemical Resistance Chart.

2. PVC & PE

- Consideration before Design

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- PVC

- PE

Mainlaying Design and Installation Considerations

Design Considerations

1. PVC pipes are usually joined using the push-fit elastomeric jointing ring or solvent cement techniques. The push-fit technique has advantages as it is less dependent on weather conditions and provides allowances for pipe movement. The solvent cement technique is usually restricted to smaller diameter pipes.

2. 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.

3. The properties of PVC make it suitable for areas subject to minor ground movements due to seismic forces, mining subsidence, compaction of filled sites or the disturbance caused by the activities of other utilities in the vicinity. In larger sizes greater than DN 160 special attention to the flexibility of the joints is necessary.

4. Where PVC is to be used in environments with temperatures greater than 20°C for prolonged periods, the allowable operating pressure should be reduced in accordance 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 on PVC 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. PVC is resistant to most chemicals, but is vulnerable to petroleum products and certain solvents. Where concentrations of such contaminants exist, PVC 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 when empty. This particularly applies to the larger diameters where special anchoring or weighting may be necessary prior to backfilling.

8. Direct connection of PVC to sources of high frequency should be avoided and a flexible joint should be used to isolated such vibration.

Laying Considerations

1. Gradual changes of direction of PVC 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.

2. PVC should generally be installed in straight runs in order to reduce the stresses induced when the pipe is bent. It is possible in some circumstances however to bend the pipe in a radius no less than 200 times the pipe diameter. Elastomeric ring joints will provide for some deflection of the pipe in the vicinity of 3° but it is unacceptable for the trailing joint to have an angular deflection greater than 1°C.

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. In cold conditions allowance should be made for expansion with push-fit joints to accommodate subsequent thermal expansion. Once a pipeline is installed the temperature variation is usually very small and is not likely to induce any significant stress or movement in the pipe system.

4. Whenever possible, a minimum distance of 300mm from obstructions 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.

5. PVC is not a conductor of electricity and no attempt should be made to use PVC 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.

6. PVC is a poor conductor of heat but can burn when subjected to a naked flame. Upon removal of the source of ignition burning ceases.

7. The installation of flanged fittings such as sluice valves, hydrant tees, end caps etc. usually requires the use of 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.

8. Where there are large diameter fabricated fittings installed in the main, similar concrete support may be necessary to counteract the imbalance of forces under working conditions.

9. PVC 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.

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

11. 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 for 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 testing.

12. 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 re-tighten all bolted and flanged joints and to check that all intermediate control valves are open.

13. 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 feature should be considered.

14 The marker tape, where used , should be laid along the line of the main and connected at each end to either a sluice valve or hydrant. The recommended position of the tape is 350mm below the surface directly above the crown of the pipe.

Mainlaying Design and Installation Considerations

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. 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.

3. The properties of MDPE make such 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 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. Where concentrations of such contaminants exist, 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 PE80 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.

Laying 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 adapter 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.

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.

... Laying Considerations

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

3. PVC

RETURN TO CONTENTS

- **Material Properties**
- **Pipe Dimensions**
- **Assembly & Socket Construction Dimensions**
- **Flow Charts**
  - **-Series 1 (PN 6, PN 9, PN 12, PN 15, PN 18)**
  - **-Series 2 (PN 4.5 to 20)**
- **Fitting Dimensions**

MATERIAL PROPERTIES

PROPERTIES OF uPVC

PROPERTY	VALUE	CONDITIONS AND REMARKS
PHYSICAL PROPERTIES		
Molecular weight	14,000	
Relative density	1.42	cf: 1.48
Water absorption	0.12%	23˚C, 24 hours
Hardness	80	Shore D Durometer, Brinell 15, Rockwell R 114
Impact strength: 20˚C	20kJ/m^2	Charpy 250 µm notch tip radius
Impact strength: 0˚C	8kJ/m^2	Charpy 250 µm notch tip radius
Coefficient of friction	0.4	uPVC to uPVC cf: PE 0.25
MECHANICAL PROPERTIES		
Ultimate tensile strength	52 MPa	AS 1175 Tensometer at constant strain rate
Elongation at break	50 - 80%	AS 1175 Tensometer at constant strain rate
Short term creep rupture	44 MPa	Constant load 1 hour value cf: PE 10 - 16
Long term creep rupture	28 MPa	Constant load extrapolated 50 year value
Elastic tensile modulus	3.0 - 3.3 GPa	1% strain at 100 seconds cf: PE 0.6 - 0.8
Elastic flexural modulus	2.7 - 3.0 GPa	1% strain at 100 seconds cf: PE 0.6 - 0.8
Long term creep modulus	0.9 - 1.2 GPa	Constant load extrapolated 50 year secant value
Shear modulus	1.0 GPa	1% strain at 100 seconds
Bulk modulus	4.7 GPa	1% strain at 100 seconds
Poissons ratio	0.4	Increases marginally with time under load
ELECTRICAL PROPERTIES		
Dielectric strength (breakdown)	14 - 20 kV/mm	Short term, 3mm specimen
Volume resistivity	$2 \times 10^{14}\ \Omega$m	AS 1255.1
Surface resistivity	$10^{13} - 10^{14}\ \Omega$	AS 1255.1
Dielectric constant (permittivity)	3.9 (3.3)	50 Hz (10^{6}Hz) AS 1255.4
Dissipation factor (power factor)	0.01 (0.02)	50 Hz (10^{6}Hz) AS 1255.4
THERMAL PROPERTIES		
Softening point	80 - 84^{0}C	Vicat method 120B BS 2782
Max. continuous service temp.	60^{0}C	
Coefficient of thermal expansion	7×10^{-5}/K	7mm per 10m per 10^{0}C cf: PE 18-20 x 10^{-5}
Thermal conductivity	0.16 W/[m.K]	0-50^{0}C
Specific heat	1,000 J/[kg.K]	0-50^{0}C
Thermal diffusivity	1.1×10^{-7} m^2/s	0-50^{0}C
FIRE PERFORMANCE		
Flammability	45%	ASTM D2683 Fennimore Martin test, cf: PE 17.5
Ignitability test	10 - 12 (/20)	cf: 9 - 10 when tested as pipe)
Smoke produced test	6 - 8 (/10)	cf: 4 - 6 when tested as pipe) AS 1530
Heat evolved test	0	) Early Fire
Spread of flame index	0	Will not support combustion) Hazard Test

General properties of uPVC compounds used in pipe manufacture are given. Properties of thermoplastics are subject to significant changes with temperature, and the applicable range is noted where appropriate. Mechanical properties are subject to duration of stress application, and are more properly defined by creep functions. More detailed data pertinent to pipe applications are given in the design section of this manual. For data outside of the range of conditions listed, users are advised to contact our Technical Department.

MARLEY UPVC PRESSURE PIPE

Standard: AS/NZS 1477:1999 series 1

		PN6				PN9				PN12				PN15				PN18			
Nominal Size	Mean OD	T Min	T Max	Mean Bore	Mass kg/m	T Min	T Max	Mean Bore	Mass kg/m	T Min	T Max	Mean Bore	Mass kg/m	T Min	T Max	Mean Bore	Mass kg/m	T Min	T Max	Mean Bore	Mass kg/m
15	21.4	-	-	-	-	-	-	-	-	-	-	-	-	1.4	1.7	18.3	0.138	1.6	2.0	17.8	0.158
20	26.8	-	-	-	-	-	-	-	-	1.4	1.7	23.7	0.175	1.7	2.1	23.0	0.212	2.0	2.4	22.4	0.243
25	33.6	-	-	-	-	1.4	1.7	30.5	0.223	1.7	2.1	29.8	0.270	2.1	2.5	29.0	0.323	2.5	3.0	28.1	0.381
32	42.3	-	-	-	-	1.7	2.1	38.5	0.344	2.2	2.6	37.5	0.430	2.7	3.2	36.4	0.521	3.2	3.7	35.4	0.601
40	48.3	1.4	1.7	45.2	0.325	1.9	2.3	44.1	0.435	2.5	3.0	42.8	0.562	3.1	3.6	41.6	0.676	3.6	4.2	40.5	0.777
50	60.4	1.6	2.0	56.8	0.473	2.4	2.8	55.2	0.675	3.1	3.6	53.7	0.858	3.8	4.4	52.2	1.036	4.6	5.3	50.5	1.232
65	75.4	2.0	2.4	71.0	0.723	3.0	3.5	68.9	1.053	3.9	4.5	67.0	1.342	4.8	5.5	65.1	1.624	5.7	6.5	63.2	1.898
80	88.9	2.4	2.8	83.7	1.008	3.5	4.1	81.3	1.453	4.6	5.3	79.0	1.867	5.7	6.5	76.7	2.269	6.7	7.6	74.6	2.626
100	114.3	3.0	3.5	107.8	1.621	4.5	5.2	104.6	2.385	5.9	6.7	101.7	3.057	7.3	8.2	98.8	3.732	8.6	9.7	96.0	4.322
125	140.2	3.7	4.3	132.2	2.448	5.5	6.3	128.4	3.560	7.2	8.1	124.9	4.555	8.9	10.0	121.3	5.551	10.6	11.9	117.7	6.517
150	160.3	4.2	4.8	151.3	3.149	6.3	7.1	146.9	4.622	8.3	9.3	142.7	5.987	10.2	11.4	138.7	7.251	12.1	13.5	134.7	7.531
200	225.3	5.4	6.1	213.8	5.719	7.9	8.9	208.5	8.138	10.5	11.7	203.1	10.68	12.9	14.4	198.0	12.98	15.3	17.1	192.9	15.22
225	250.4	6.0	6.7	237.7	6.961	8.8	9.9	231.7	10.12	11.6	13.0	225.8	13.15	14.4	16.0	220.0	16.06	17.0	19.0	214.4	18.79
250	280.4	6.7	7.5	266.2	8.717	9.9	11.1	259.4	12.73	13.0	14.5	252.9	16.47	16.1	17.9	246.4	20.12	19.1	21.2	240.1	23.56
300	315.5	7.5	8.5	299.5	11.05	11.1	12.4	292.0	16.03	14.7	16.3	284.5	20.89	18.1	20.1	277.3	25.43	21.5	23.8	270.2	29.79
375	400.5	9.5	10.7	380.3	17.71	14.1	15.7	370.7	25.81	18.6	20.7	361.2	33.62	23.0	25.5	352.0	40.99	27.3	30.2	343.0	48.02

MARLEY UPVC SUPER BLUE

Standard: AS/NZS 1477:1999 series 2

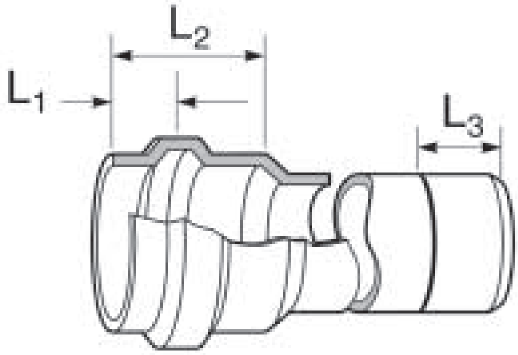
		PN12				PN18			
Nominal Size	Mean OD mm	T Min mm	T Max mm	Mean Bore mm	Mass kg/m	T Min mm	T Max mm	Mean Bore mm	Mass kg/m
100	121.9	6.3	7.1	108.5	3.467	9.2	10.3	9.8	4.912
150	177.4	9.2	10.3	157.9	7.341	13.4	14.9	14.2	10.374
200	232.3	10.8	12.1	209.4	11.358	15.9	17.7	16.8	16.261

MARLEY UPVC PRESSURE PIPE

Assembly and Socket Construction Dimensions (RRJ)

Standard: AS/NZS 1477:1999 series 1

nom size	S	L1	L2	L3
50	80.7	25-30	120	91
65	97.1	30-37	130	103
80	115.0	33-40	135	110
100	147	40-45	130	100
125		47-55	135	110
150	204	55-63	160	130
175	242		173	145
200	272	65-75	190	160
225	294	65-75	185	160
250	331	65-80	225	195
300	382	85-95	230	170
375	476	95-115	250	200

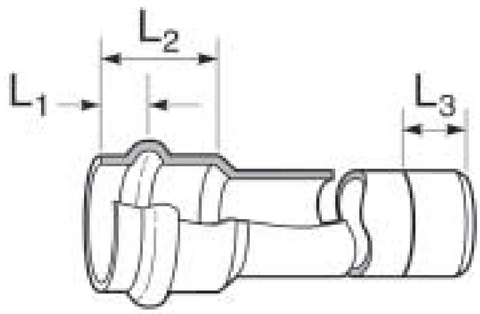


MARLEY UPVC SUPER BLUE

Assembly and Socket Construction Dimensions

Standard: AS/NZS 1477:1999 series 2

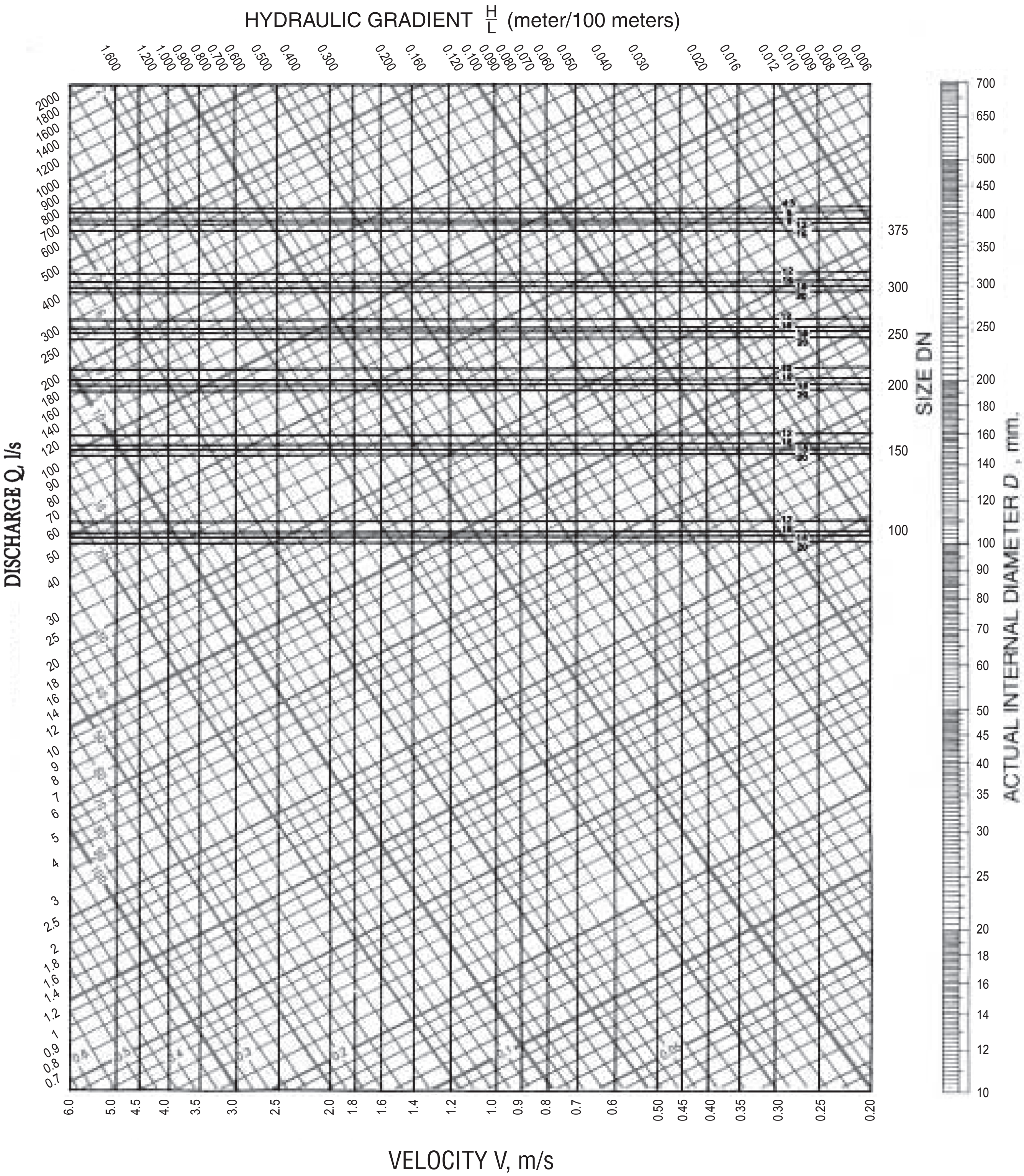
nom size	S	L1	L2	L3
100	157	46-52	134	130
150	221	60-70	172	155
200	288	60-70	183	171



PVC Flow Chart

- PN 4.5 to PN 20

AS1477 PVC (Marley Super Blue)

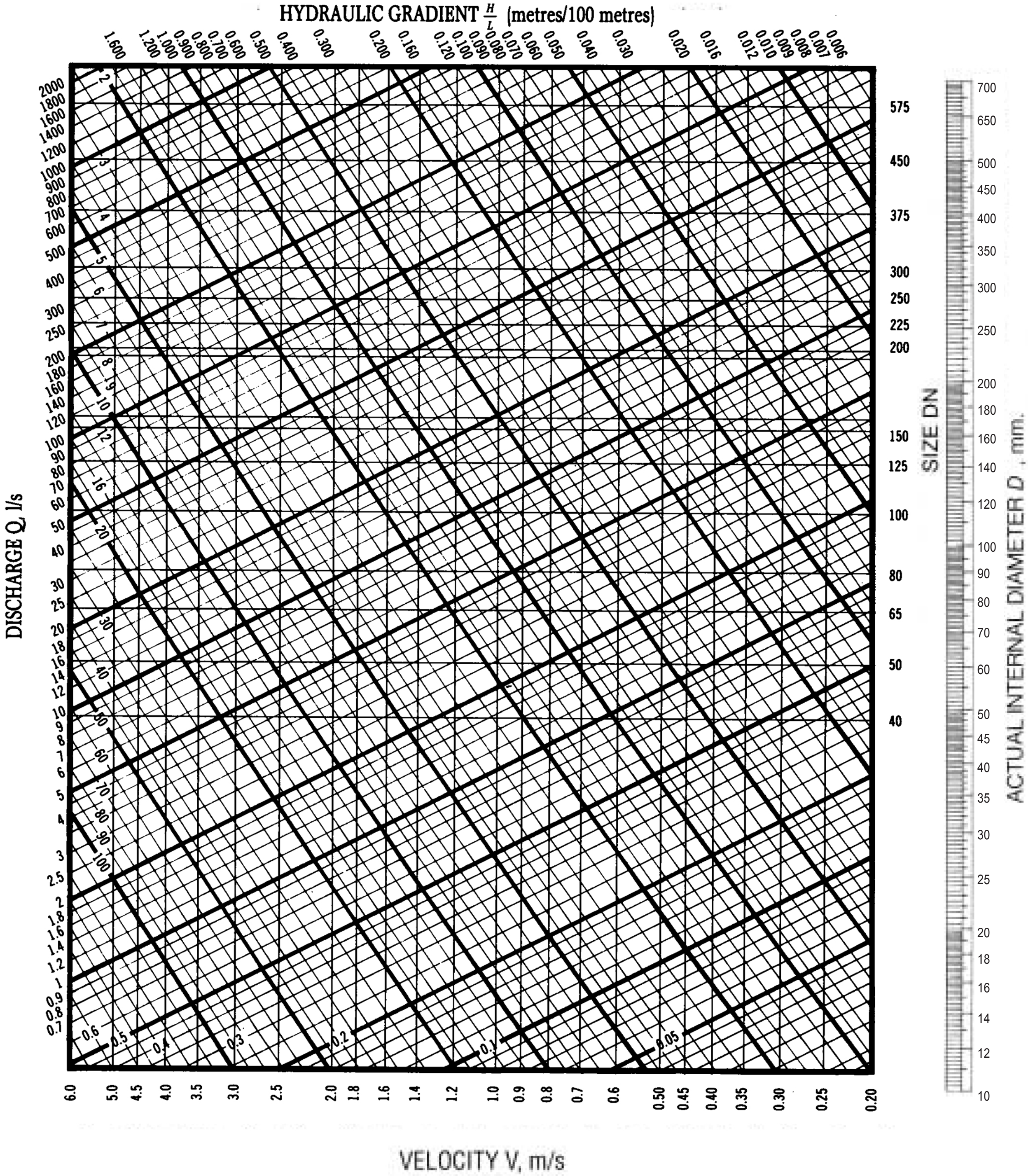


Hydraulic design of pipes k = 0.003mm based on Colebrook-White formula for pipes flowing full with water at 20˚c

PVC Flow Chart

- PN 6

AS1477 Series 1

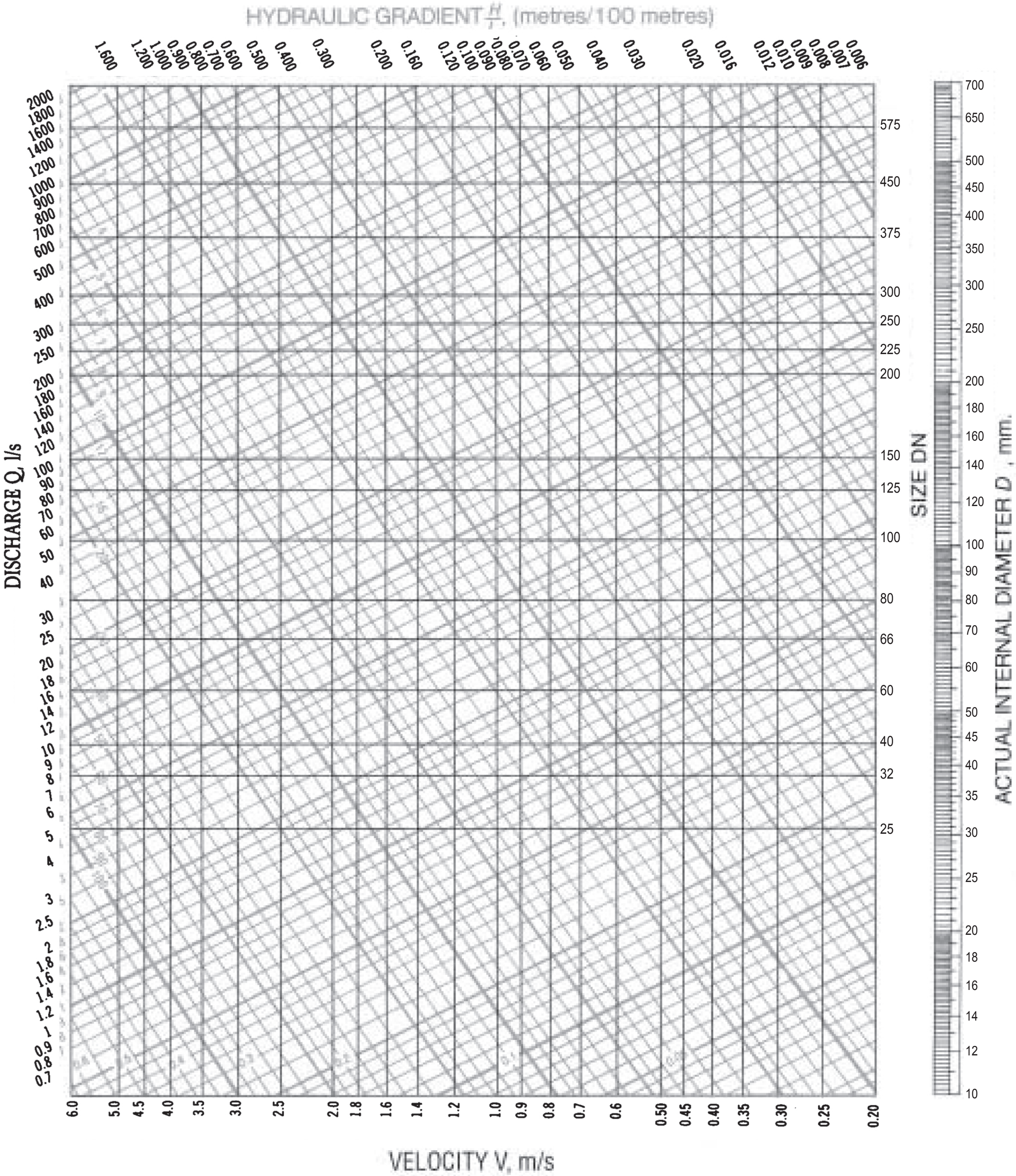


HYDRAULIC DESIGN OF PIPES k = 0.003mm BASED ON COLEBROOK-WHITE FORMULA FOR PIPES FLOWING FULL WITH WATER AT 20°C.

PVC Flow Chart

- PN 9

AS1477 Series 1

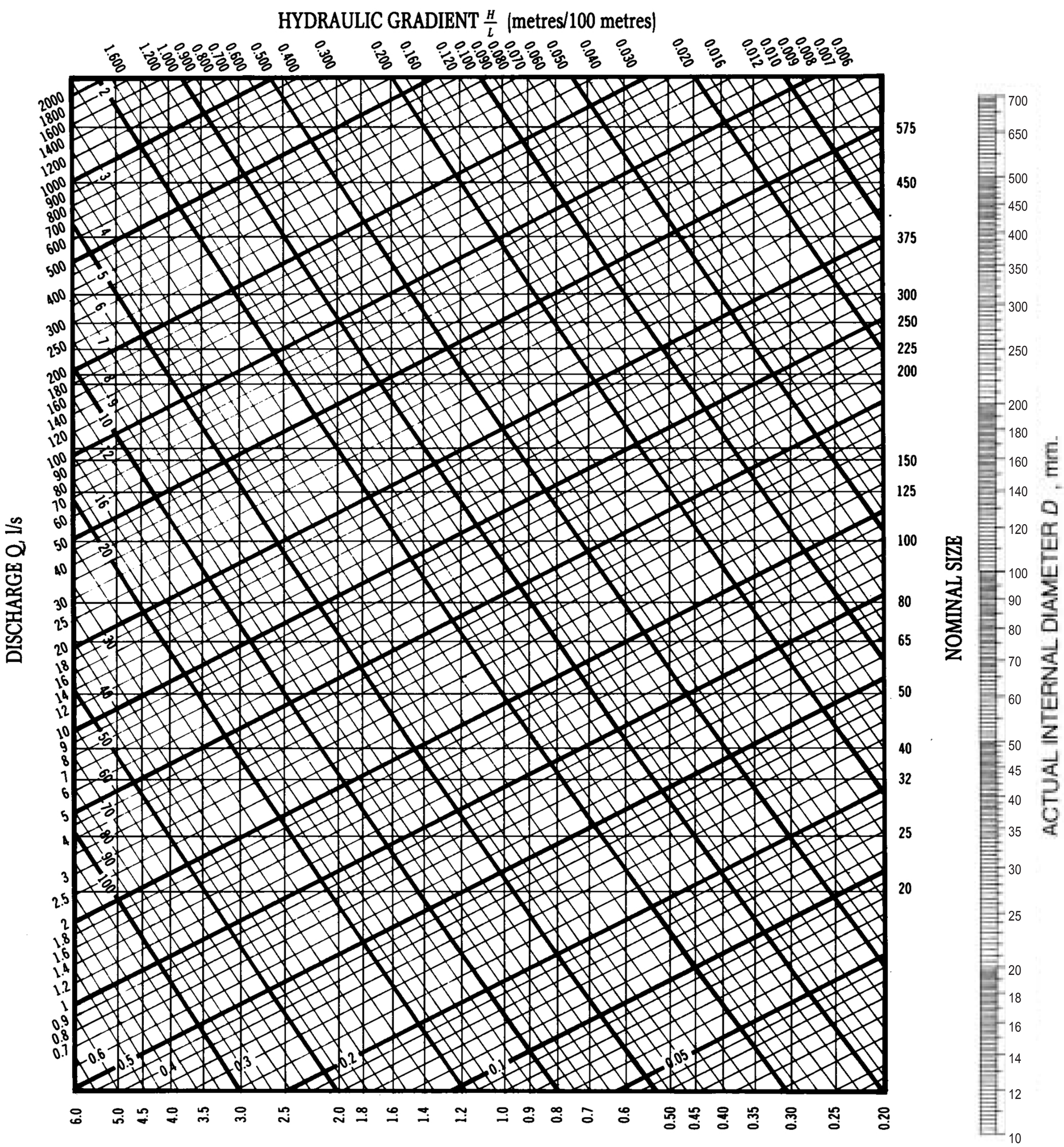


HYDRAULIC DESIGN OF PIPES k = 0.003mm BASED ON COLEBROOK-WHITE FORMULA FOR PIPES FLOWING FULL WITH WATER AT 20°C.

PVC Flow Chart

- PN 12

AS1477 Series 1

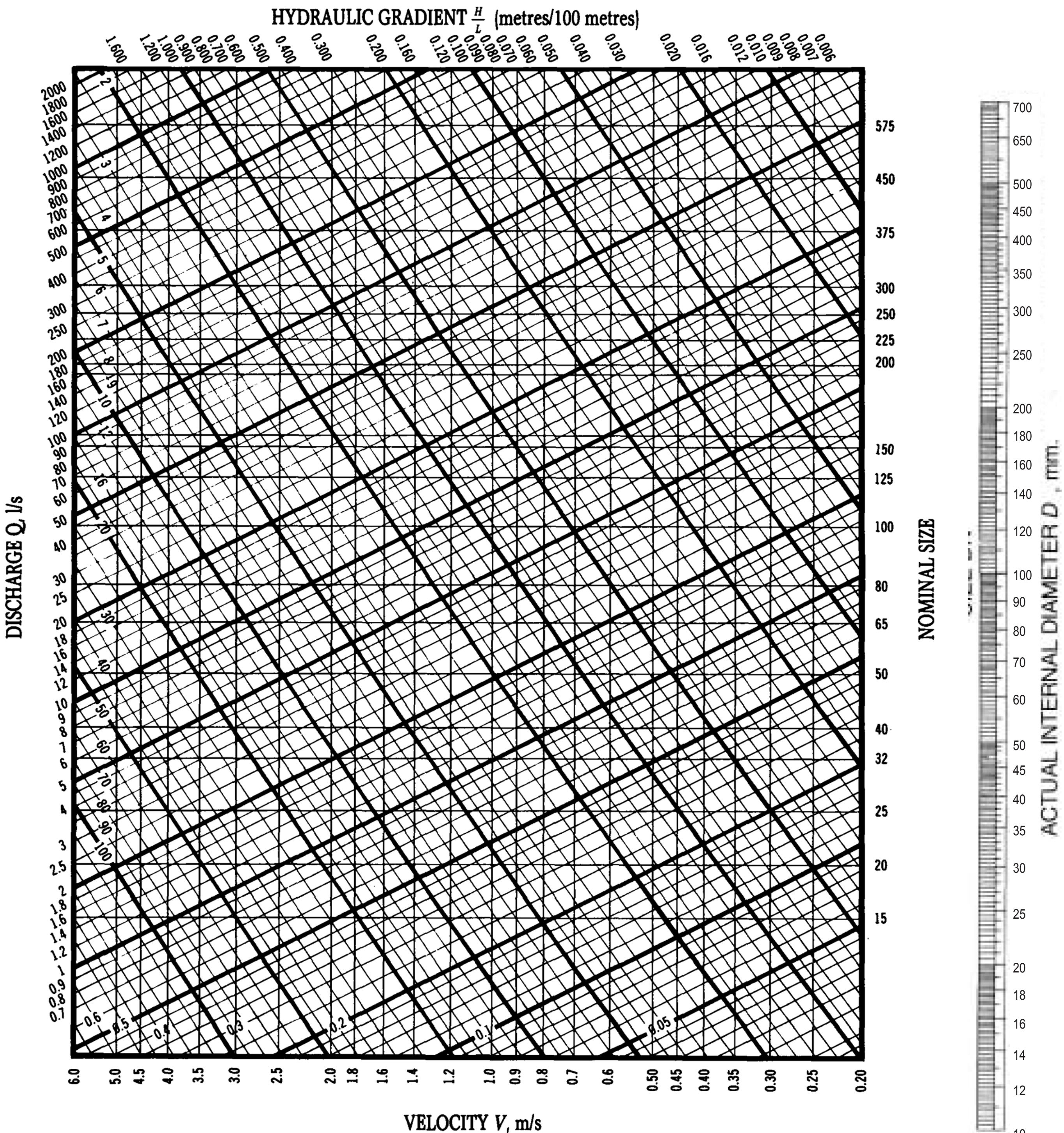


Hydraulic design of pipes k = 0.003mm based on Colebrook-White formula for pipes flowing full with water at 20°C

PVC Flow Chart

- PN 15

AS1477 Series 1

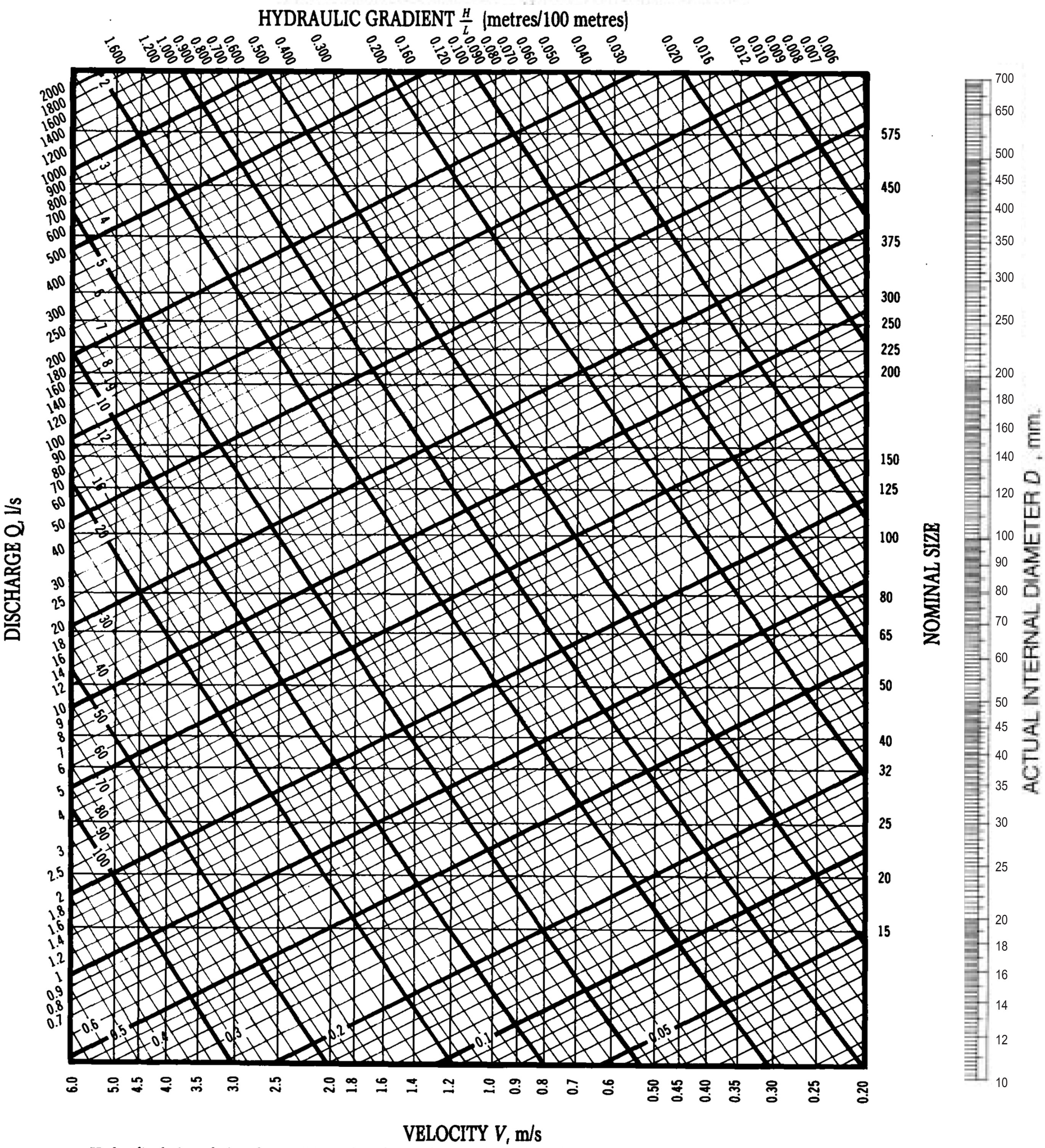


Hydraulic design of pipes k = 0.003mm based on Colebrook-White formula for pipes flowing full with water at 20°C

PVC Flow Chart

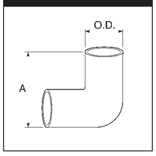
- PN 18

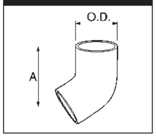
AS1477 Series 1

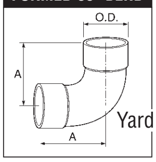


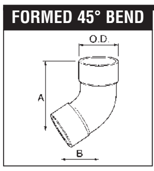
Hydraulic design of pipes k = 0.003mm based on Colebrook-White formula for pipes flowing full with water at 20°C

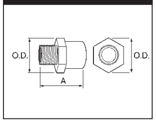
Fitting Dimensions

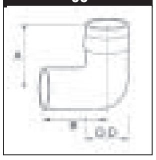
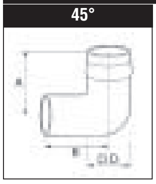
DESCRIPTION		CODE	NOMINAL SIZE	A	O.D.
PLAIN 90 ° ELBOW 		801-15-90	15	49	28
		801-20-90	20	59	32
		801-25-90	25	65	41
		801-32-90	32	94	51
		801-40-90	40	112	57
		801-50-90	50	101	69
		801-65-90	65	135	84
		801-80-90	80	145	102
		801-100-90	100	202	135
	G1361	801-125-90	125	234	163
		801-150-90	150	271	178
	G106	801-175-90	175		
		801-200-90	200	357	248
	Not on list	801-225-90	225		
	Not on list	801-300-90	300		

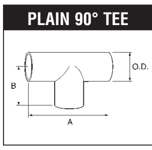
DESCRIPTION		CODE	NOMINAL SIZE	A	O.D.
PLAIN 45 ° ELBOW 		801-15-45	15	57	25
		801-20-45	20	52	33
		801-25-45	25	49	41
		801-32-45	32	78	50
		801-40-45	40	77	51
		801-50-45	50	83	69
		801-65-45	65	117	88
		801-80-45	80	145	104
		801-100-45	100	165	135
	G0082	801-125-45	125		
	G0102	801-150-45	150	231	179
		801-175-45	175	287	230
		801-200-45	200	300	260
	Not on list	801-225-45	225		
	Not on list	801-300-45	300		

DESCRIPTION		CODE	NOMINAL SIZE	A	O.D.
FORMED 90° BEND 		803-15D-90	15	63	25
		803-20D-90	20	148	31
		803-25D-90	25	166	38
		803-32D-90	32	199	48
		803-40D-90	40	135	55
		803-50D-90	50	309	69
	Yard	803-65D-90	65		
		803-80D-90	80	374	100
		803-100D-90	100	471	131
	Yard	803-125D-90	125	578	162
	Not on list	803-150D-90	150		
	Yard	803-175D-90	175		
		803-200D-90	200		
	Not on list	803-225C-90	225		
	Not on list	803-300C-90	300		

DESCRIPTION		CODE	NOMINAL SIZE	A	B	O.D.
FORMED 45° BEND 		803-15D-45	15	180	71	25
		803-20D-45	20	177	76	31
		803-25D-45	25	203	78	38
		803-32D-45	32	215	78	48
		803-40D-45	40	250	113	55
		803-50D-45	50	246	115	68
	Yard	803-65D-45	65			
		803-80D-45	80	326	182	99
		803-100D-45	100	648	333	125
	Yard	803-125D-45	125			
	Yard	803-150D-45	150			
	Not on list	803-175D-45	175			
	Yard	803-200D-45	200			
	Not on list	803-225D-45	225			
	Not on list	803-300D-45	300			

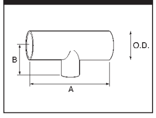
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
REDUCING VALVE ADAPTOR 	817-20-15	20x15	45	31
	817-25-20	25x20	49	37
	817-32-15	32x15	54	42
	817-32-25	32x25	58	47
	817-40-32	40x32	63	57
	817-50-32	50x32	69	60

DESCRIPTION	CODE	NOMINAL SIZE	A	B	O.D.@ socket
M & F RRJ FORMED BEND 90° 	Z803-50D-90	50			
	Z803-65D-90	65	440	400	75
	Z803-80D-90	80	523	476	89
	Z803-100D-90	100	475		
	Z803-125D-90	125			
	Z803-150D-90	150			
	Z803-175D-90	175	989	985	246
	Z803-200D-90	200	1013	976	282
	Z803-225C-90	225			
	Z803-300C-90	300			
45° 	803-50D-45	50			
	803-65D-45	65	565	281	102
	803-80D-45	80			
	803-100D-45	100			
	803-125D-45	125			
	803-150D-45	150			
	803-175D-45	175			
	803-200D-45	200			
	803-225D-45	225			
	803-300D-45	300			

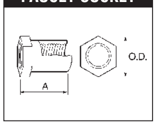
DESCRIPTION		CODE	NOMINAL SIZE	A	B	O.D.
PLAIN 90° TEE 		804-15	15	89	45	26
		804-20	20	65	33	33
		804-25	25	125	62	40
		804-32	32	138	69	52
		804-40	40	166	83	57
		804-50	50	192	97	70
		804-65	65	185	93	84
		804-80	80	214	107	106
		804-100	100	233	118	131
		804-150	150	347	166	179
		804-175	175	415	209	229
		804-200	200	464	230	249
	Yard	804-225	225			
		804-300	300	1020	670	335

Fitting Dimensions

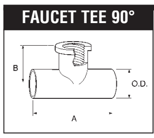
DESCRIPTION	CODE	NOMINAL SIZE	A	B	O.D.
PLAIN 90° REDUCING TEE	805-20-15	20x15	86	43	31
	805-25-15	25x15	60	35	41
	805-25-20	25x20	93	47	39
	805-32-20	32x20	96	46	53
	805-32-25	32x25	96	46	53
	805-40-25	40x25	102	49	60
	805-40-32	40x32	111	57	58
	805-50-15	50x15	98	52	71
	805-50-20	50x20	114	55	75
	805-50-25	50x25	111	60	71
	805-50-32	50x32	119	64	71
	805-50-40	50x40	125	65	71
	805-80-25	80x25	134	68	103
	805-80-32	80x53	161	72	102
	805-80-40	80x40	199	81	104
	805-80-50	80x50	200	88	104
	805-100-50	100x50	189	99	132
	805-100-80	100x80	222	127	132



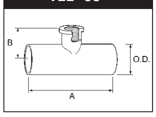
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
FAUCET SOCKET	806.15	15	98	39
	806-20	20	57	43
	806-25	25	57	49
	806-32	32	62	60
	806-40	40	69	66
	806-50	50	71	81
	806-65	65	84	96
	806-80	80	94	113
	806-100	100	112	144



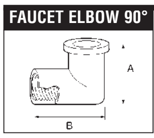
DESCRIPTION	CODE	NOMINAL SIZE	A	B	O.D.
FAUCET TEE 90°	807-15-90	15	89	32	26
	807-20-90	20	86	44	31
	807-25-90	25	92	46	39



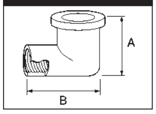
DESCRIPTION	CODE	NOMINAL SIZE	A	B	O.D.
FAUCET REDUCING TEE 90°	807-20-15-90	20x15	54	32	33
	807-25-15-90	25x15	60	40	31
	807-25-20-90	25x20	92	46	39



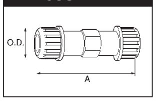
DESCRIPTION	CODE	NOMINAL SIZE	A	B	O.D.
FAUCET ELBOW 90°	808-15-90	15	44	58	27
	808-20-90	20	54	54	34
	808-25-90	25	66	47	39
	808-32-90	32	80	55	51



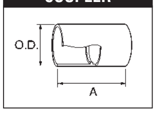
DESCRIPTION	CODE	NOMINAL SIZE	A	B	O.D.
FAUCET REDUCING ELBOW 90°	808-25-15-90	25X15	66	47	39
	808-25-20-90	25X20	66	46	39



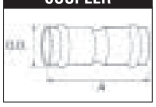
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
EXPANSION COUPLER	809-15	15	126	47
	809-20	20	138	153
	809-25	25	141	61
	809-32	32	149	73
	809-40	40	175	80
	809-50	50	185	93
	809-100	100	313	162



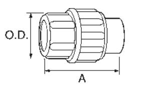
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
PLAIN SOCKET COUPLER	810-15	15	54	27
	810-20	20	66	34
	810-25	25	53	39
	810-32	32	58	49
	810-40	40	65	56
	810-50	50	77	70
	810-65	65	110	66
	810-80	80	105	103
	810-100	100	126	133
	810-125	125	184	165
	810-150	150	184	190
	810-175	175		
	810-200	200	239	248
	810-225	225		
	810-300	300	570	347



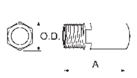
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
RRJ SOCKET COUPLER	Z810-50	50		
	Z810-65	65		
	Z810-80	80		
	Z810-100	100		
	Z810-125	125	402	180
	Z810-150	150	448	202
	Z810-175	175	450	146
Yard	Z810-200	200		
	Z810-225	225	490	272
Yard	Z810-300	300		



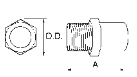
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
SOCKET UNION	**811-15**	**15**	67	56
	811-20	**20**	67	63
	811-25	**25**	74	70
	811-32	**32**	81	83
	811-40	**40**	91	96
	811-50	**50**	98	111



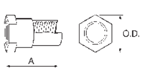
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
VALVE SOCKET	**813-15**	**15**	51	30
	813-20	**20**	68	33
	813-25	**25**	72	42
	813-32	**32**	78	55
	813-40	**40**	91	62
	813-50	**50**	107	75
	813-65	**65**	93	92
	813-80	**80**	93	113
	813-100	**100**	112	144



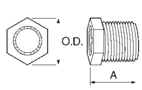
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
VALVE ADAPTOR	**817-15**	**15**	43	31
	817-20	**20**	47	37
	817-25	**25**	53	47
	817-32	**32**	60	57
	817-40	**40**	64	63
	817-50	**50**	79	80
	817-80	**165**	113	152
	817-100	**186**	144	154



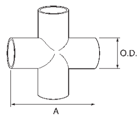
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
REDUCED FAUCET ADAPTOR	**819-15-15**	**15x15**	42	34
	819-25-15	**25x15**	45	36
	819-25-20	**25x20**	49	40
	819-32-25	**32x25**	55	49
	819-40-25	**40x25**	58	54
	819-50-15	**50x15**	56	65
	819-50-25	**50x25**	62	65
	819-50-50	**50x50**	68	81



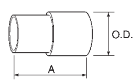
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
THREADED BUSH	**818-20-15**	**20X15**	26	36
	818-25-20	**25X20**	30	37



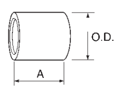
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
PLAIN CROSS (Rated PN9 Only)	**820-15**	**15**	64	28
	820-20	**20**	84	34
	820-25	**25**	98	41
	820-32	**32**	114	52
	820-40	**40**	124	59
	820-50	**50**	139	71



DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
REDUCING SOCKET	**823-20-15**	**20X15**	46	33
	823-25-15	**25X15**	53	42
	823-25-20	**25X20**	52	39
	823-32-25	**32X25**	66	50
	823-40-20	**40X20**	64	57
	823-40-32	**40X32**	72	57
	823-50-40	**50X40**	75	70
	823-65-50	**65X50**	104	86
	823-80-50	**80X50**	100	103
	823-80-65	**80X65**	120	101
	823-100-50	**100X50**	116	133
	823-100-80	**100X80**	124	133
	823-125-100	**125X100**	78	48
	823-150-125	**150X125**	205	198
	823-150-100	**150X100**	183	187
	823-155-150	**155X150**	218	197

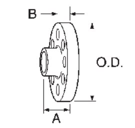


DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
REDUCING BUSH	**824-20-15**	**20x15**	21	27
	824-25-15	**25x15**	25	33
	824-25-20	**25x20**	32	38
	824-32-25	**32x25**	35	48
	824-40-25	**40x25**	79	48
	824-40-32	**40x32**	30	48
	824-50-25	**50x40**	37	60
	824-50-40	**65x50**	48	70
	824-65-50	**80x50**	45	75
	824-80-50	**80x65**	53	89
	824-80-65	**80x65**	51	89
	824-100-50	**100x50**	63	115
	824-100-80	**100x80**	61	114
	824-125-100	**125x100**	79	139
	824-150-100	**150x100**	88	161
	824-150-125	**150x125**	86	160
	824-175-150	**175x150**	109	200
	824-200-150	**200x150**	155	225
	824-200-175	**200x175**		
	824-300-225	**300x225**		

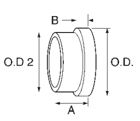


Fitting Dimensions

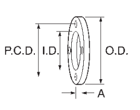
DESCRIPTION	CODE	NOMINAL SIZE	A	B	O.D.
FULL FACE FLANGE	825-15	15	28	13	96
	825-20	20	30	13	102
	825-25	25	33	30	115
	825-32	32	121	13	33
	825-40	40	42	13	132
	825-50	50	46	13	153
	825-65	65	67	13	169
	825-80	80	57	13	184
	825-100	100	68	16	216
	825-125	125	99	19	253
	825-150	150	98	20	280



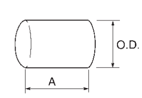
DESCRIPTION	CODE	NOMINAL SIZE	A	B	O.D.	O.D.2
STUB FLANGE	826-50	50	39	14	97	74
	826-65	65	55	10	106	89
	826-80	80	69	12	129	106
	826-100	100	75	13	161	137
	826-125	125	81	14	188	165
	826-150	150	91	17	212	188
	826-200	200	126	26	273	245
G0722	826-225	225				
	826-300	300	178	32	376	346



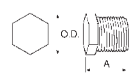
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.	P.C.D.	I.D.
METAL BACKING RING	827-50	50	11	163	118	77
	827-65	65	11	165	129	92
	827-80	80	10	189	150	113
	827-100	100	13	215	176	138
	827-125	125	10.5	226	210.5	166.2
	827-150	150	11	284	240	191
	827-175	175	10.5	335	295.4	235.4
	827-200	200	10	342	293	249
	827-225	225	11	372	326	276
	827-300	300	10	462	408	348



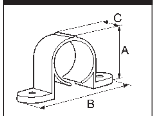
DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
PLAIN END CAP	830-15	15	26	25
	830-20	20	30	31
	830-25	25	34	39
	830-32	32	40	49
	830-40	40	46	56
	830-50	50	55	70
	830-65	65	72	86
	830-80	80	77	103
	830-100	100	93	133
	830-125	125	135	164
	830-150	150	135	190
	830-200			



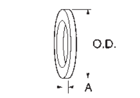
DESCRIPTION	CODE	NOMINAL SIZE	A	B	O.D.
THREADED END PLUG	837-15	15	25.1	7	30
	837-20	20	30	7	36
	837-25	25	30	8	45
	837-32	32	32.2	8	58
	837-40	40	33.2	9	63
	837-50	50	37.3	9	80
	837-80	80	53.4	20	113
	837-100	100	58	20	144



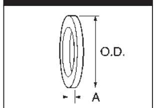
DESCRIPTION	CODE	NOMINAL SIZE	A	B	C
PIPE CLIP	840-15	15	34	59	19
	840-20	20	39	65	19
	840-25	25	52	73	19
	840-32	32	62	82	19
	840-40	40	67	87	19
	840-50	50	81	102	19



DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
NEOPRENE GASKET FOR FULL FACE FLANGE 825	842-15	15		
	842-20	20	3	56
	842-25	25	3	50
	842-32	32	3	71
	842-40	40	3	78
	842-65	65	3	106
	842-80	80	3	126
	842-100	100	3	156
	842-150	150	3	217



DESCRIPTION	CODE	NOMINAL SIZE	A	O.D.
NEOPRENE GASKET FOR STUB FLANGE 826	845-50	50	3	85
	845-65	65	3	100
	845-80	80	3	115
	845-100	100	3	144
	845-125	125	3	182
	845-150	150	3	215
	845-175	175	3	255
	845-200	200	3	282
	845-225	225	10	300
	845-300	300	10	380



4. POLYETHYLENE

RETURN TO CONTENTS

1.1 Mechanical Properties of Polyethylene @ 20.0ºC

	PE80	PE100
Density		
-Blue	>944 kg/m^3	>950 kg/m^3
-Black	>949 kg/m^3	>959 kg/m^3
Water Abrasion		
Hardness	67% (Shore D)	67% (Shore D)
Izod Impact Strength @(-20°C)	90 J/m	90 J/m
Coefficient of Friction		
Ultimate Tensile Strength	39 N/mm^2 (50mm/min)	30 N/mm^2 (50mm/min)
Tensile strength at yield	18 MPa	22 MPa
Elongation at Break	>600%	>600%
Environmental Stress Cracking resistance	>700h	>700h
Minimum Required Strength	8.0 MPa	10.0 MPa
Elastic Flexural Modulus	700 MPa	1000 MPa
Shear Modulus	400-470 N/mm2	600 N/mm2
Charpy Impact strength	22-35 kJ/m2	17-26 kJ/m2

1.2 Electrical Properties

	PE80	PE100
Dielectric Strength	70 kV/mm	22-53 kV/mm
Specific Volume Resistivity	1015 OHM.cm	1015 OHM.cm
Surface Resistivity	>1015 OHM	>1015 OHM
Dissipation Factor	5.5 (50 Hz) 2.5 (106 Hz)	5.5 (50 Hz) 2.5 (106 Hz)

1.3 Thermal Properties

	PE80	PE100
Vicat Softening Point	116 °C	124 °C
Thermal Conductivity	0.423-0.45W/m°K	0.4W/m°K
Specific Heat	2.6 KJ/[kg.K]	2.6 KJ/[kg.K]
Brittleness Temperature	<-70 °C	<-100 °C
Linear Thermal Expansion	1.4x10^{-4}/K	1.3x10^{-4}/K

.3.0 PE80 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												

PE80: SDR 13.6 - SDR 9

3.0 PE80B Pipe Dimensions

Standard AS/NZS 4130

PE80B: SDR 33 - SDR 17

		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

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

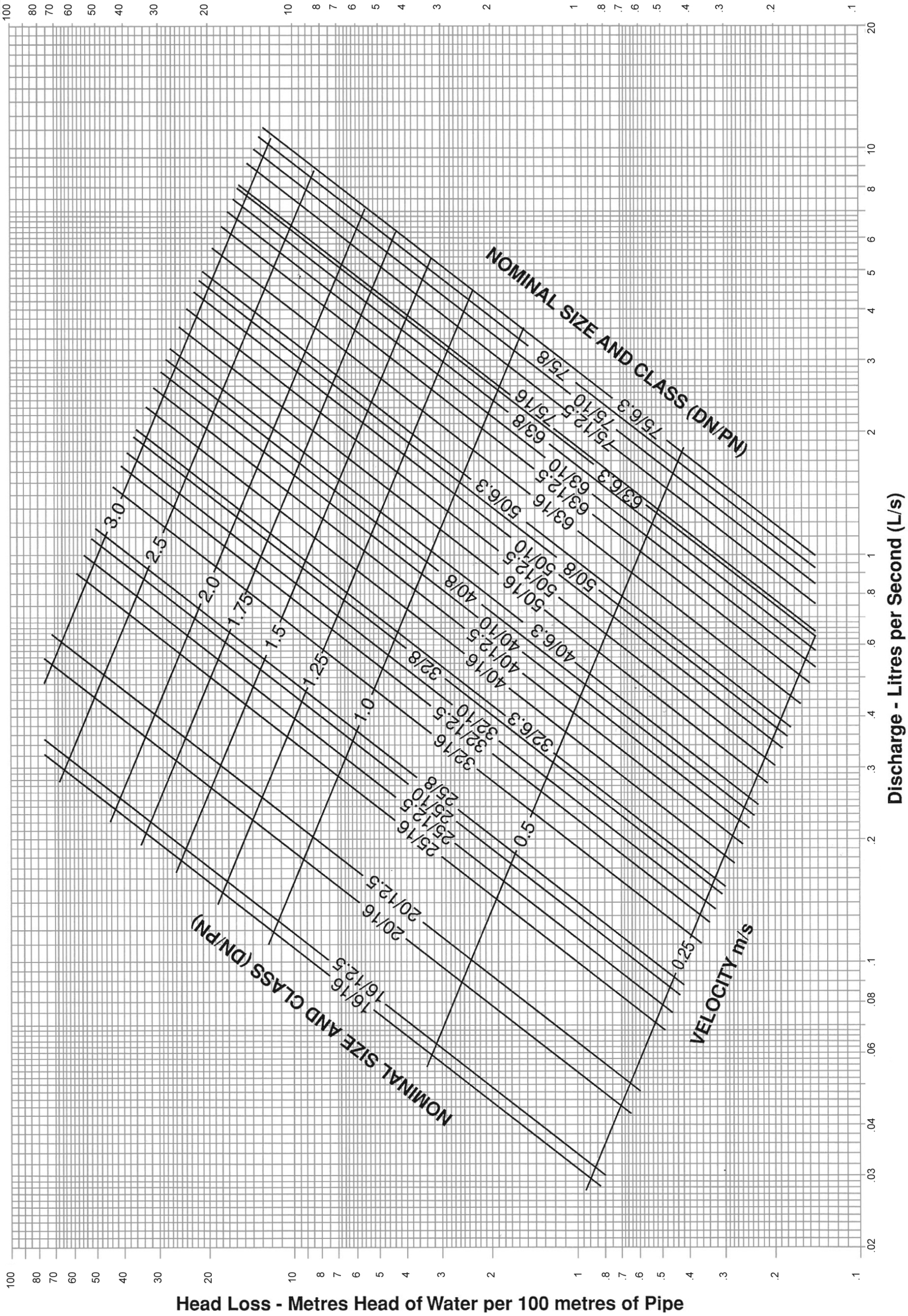
PE100 Pipe Dimensions

Standard AS/NZS 4130

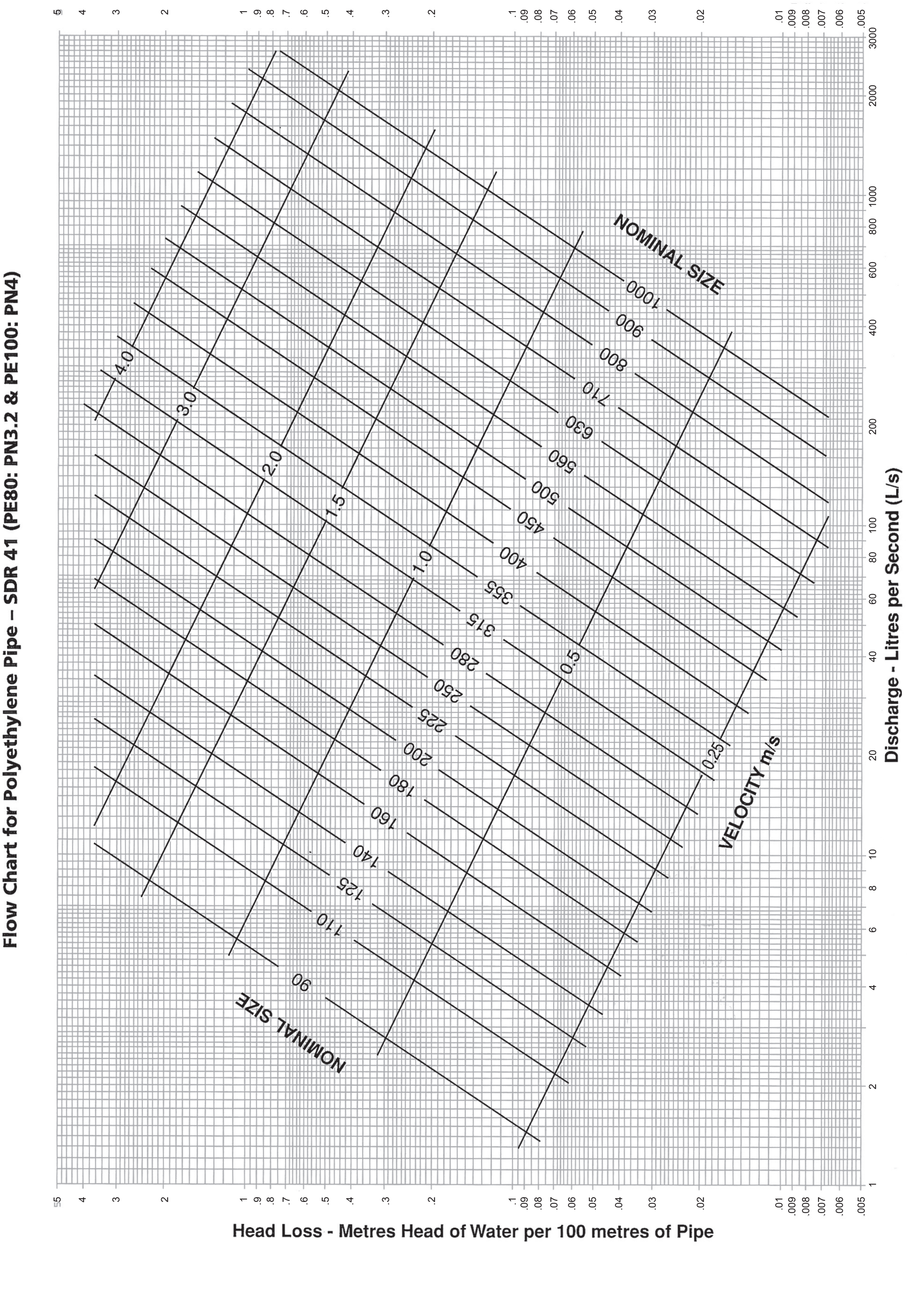
		PN10 SDR 17				PN12.5 SDR 13.6				PN16 SDR 11			
Nominal Size	**Mean OD**	**Mean Bore**	**T Min**	**T Max**	**Mass kg/m**	**Mean Bore**	**T Min**	**T Max**	**Mass kg/m**	**Mean Bore**	**T Min**	**T Max**	**Mass kg/m**
20	20.2	16.7	1.6	1.9	0.096	16.7	1.6	1.9	0.096	16.1	1.9	2.2	0.110
25	25.2	21.7	1.6	1.9	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								

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

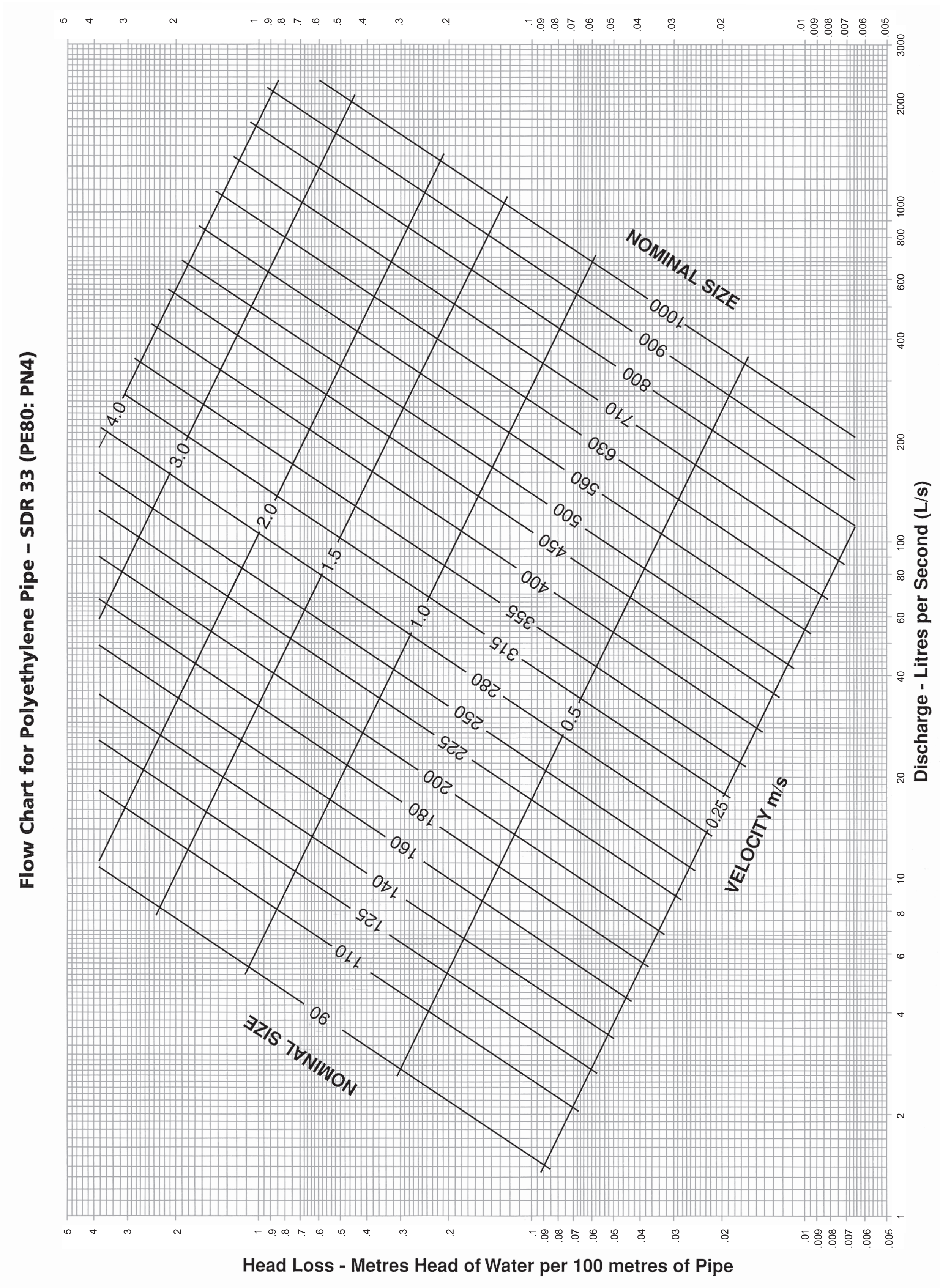
Flow Chart for Small Bore Polyethylene Pipe – DN16 to DN75 (PE80B, Materials)



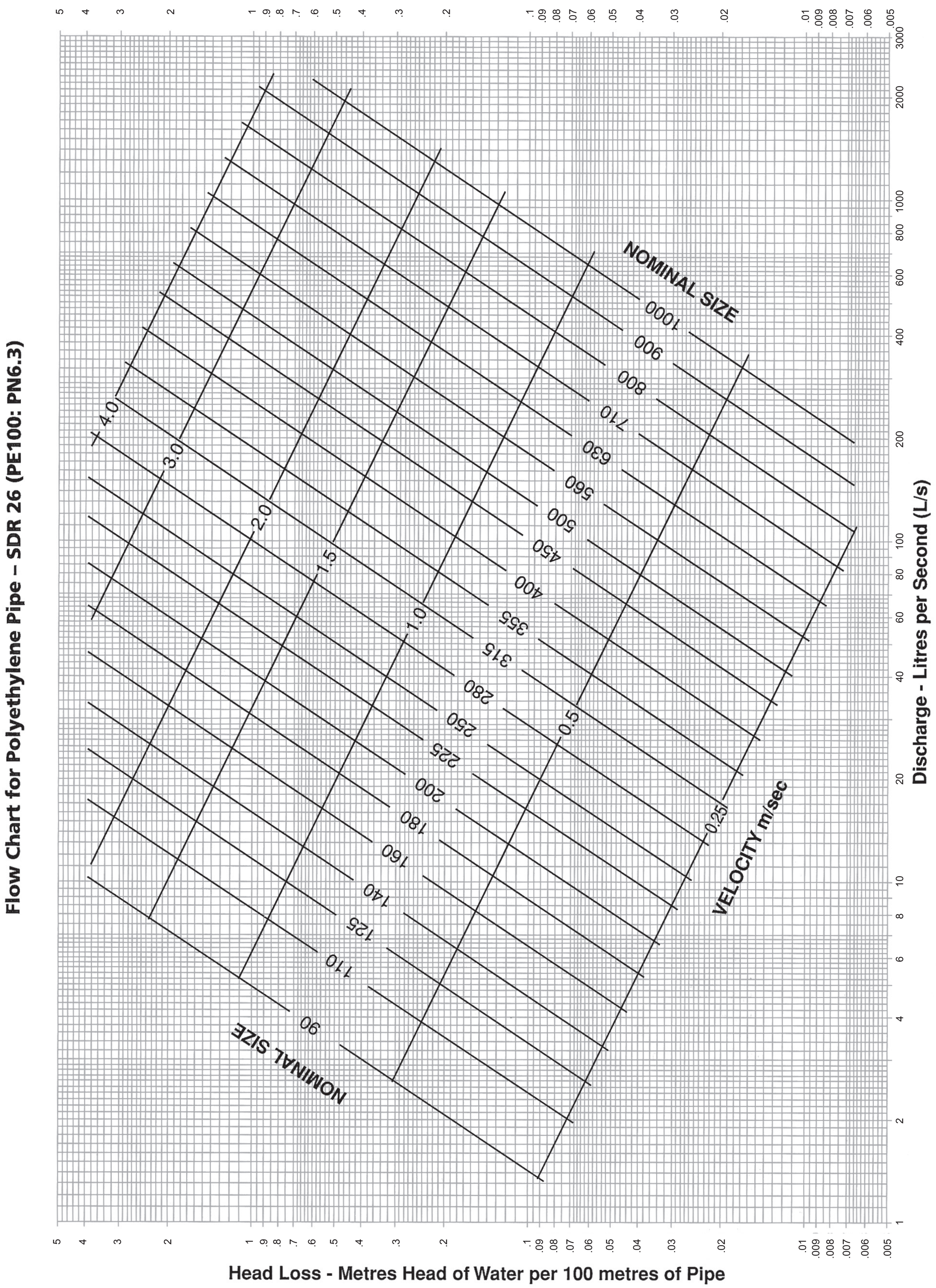
Polyethylene Pipe - SDR 41
(PE80: PN3.2 & PE100: PN4)



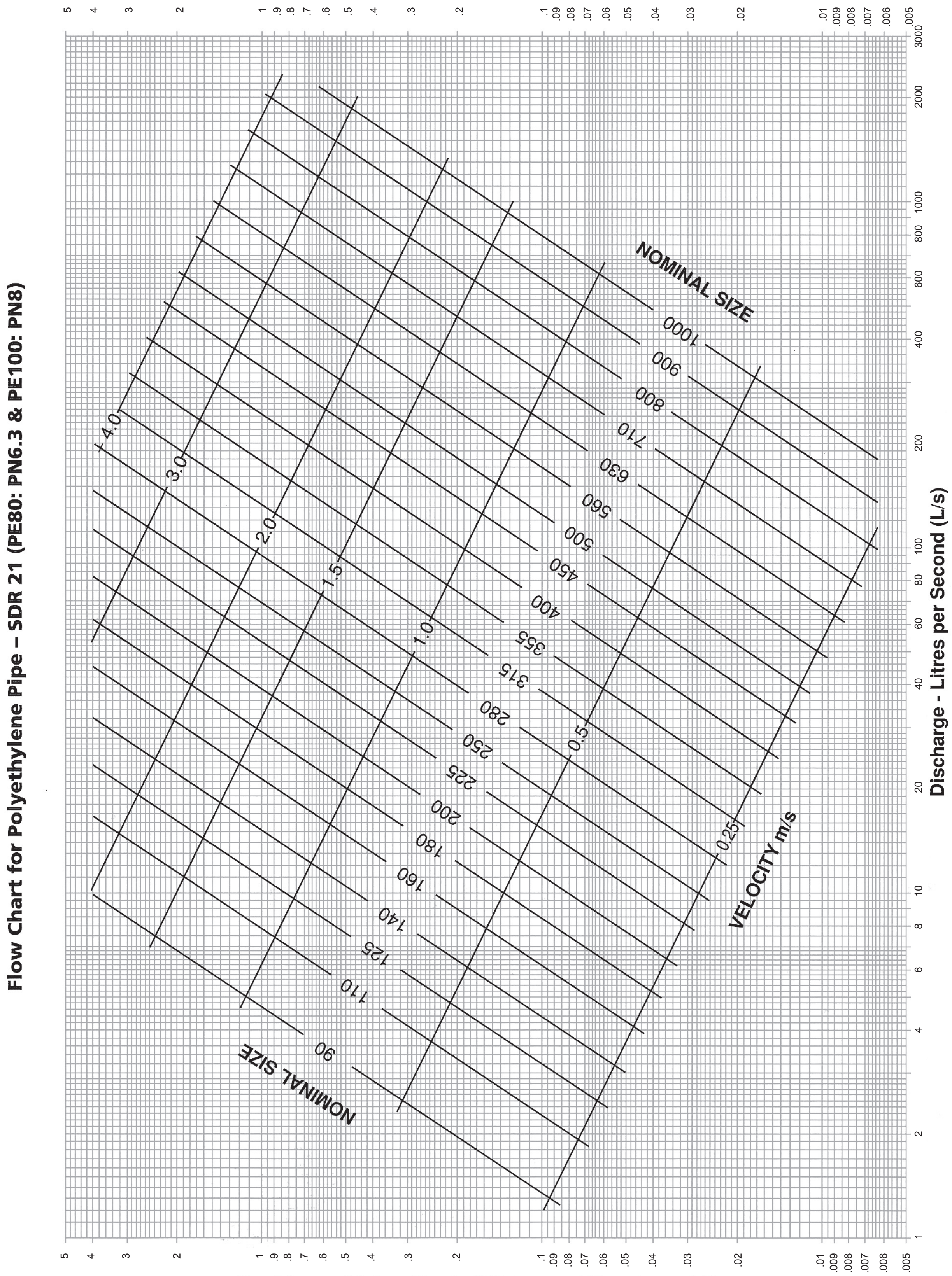
Polyethylene Pipe - SDR 33
(PE80: PN4)



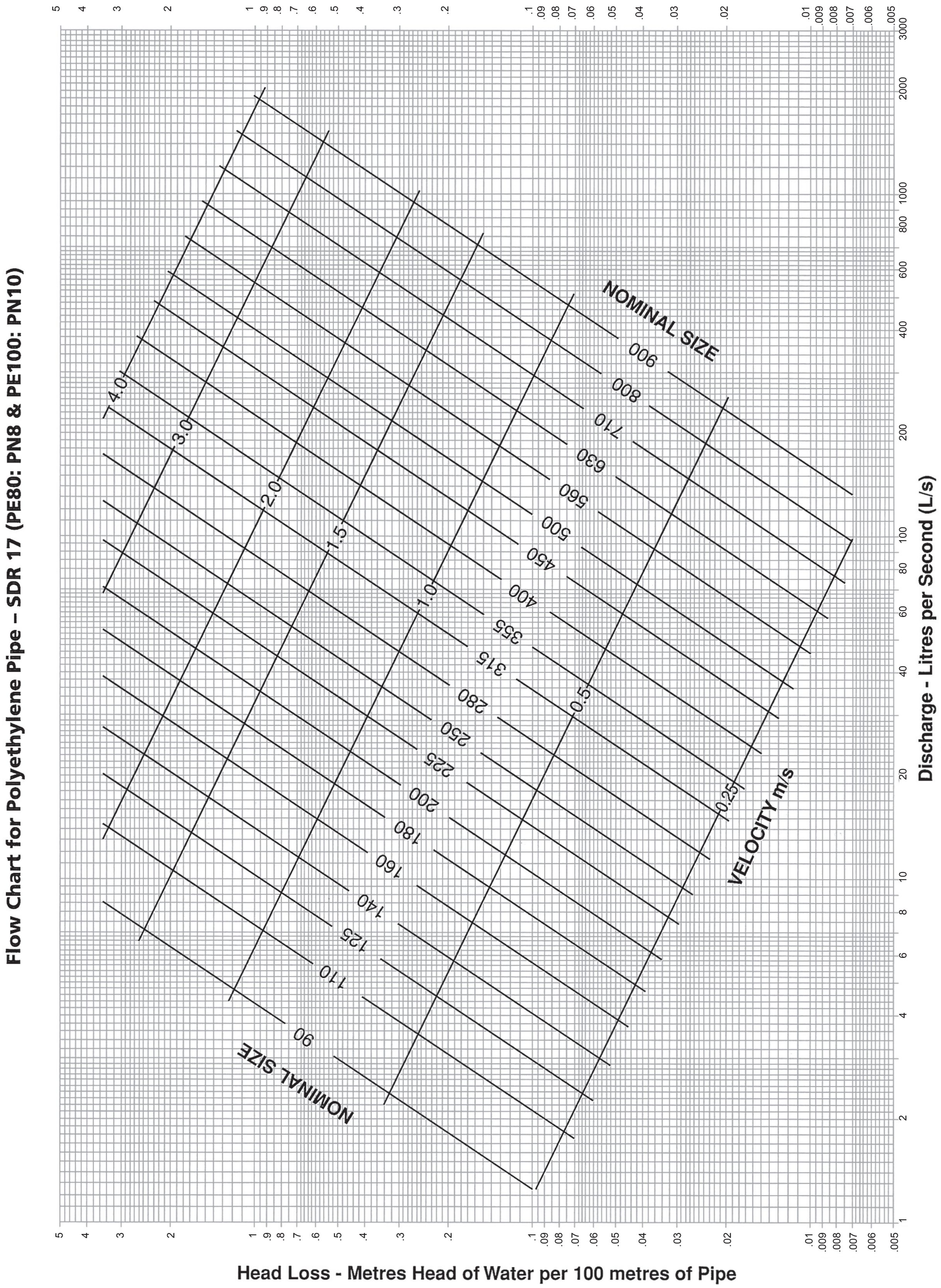
Polyethylene Pipe - SDR 26
(PE 100: PN6.3)



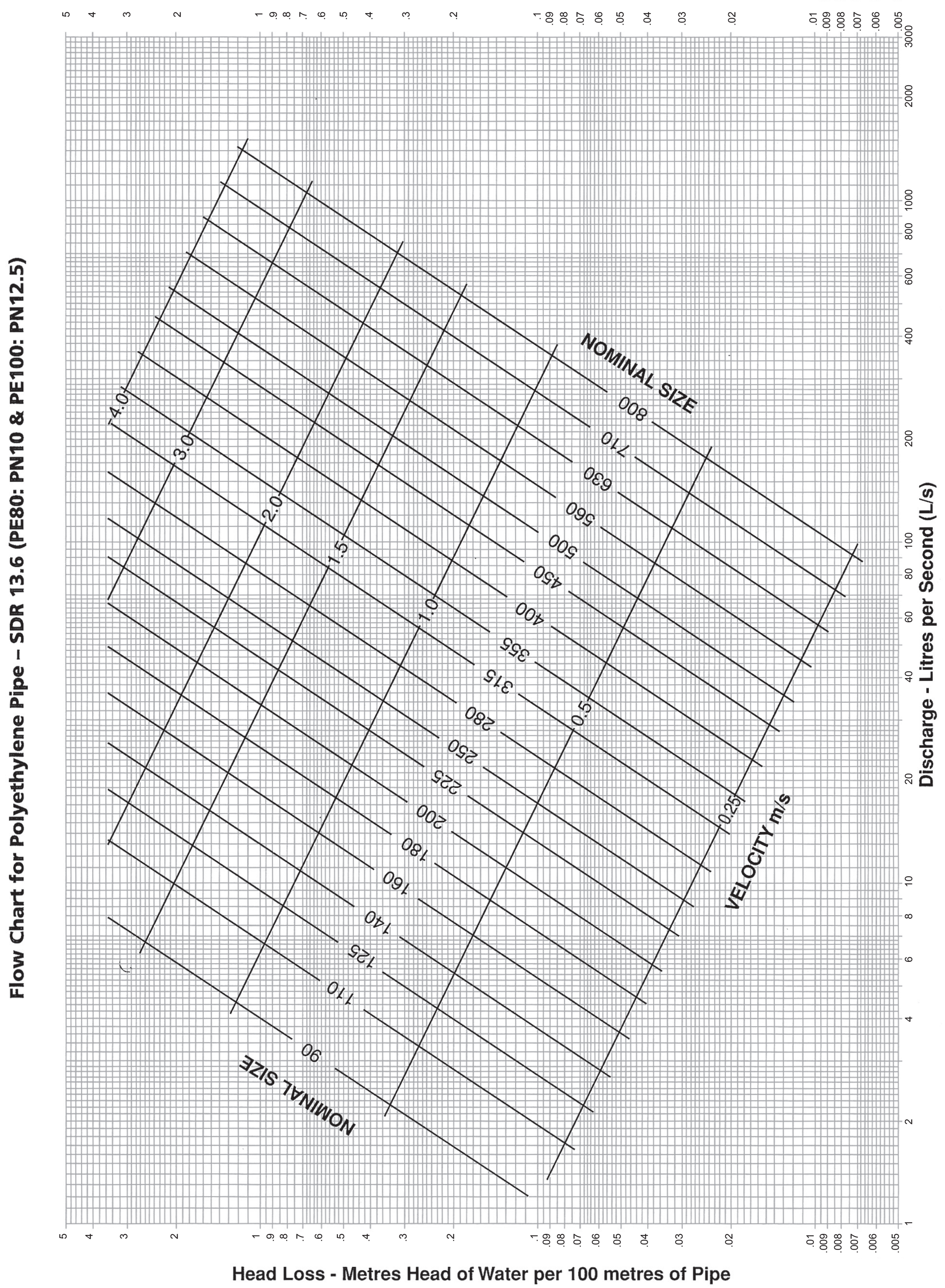
Polyethylene Pipe - SDR 21
(PE 80: PN6.3 & PE100: PN8)



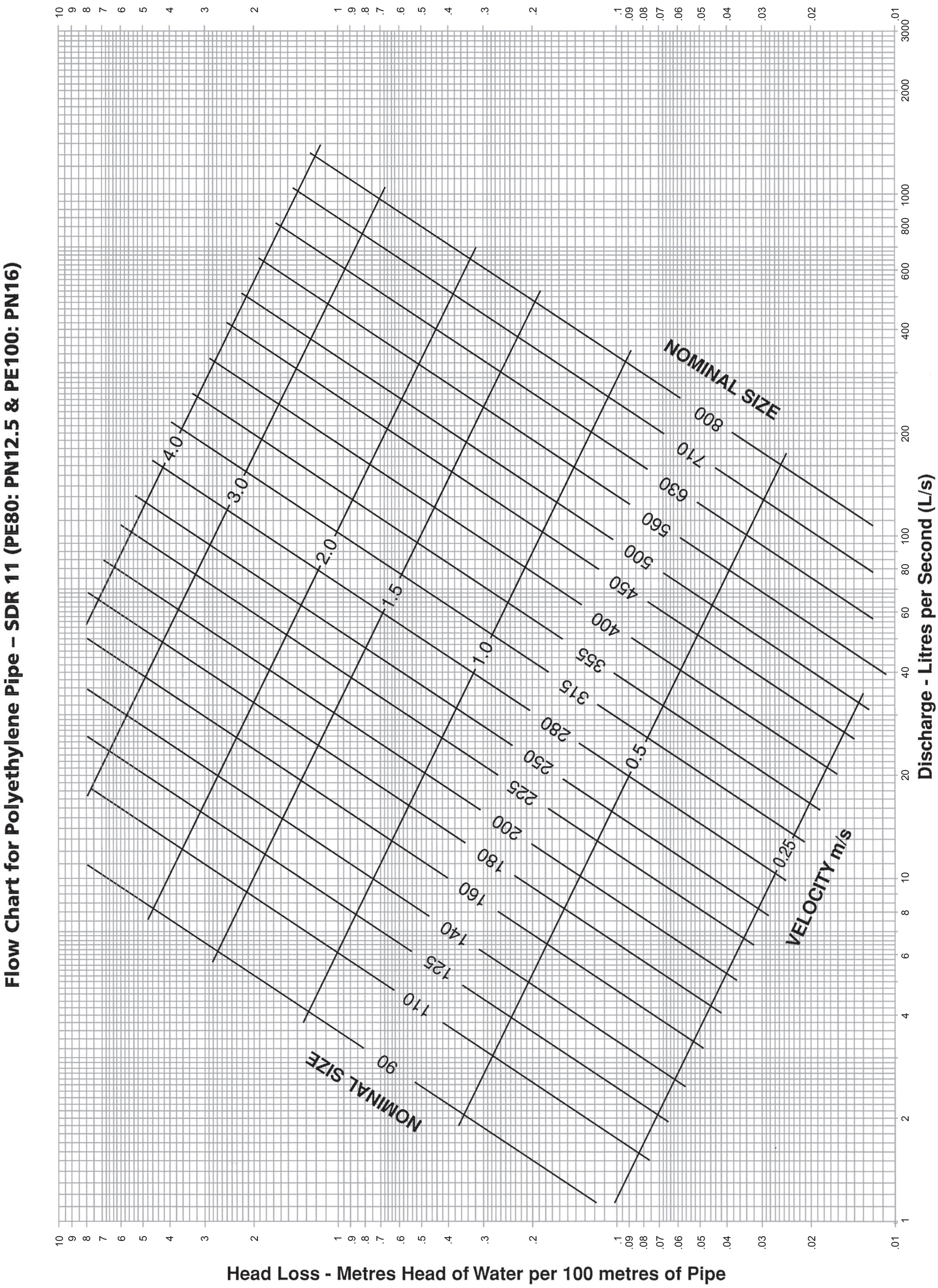
Polyethylene Pipe - SDR 17
(PE 80: PN8 & PE100: PN10)



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



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



5. DESIGN

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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 this rated pressure of the pipe.

Hydrostatic Design Stress and Minimum Required Strength Values

- for MDPE

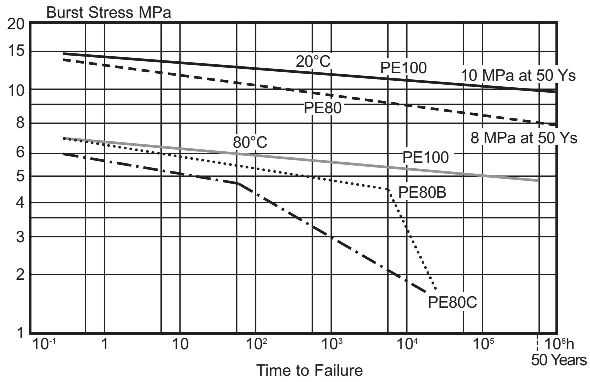
Material Designation	Minimum Required Strength (MRS)MPa	Hydrostatic DesignStress (S) MPa
PE63	5.0	6.3
PE80	6.3	8.0
PE100	8.0	10.0

- for PVC

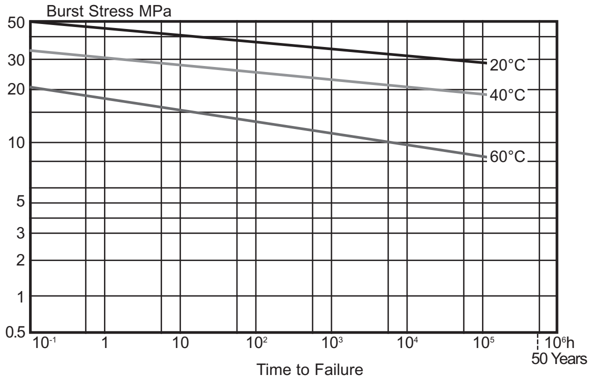
Material Designation	Minimum Required Strength (MRS)MPa
up to 20mm nominal size -	9.8 MPa
25 to 150 nominal size -	11.0 MPa
175 nominal size and larger -	12.3 MPa

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 PE80 and PE100 pipes at 20°C and 80°C. The standard curve for HDPE Type 2 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.



Stress/time curves for PVC at 20°C, 40°C and 60°C.

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 occasion, 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.

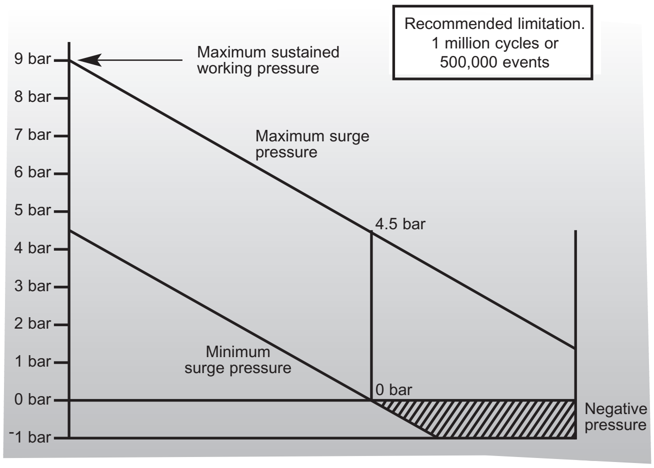
The DYNAMIC loads normaly considered during operation are:

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

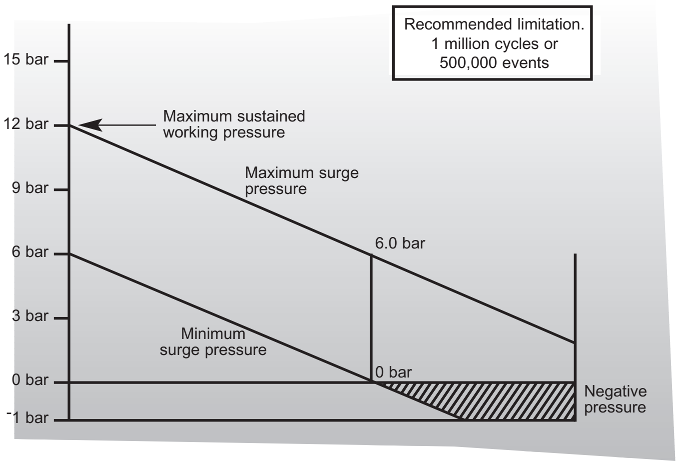
In general terms and for normal use, polymer pipelines which are correctly laid, bedded and supported are capable of withstanding such imposed loadings, within these recommendations.

SURGE PRESSURE ENVELOPES - PVC

9 Bar PVC-U pipe

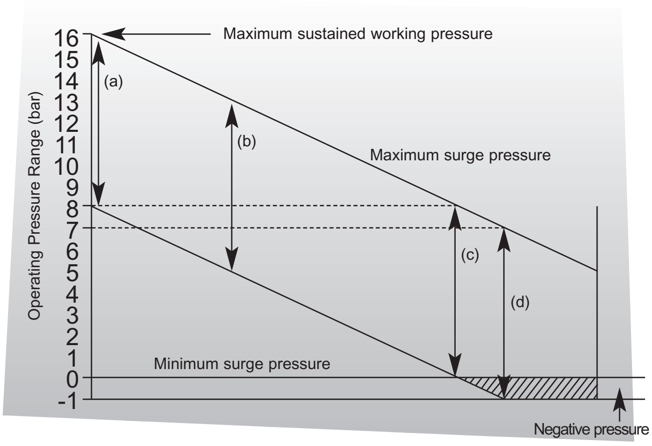


12 Bar PVC-U pipe



SURGE PRESSURE ENVELOPES - PE

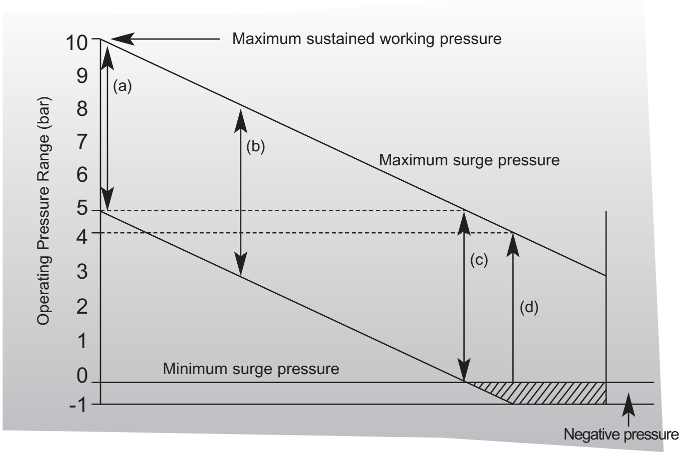
PE100, SDR 11



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)



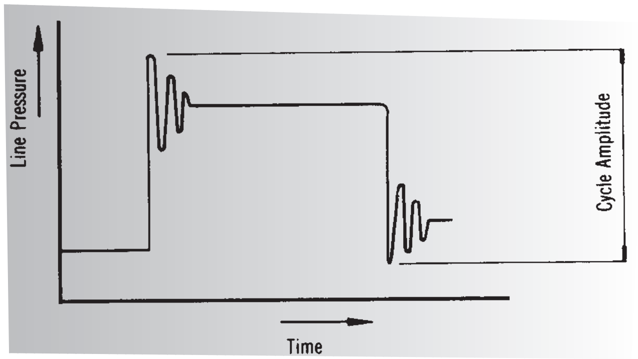
The vertical lines a, b, c, d illustrate that the permissable range of fluctuation in pressure should not exceed 5 bar and may be, for example, between the following limits;

(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.

Design

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 and 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 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

Research to date (ref.[2]) suggests that crack growth rates in uPVC is not greatly affected by temperature change.
Therefore while temperature rating principles must be applied in pressure rating selection for static pressures, (ductile burst), no adjustment need be applied for dynamic design. Select the highest according to:
(a) static design including temperature derating
 or
(b) dynamic design as discussed in this section.

SAFETY FACTORS

The analysis and design method adopted by Joseph can be considered conservative. Given reasonable confidence in prediction of pressure cycle amplitude, no additional factor of safety need be applied for selection of pipe class.
The more likely area of deficiency is in the frequency of number of cycles. Lack of confidence in this parameter may warrant application of an appropriate factor of safety. This judgement is in the hands of the designer. It is recommended that systems that are of concern to the designer should be monitored on commissioning to ensure that operation is in accordance with design criteria. Pressure cycling outside acceptable limits can be mitigated by a number of techniques, as outlined above.

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. Injection moulded fittings up to and including 50 mm diam. should be rated PN15. Larger sizes are rated PN12. In large pipe installations, where high pressures are expected, cast iron fittings are preferred. With PVC full faced flanges should be fitted with backing rings behind both bolt head and nut when used at pressures above 240kPa. Stub flanges are recommended.

WAVE SPEED TRANSMISSION

In applications where surgepressures 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 pipematerials and wall thicknesses. Wave speed is approximately related to pressure change by the Joukowski formula:

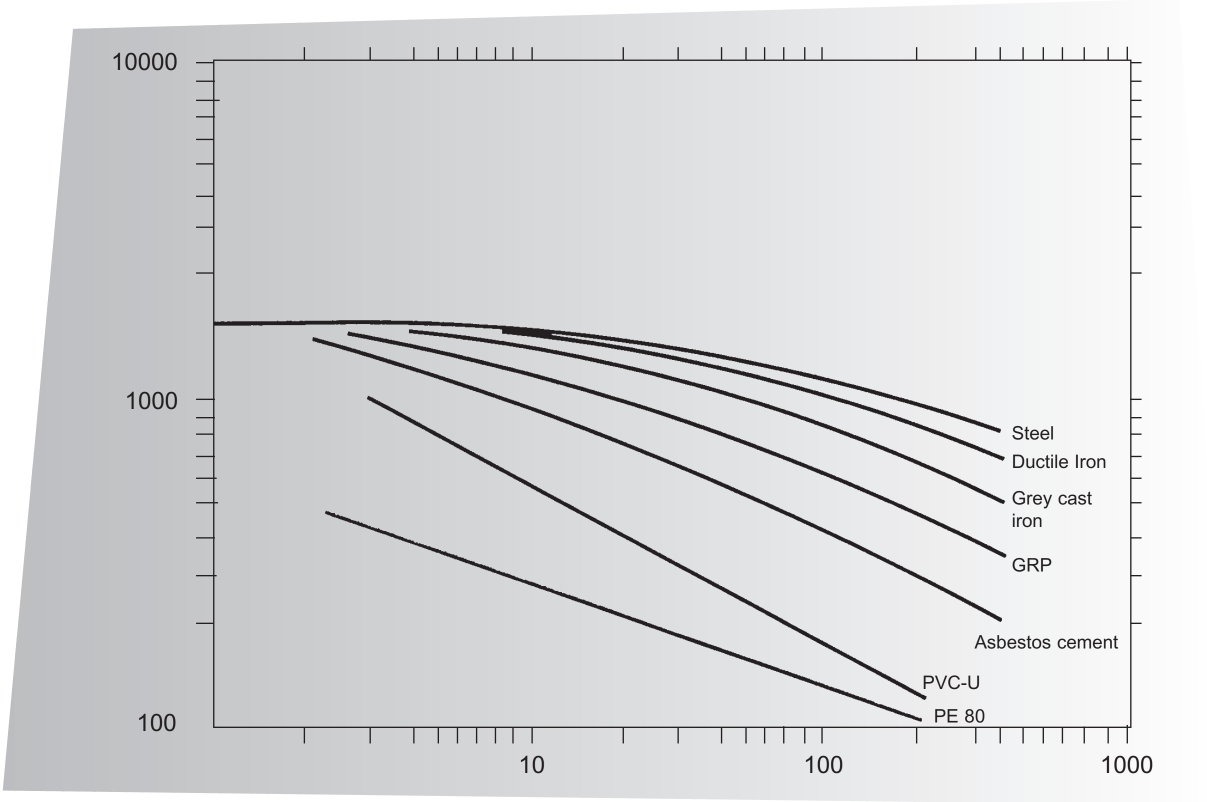
$$\Delta p = p.a.\ \Delta V$$

where

Δp = pressure change (N/m^2)
p = fluid density (kg/m^3)
a = wave speed (m/s)
ΔC = 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 Pressure 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.
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

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

$$P_1 = C.V$$

where
P1 = pressure rise in kPa
v = liquid velocity in m/sec

If the valve closure time t_c 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)

MDPE Surge Celerity

SDR	Celerity m/s 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

PVC Surge Celerity

PN Class	SIZE UP TO AND INCL. DN 150		SIZES DN 175 AND LARGER	
	SDR	a(m/s)	SDR	a(m/s)
6	36.7	281	39.3	272
9	24.4	341	26.2	330
12	18.3	390	19.7	377
15	14.7	432	15.7	419
18	13.8	444	14.8	430

Dimension Ratio (SDR) and Celerity (a)

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

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 Marley 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 Marley 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:

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

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.

Substituting for f in the Darcy equation note that:

Q = flow velocity x pipe internal area.
Where Q = discharge (m³/s)

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

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

Where
- V = velocity in metres per second
- g = gravitational acceleration (a valve of 9.807 ms-2 maybe 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 = head of loss (meters/100 metres of pipe)

Flowcharts for pipe systems using this formula have been in operation in New Zealand for over 20 years for transmission of water and have been proven in practical installations.

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 by1% for each 3°C below 20°C.
   Decrease the chart value of the hydraulic gradient by1% for each 3°C above 20°C.

Manufacturing Diameter Tolerance

Marley pressure pipe is manufactured in accordance with AS/NZS 1477 and NZ/4130 which permits specific manufacturing tolerance on both its mean outside diameter and wall thickness. Hence the mean bore of a pipe is given by:

$$\text{Mean bore} = \underbrace{De}_{\text{mean OD}} - 2 \bullet \underbrace{te}_{\text{mean wall thickness}}$$

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 Marley pressure pipe. This figure for k agrees with recommended values given in Australian Standard 2200 (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 Marley pipe compare favourably with accepted values for smooth pipes for flows with Reynolds’ Number exceeding 10^4.
Roughness may vary within a pipeline for a variety of reasons. However, in water supply pipelines using clean Marley 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 incrustations 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.

(1) HOUSEN, “Tests find friction factors in uPVC pipe”. Oil and Gas Journal Vol. 75, 1977.

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 other two formulas can be compared as follows:

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

$$C = 5.64\ D^{0.13}\left(\frac{H}{L}\right)^{-0.04}\sqrt{2g}\ \log_{10}\left[\frac{D}{\frac{k}{3.7} + \frac{2.51v}{\sqrt{2gD\frac{H}{L}}}}\right]$$

EQUIVALENT ROUGHNESS COEFFICIENTS

ID (m)	k (m)	v (m^2/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.

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

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
v = liquid velocity
g = acceleration due to gravity
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 80 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).

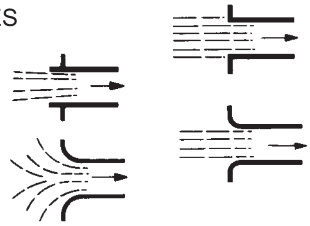
For practical purposes, designers of water mains for normal housing layouts may consider alternative methods to take account of all secondary and minor losses for small and medium sized developments.

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	_	0.6	3.7	9.5		
		_	0.2	1.2	1.9		
		1		0.4	0.7		
		1 _		0.1	0.2	0.9	2.2
		2			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

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

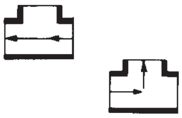
TYPE OF FITTING		K
PIPE ENTRY LOSSES		
Square Inlet		0.50
Re-entrant Inlet		0.80
Slightly rounded Inlet		0.25
Bellmouth Inlet		0.05



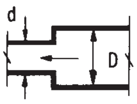
PIPE INTERMEDIATE LOSSES		
Elbows: R/D < 0.6	45°	0.35
e.g. uPVC	90°	1.10

Long Radius Bends	$11\frac{1}{4}$°	0.05
(R/D>2)	$22\frac{1}{2}$°	0.10
	45°	0.20
	90°	0.50

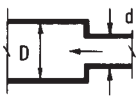
TEES	
(a) Flow in line	0.35
(b) Line to branch flow	1.00



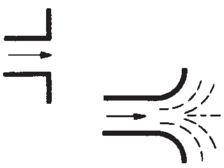
SUDDEN ENLARGEMENTS	
Ratio d/D	
0.9	0.04
0.8	0.13
0.7	0.26
0.6	0.41
0.5	0.56
0.4	0.71
0.3	0.83
0.2	0.92
<0.2	1.00



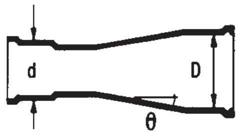
SUDDEN CONTRACTIONS	
Ratio d/D	
0.9	0.10
0.8	0.18
0.7	0.26
0.6	0.32
0.5	0.38
0.4	0.42
0.3	0.46
0.2	0.48
<0.2	0.50



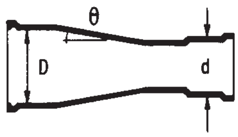
PIPE EXIT LOSSES	
Square Outlet	1.00
Rounded Outlet	1.00



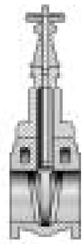
TYPE OF FITTING	K
GRADUAL ENLARGEMENTS	
Ratio d/D q = 10° typical	
0.9	0.02
0.7	0.13
0.5	0.29
0.3	0.42

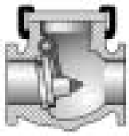


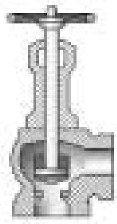
GRADUAL CONTRACTIONS	
Ratio d/D q = 10° typical	
0.9	0.03
0.7	0.08
0.5	0.12
0.3	0.14

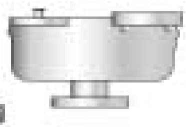


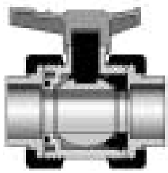
VALVES	
Gate Valve (fully open)	0.20
Reflux Valve	2.50
Globe Valve	.00
Butterfly Valve (fully open)	0.20
Angle Valve	5.00
Foot Valve with strainer hinged disc valve	15.00
unhinged (poppet) disc valve	10.00
Air Valves	zero
Ball Valve	0.10











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.
PVC rubber ring jointed pressure pipes are capable of performing under the most severe conditions of negative pressure. Both AS1477 and AS2977 specify that joints must withstand a minimum vacuum of 90 kPa for 2 hours without leakage.
For a circular ring subjected to a uniform external pressure (or internal vacuum) the critical buckling pressure P_{CR} is defined by Timoshenko as:

$$P_{CR} = \frac{2.E}{\left(\frac{D - t}{t}\right)^3}$$

where
E = Young's Modulus (MPa)
D = outside diameter (mm)
t = wall thickness (mm)

For long tubes such as pipelines under combined stress, Poissons effect must be taken into account, and the equation becomes:

$$P_{CR} = \frac{2.E}{1 - \upsilon^2} \times \left(\frac{t}{D - t}\right)^3$$

Young's Modulus (E) for short term loading i.e. where the negative pressure is only present for a short duration, such as column separation under severe water hammer conditions, = 2750 MPa.
Young's Modulus (E) for long term loading, such as for pipe installed underwater is recommended as = 1370 MPa.

Poisson's Ratio
υ = 0.38

EXPANSION AND CONTRACTION

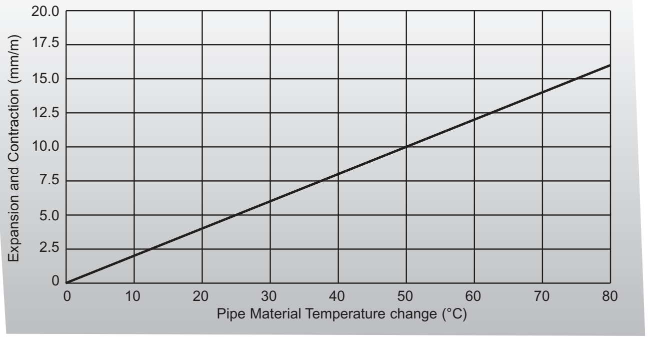
Expansion and contraction of Marley pipes occurs with changes in the pipe material service temperature.
This is in common with all pipe material and in order to determine the actual amount of expansion or contraction, the actual temperature change, and the degree of restraint of the installed pipeline need to be known.
For design purposes, an average value of

2.0×10^{-4}/°C for Marley PE pipes
8.0×10^{-5}/°C for Marley PVC pipes

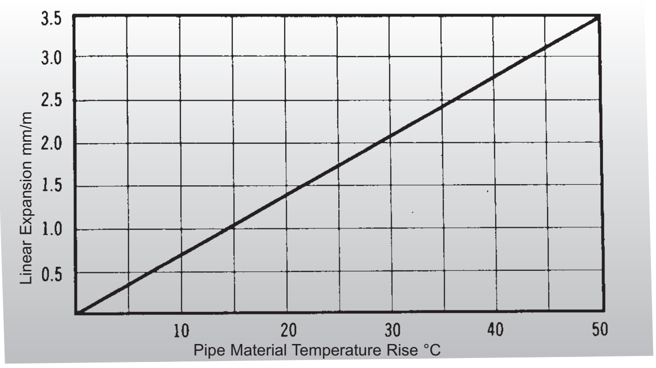
may be used.
The relationship between temperature change and length change for different materials.
Where pipes are buried, the changes in temperature are small and slow acting, and the amount of expansion/contraction of the pipe is relatively small. In addition, the frictional support of the backfill against the outside of the pipe restrains the movement and any thermal effects are translated into stress in the wall of the pipe.
Accordingly, in buried pipelines the main consideration of thermal movement is during installation in high ambient temperatures.
Above ground PE 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. But with PVC pipes allowance must be made for expansion and contraction.

Thermal Expansion and Contraction

- for MDPE



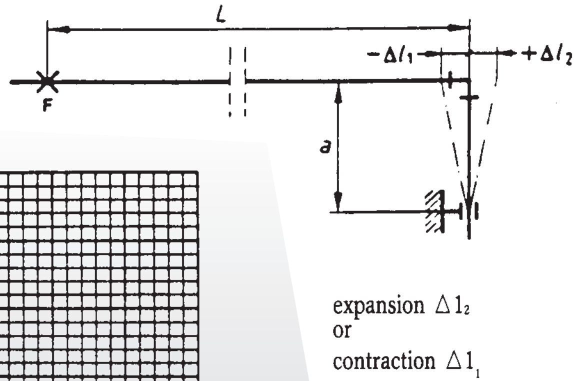
- for PVC

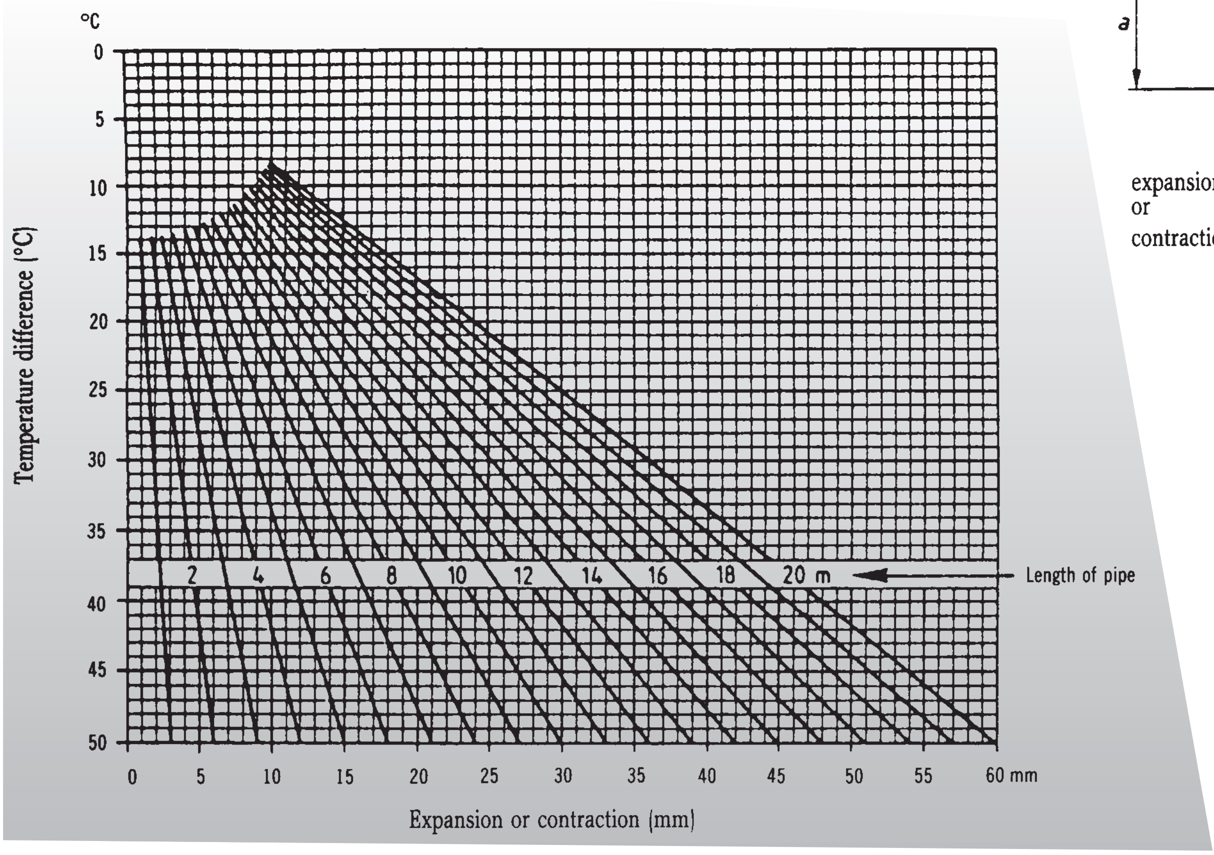


Design

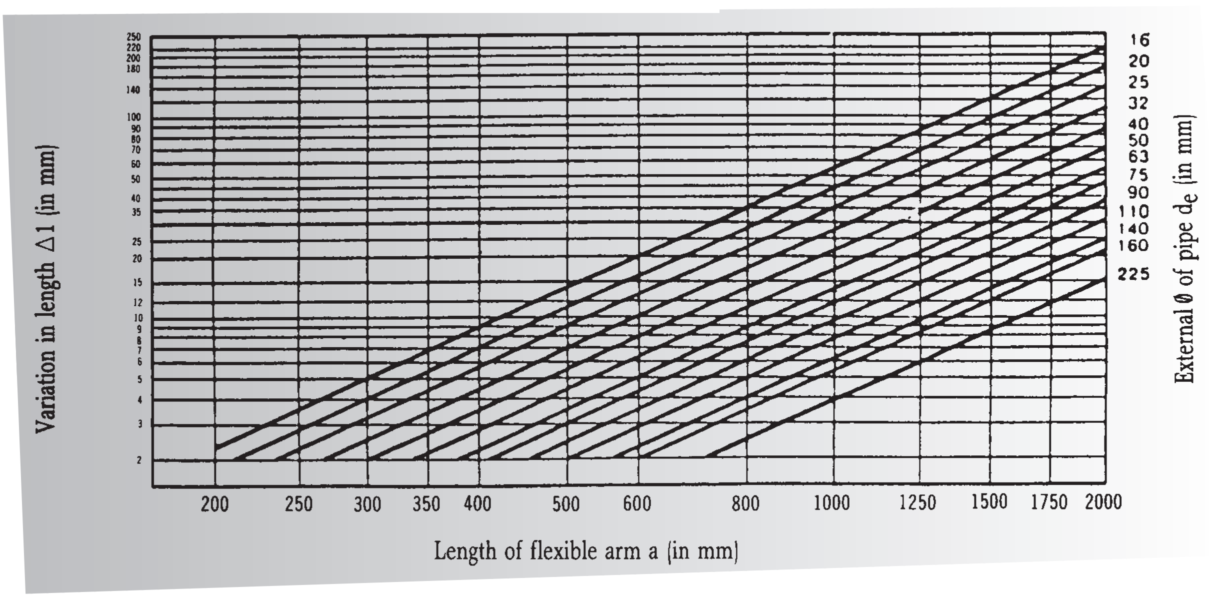
THERMAL EXPANSION OR CONTRACTION

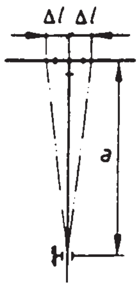
Maximum Expansion or Contraction of Unplasticised uPVC Pipe





Determination of the Length of the Flexible Arm





Example: For a pipe with expansion of 10mm and an external diameter (d_e) of 50mm, the length of the arm (a) shall be at least 750mm.

6. INSTALLATION

RETURN TO CONTENTS

6.1 DESIGN CONSIDERATION

1. Where Marley Pressure Pipes are selected the designer must consider:
 • the use of straight or coiled pipes
 • the jointing method
 • the trench width (standard or narrow)
 • directional drilling – no trench installation

2. Marley Pressure pipes are available either in coils or straight lengths depending upon pipe size and material selected.

 Straight pipes are usually produced in 6m or 12m lengths and MDPE coils are currently available in sizes up to 125mm.

3. Open trench pipeline 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 but 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. Trenchless techniques such as directional drilling and impact moling can be used particularly well with PE systems.

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.

6.2 LOADS ON PIPES

6.2.1 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 2053 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 warranted. This applies to all classes of pipe.
For depth 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 2566 (Australian Standards 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.

6.2.2 Bending Loads

Under bending stress Marley 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 independantly.

6.3 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)
U	=	Poissons Ratio (0.4)
t	=	wall thickness (mm)
D_m	=	mean pipe diameter (mm)

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.

See table Section

Tabulations of the value of E` for various combinations of soil types and compactions are contained in AS2566.
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 a Class 9 pipe should be used as a minimum for pump suction lines or when negative pressure will be generated due to gradient the pipe is laid.
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.

6.4 EXTERNAL LOADING

Underground pipes behave as structural elements and as such are required to withstand external loads from various sources.
The actual loading on the pipe may be caused by one of more of the following:

1) Earth loads in either trench or embankment installations.
2) Imposed loading either concentrated point loading or uniformly distributed loading such as in footings or foundations.
3) Traffic loads from aircraft, railway and motor vehicles.

AS/NZS2555 – 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 1,2 and 3 is as follows:

4) Earth Loads

Trench

a) Embankment
b) $W = C_e w D^2$

1) Imposed Loads

Uniformly distributed load

2) Trench
$W = C_u B U$
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

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

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
= 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)

6.5 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 AS2566 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 in AS1477 & AS/NZS4130. This value originally related to the limit applied to cement lined steel pipe as being the limit before the lining cracked under loading.
In the case of homogeneous flexible pipes this limit has not engineering basis and may be exceeded without structural damage. For such pipes deflection of 20% O.D may be tolerated without structural distress.
In several overseas countries deflection values of 7 and 12.5% O.D. are used for design purposes.
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% O.D. 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 AS2566 using the approach developed by Spangler in the USA at Iowa State College.

In this case the deflection is calculated as follows:

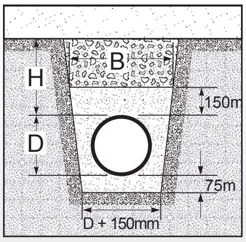
$$\Delta x = \frac{1.5 \times 10^{6} L_{D} R(D/T)^{3} W}{Ec + 0.0915 E` (D/T)^{3}}$$

Where

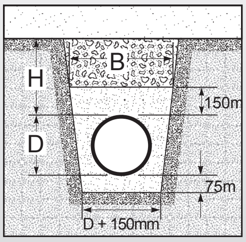
Δ	=	diametrical deflection (m)
D	=	mean pipe diameter (m)
T	=	pipe wall thickness (m)
Ec	=	elastic modulus of pipe material (MPa)
E`	=	modulus of soil reaction (MPa)
W	=	load acting on pipe (N/m)

As indicated previously, 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 as follows:

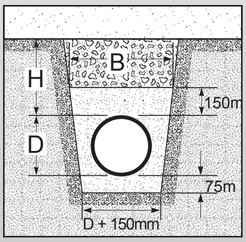
a) Type 1
The highest level of compaction as used in the highway and road pavements and requires mechanical compaction techniques.

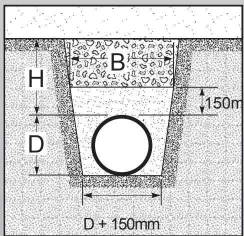


b) Type 2
The level of compaction attained by thorough hand tamping methods normally used in trench and embankment conditions for sewer and drain applications.



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.





6.6 BELOW GROUND INSTALLATION

6.6.1 Preparing the Pipes

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. Pipe ends should be checked to ensure that the spigots and sockets are free from damage.
Pipes of the required diameter and pressure rating should be identified and matched with their respective fittings and placed ready for installation.

6.6.2 Preparing the Trench

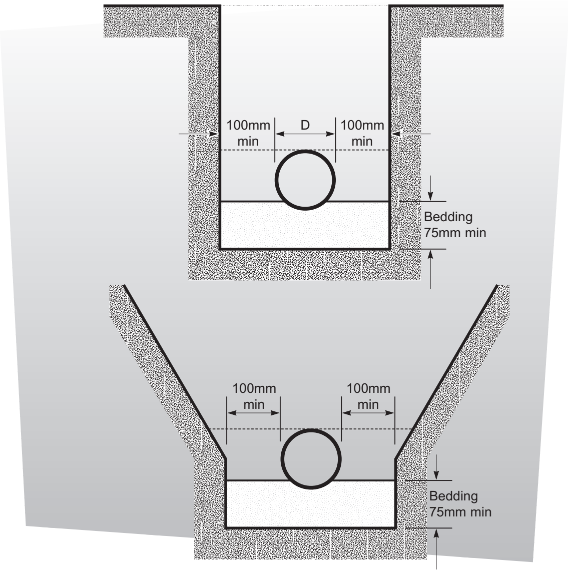
Marley pipe can be damaged or deformed if its support by the ground on which it is laid is not made as uniform as possible. The trench bottom should be examined for irregularities and any hard projections removed.
The minimum trench width should allow for adequate tamping of side support material and should be not less than 200mm 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

Trench Widths

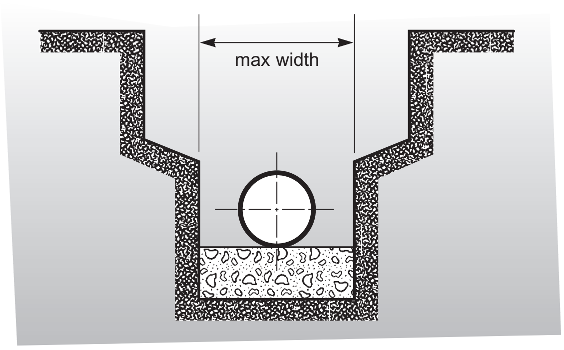
In general, the width of trenches should be kept to the minimum that enable construction to readily proceed.



The width of trenches used with PE pipe may be reduced from those used with PVC 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.

6.6.3 Wide Trenches

For deep trenches where significant soil loading may occur, the trench should not exceed the widths given in 6.6.2 without further investigation.
Alternatively the trench should be widened until stability is reached. At this point, a smaller trench may then be excavated in the bottom on the trench to accept the pipe. In either case do not exceed the maximum trench width at the top of the pipe unless allowance has been made for the increased load.



6.6.4 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.

6.6.5 Minimum Cover

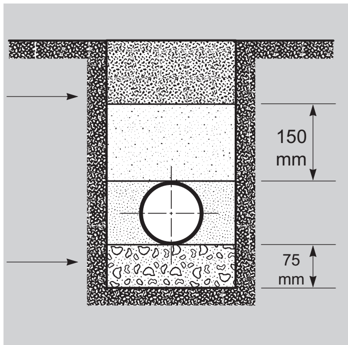
Trenches should be excavated to allow for the specified depth of bedding, the pipe diameter and the minimum recommend cover, overlay plus backfill, above the pipes. Table below provides recommendations for minimum cover to pipe crown.

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 pressure ratings of pipe. 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.



6.6.6 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.
Sands containing fines, and clays, are difficult to compact and should only be used where it can be demonstrated that appropriate compaction can be achieved.

Variations in the hard bed should never exceed 20% of the bedding depth. Absolute minimum underlay should be 50 mm.

6.6.7 Pipe Side Support

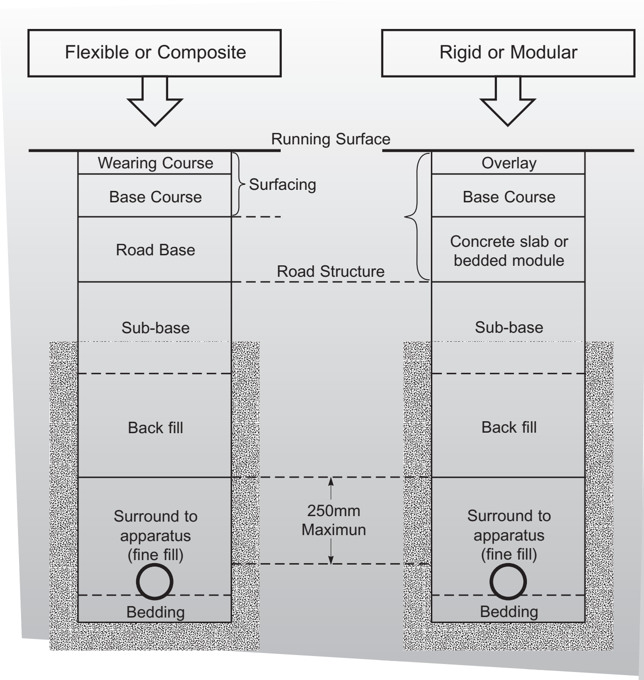
Material selected for pipe side support should be adequately tamped in layers of not more than 75mm for pipes up to 250mm diameter and 150mm for pipes of diameters 300mm and above. Care should be taken not to damage the exposed pipe and to tamp evenly on either side of the pipe to prevent pipe distortion. Care should be taken not to disturb the line or grade of the pipeline, where this is critical, by excessive tamping.

Unless otherwise specified, the pipe side support and pipe overlay material used should be identical with the pipe bedding material.

Compaction should be brought evenly to the design value required by AS/NZS2566 for the specification installation.

6.6.8 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. If water flooding is used and extra soil has to be added to the original backfill, this should be done only when the flooded backfill is firm enough to walk on.
When flooding the trench, care should be taken not to float the pipe, or wash fines into rear joints.
All ground should be compacted back to 91-



Trench Reinstatement Zone Terminology

95%.The loads arise from two sources; the static or pressure force and the kinetic or velocity force.

6.7 THRUST SUPPORT

An imbalanced thrust is developed by a pipeline at:
- Direction changes (>10°), e.g. tees and bends.
- Changes in pipeline size at reducers.
- Pipeline terminations, e.g. at blank ends and valves.

The support system or soil must be capable of sustaining such thrusts.
Pressure thrust results from internal pressure in the line acting on fittings. Velocity thrust results from inertial forces developed by a change in direction or flow. The latter is usually insignificant compared to the former.

6.7.1 Anchorage and Thrust Blocks MDPE

1. One of the fundamental features of fully integrated Butt welded PE pipe systems is that they are end-load resistant and anchorage is not normally required at junctions or bends.
2. However, for push-fit systems or where individual non end-load resistant fittings are used, anchor blocks to withstand the resultant thrusts must be provided in the traditional manner. For pipes greater than 63mm, the use of concrete anchor blocks should be specified.

6.7.2 Anchorage and Thrust Blocks PVC

Underground PVC pipelines jointed with rubber ring joints require concrete thrust blocks to prevent movement of the pipeline when a pressure load is applied. In some circumstances, thrust support may also be advisable in solvent cement jointed systems. Uneven thrust will be present at most fittings. The thrust block transfers the load from the fitting, around which it is placed, to the larger bearing surface of the solid trench wall.

6.7.3 Anchorage at Fittings

It is advisable to rigidly clamp at valves and other fittings located at or near sharp directional changes, particularly when the line is subjected to wide temperature variations.
Ffittings should be supported individually and valves should be braced against operating torque.

Pressure Thrust

The pressure thrust developed for various types of fittings can be calculated as follows:

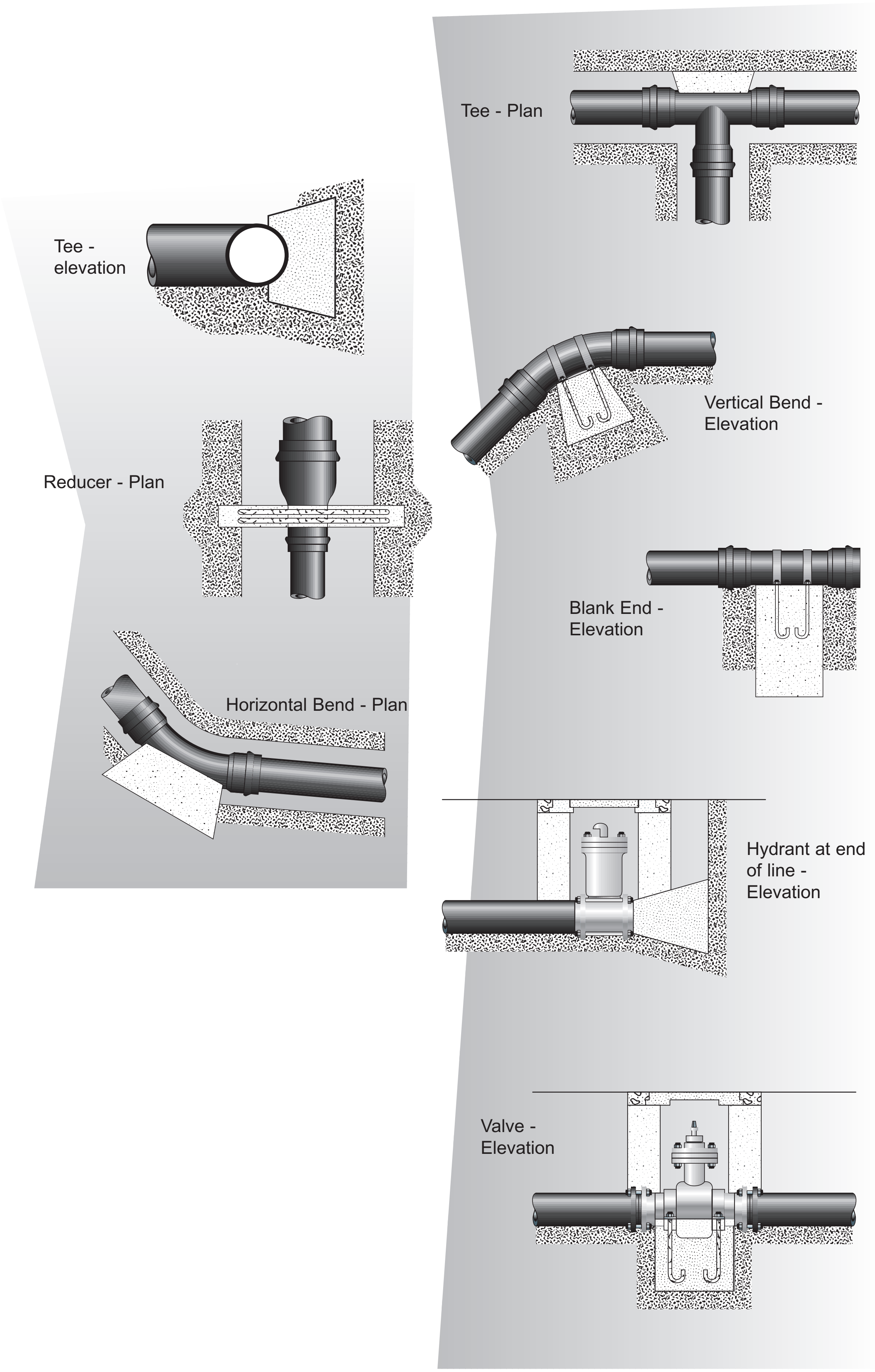
Blank ends, tees, valves	$F = A\ P\ 10^{-3}$
Reducers and tapers	$F = (A_1 - A_2)\ P\ 10^{-3}$
Bends	$F = 2\ A\ P\ \sin(O/2)\ 10^{-3}$

Where:

F	= resultant thrust force	(kN)
A	= area of pipe taken at the OD	(mm^2)
P	= design internal pressure	(MPa)
O	= included angle of bend	(degrees)

The design pressure used should be the maximum pressure, including water hammer, to be applied to the line. This will usually be the field test pressure.

THRUST SUPPORT DETAIL



Pressure Thrust at Fittings in kN for Each 10 Metres Head of Water

SIZE DN	AREA (mm2)	BENDS 11 Qr °	22 Qw °	45°	90°	TEES ENDS
15	363	.01	.01	.03	.05	.04
20	568	.01	.02	.04	.08	.06
25	892	.02	.03	.07	.12	.09
32	1410	.03	.05	.11	.20	.14
40	1840	.04	.07	.14	.26	.18
50	2870	.06	.11	.22	.40	.28
65	4480	.09	.17	.34	.62	.44
80	6240	.12	.24	.47	.87	.61
100	6240	.20	.39	.77	1.43	1.01
125	10300	.30	.59	1.16	2.15	1.52
150	20200	.39	.77	1.52	2.80	1.98
200	40000	.77	1.53	3.00	5.55	3.92
225	49400	.95	1.89	3.71	6.85	4.84
250	61900	1.19	2.37	4.65	8.58	6.07
300	78400	1.51	3.00	5.88	10.87	7.69
375	126000	2.42	4.82	9.46	17.47	12.36

6.7.4 Construction of Thrust Blocks

Concrete should be placed around the fitting in a wedge shape with its widest part against the solid trench wall. Some forming may be necessary to achieve an adequate bearing area with a minimum of concrete. The concrete mix should be allowed to cure for seven days before pressurisation.

A thrust block should bear firmly against the side of the trench and to achieve this, it may be necessary to hand trim the trench side or hand excavate the trench wall to form a recess. The thrust acts through the centre line of the fitting and the thrust block should be constructed symmetrically about this centre line.

Pipes and fittings should be covered with a protective membrane of PVC, polyethylene or felt when adjacent to concrete so that they can move without being damaged.

The designer should consider all aspects of the system, including the unbalanced loads imposed by testing procedures, unusual configurations, large temperature variations, etc and where excessive load on the pipe system is envisaged, additional anchorage should be considered. To establish thrust block size establish the pressure to be applied to the line, calculate thrust developed consider the safe bearing capacity of the soil type using one 3 x safety factor.

In shallow (<600mm) cover, installations or in unstable conditions of fill, the soil support may be considerably reduced and a complete soil analysis may be needed.

The velocity thrust is generally small in comparison to the pressure thrust.

The pressure used in the calculations should be the maximum working or test pressure applied to the line.

Where pipes are installed on steep slopes (greater than 1:5) then bulkheads may need to be placed along the pipeline to prevent movement of the pipes, these can be placed at such support points as flange locations. Additional supports, such as sand bags, may be required to prevent scouring of bedding and backfill materials down the trench floor.

Calculating Thrust Block Size.

1) Establish the maximum working or test pressure to be applied to the line.

2) Calculate the thrust developed at the fitting being considered.

3) Divide 2) above by the safe bearing capacity per square metre for the soil type against which the thrust block must bear.

Example

What bearing area of thrust block is required for a 150mm Class 12 90º. Bend in hard dry clay.

i) Maximum working pressure of Class 12 pipe is 1.2 MPa. Test pressure is 1.5 times working pressure = 1.0 MPa.

ii) A 150mm x 90º bend develops a thrust of 24.9×10^{-3} newtons for each pascal of pressure applied.
Therefore thrust =
$(24.9 \times 10^{-3}) \times (1.8 \times 10^{6}) = 4.4 \times 10^{4}$ newtons.

iii) Bearing capacity of hard dry clay is 15×10^{4} newtons per square metre. Therefore bearing area of thrust block =

Velocity Thrust

Applies only at changes in direction of flow:

$$F = W a V^2 \cdot 2 \sin(0/2) \cdot 10^{-9} \qquad \text{(kN)}$$

Where:

a = cross sectional area of pipe take at the inside diameter (mm^2)
W = density of fluid (water = 1,000) (kg/m^3)
V = velocity of flow (m/s)

6.7.5 Bearing Loads of Soils

The indicative capacities of various soil types are tabulated below:

Soil Type	Safe Bearing Capacity (newtons per square metre)
Rock and sandstone (hard thick layers)	100 x 10^5
Rock – solid shale and hard medium layers	90 x 10^4
Rock – poor shale, poor limestone, etc	24 x 10^4
Gravel and coarse sand (mixed)	20 x 10^4
Sand – compacted, firm, dry	15 x 10^4
Clay – hard, dry	15 x 10^4
Clay – readily indented by thumb but penetrated with difficulty	12 x 10^4
Clay – easily penetrated several inches by thumb, sand loam	9 x 10^4
Peat, wet alluvial soils, silt, etc	nil

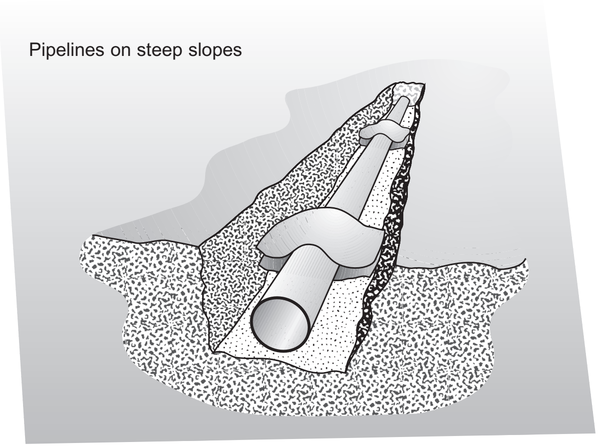
6.8 PIPELINES ON STEEP SLOPES

Two problems can occur when pipes are installed on steep slopes, i.e. slopes steeper than 20% (1:5).

1. The pipes may slide downhill so that the witness mark positioning is lost. It may be necessary to support each pipe with some cover during construction to prevent the pipe sliding.

2. The generally coarse backfill around the pipe may be scoured out by water movement in the backfill. Clay stops or sandbags should be placed in appropriate intervals above and below the pipe to stop erosion of the backfill.

Pipelines on steep slopes



6.9 PIPELINE BUOYANCY

Pipe under wet conditions can become buoyant in the trench. Marley pipes, being lighter than most pipe materials 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.

6.10 EXPANSION JOINTS

For above ground installations with solvent cement joints provision should be made in the pipeline for expansion and contraction. If the ends are constrained and there is likely to be significant thermal variation, then a rubber ring joint should be installed at least every 12m to allow for movement within the pipeline, or such spacing as determined by calculation.

6.11 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.

6.11.1 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 4-20MH_Z 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.

6.11.2 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.

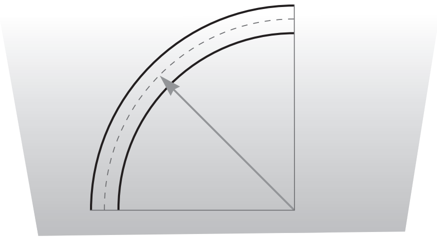
6.11.3 Audio Detection

Acoustic, or ultrasonic, 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.

6.12 BENDS AND BENDING

6.12.1 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. However, for PE materials the pipe should not normally be cold bent to a radius less than 20 times the outside diameter of the pipe. 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.

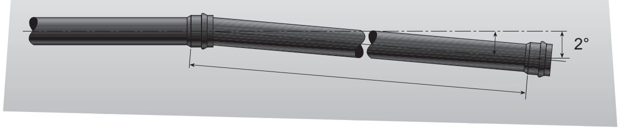
6.12.1 Bending PVC Pipes

When installing PVC pipes on a curve, the pipe should be jointed straight and then laid to the curve.
Significant bending moments should not be exerted on the joints, since this introduces undesirable stresses in the spigot and socket that may be detrimental to long term performance. To avoid this, the joints in curved lines must be thoroughly supported by compacted soil, with the bending occurring primarily at the centre of each pipe.
Some changes in the alignment of the pipe may be achieved without the use of direction-change fittings such as elbows and sweeps. PVC pipe is capable of controlled longitudinal bending within acceptable limits. A combination of axial flexure and joint deflection can achieve further longitudinal deviation of the pipeline. As a guide, PVC pipe can be bent to a radius equal to 130 times the diameter. However, Marley recommends that pipe under pressure should be bent to a radius not less than 300 times the diameter, e.g. a 100 mm pipe should have a minimum radius of curvature of 30 metres.

6.12.3 Joint Deflection

PVC Solvent cement joints have no flexibility but rubber ring joints can provide some joint deflection. The allowable deflection at the pipe Z socket should not be greater than a deflection of 2°.

Angular deflection of a single pipe joint (shown exaggerated for clarity).



Flexural Stress

One critical limit to the bending of PVC pipe is long term flexural stress. Axial bending causes only a small amount of ovalisation or diametric deflection of the pipe, which indicates some change in circumferential stress. PVC pipe has short term strengths of 48 - 55 MPa in tension and 75 - 100 MPa in flexure. The long term strength of PVC pipe in tension, compression or flexure can conservatively be assumed to equal the ultimate hydrostatic design stress of 23.6 MPa. The recommended design stress of 11.0 MPa for PVC pipe at 20°C be used for the allowable long term flexural stress in rubber ring pipe that is free of longitudinal stress from longitudinal pressure thrust. However, when the joints are restrained as they are when solvent cemented, and the pipe is not snaked in the trench, then the end thrust from internal pressure imposes a longitudinal tensile stress equal to one half of the hoop stress.

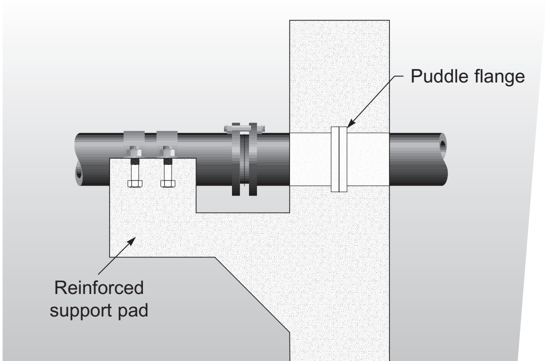
6.13 CONCRETE ENCASEMENT

6.13.1 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 by a flange to a large rigid structure, localised movement and bending at the flange can be prevented by a reinforced support pad as shown below. This pad should extend one pipe diameter or a minimum of 300mm from the flanged joint. The strapping should be provided with a compressible protection to the pipe.



Flanged entry into a large rigid structure

3. Although the flexibility and toughness of PE is advantageous in these situations it is recommended that before filling;

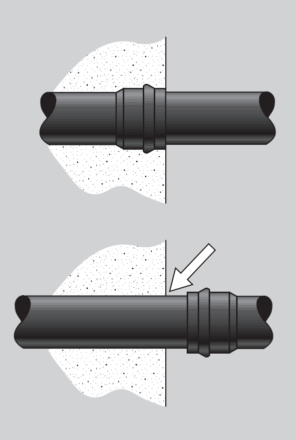
- all bolts should have a check retightening before final backfill;
- particular attention is paid to the compaction around and several diameters beyond, all fittings associated with the connection. Compaction to 90%. Proctor density or greater in these areas should be ensured.

4. These points of detail are important since these connections are often deep and sometimes associated with underdrainage, (e.g.outlets to reservoirs). This usually means any subsequent defect is difficult to identify, expensive to locate and very costly to remedy.

6.13.2 Setting of Pipes in Concrete

When PVC pipes are encased in concrete, certain precautions should be taken:

1. Pipes should be fully wrapped with a compressible material such as felt or poly film.
2. Alternatively, flexible (rubber ring) joints should be provided at entry to and exit from the concrete as shown. This procedure also allows for possible differential movement between the pipeline and concrete structure.
   It must be borne in mind, however, that without a compressible membrane, stress transfer to the concrete will occur and may damage the concrete section.



3. Expansion joints coinciding with concrete expansion joints should be provided to accommodate movement due to thermal expansion or contraction in the concrete.

PE pipes behave as flexible structures when externally loaded, and care needs to be exercised by the designer when using concrete encasement so that the effective strength of the pipeline is not reduced.

6.14 ABOVE GROUND INSTALLATION

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

Black PE pipes made to AS/NZS 4130 requirements may be used in direct sunlight exposure conditions without any additional protection. Where MDPE pipes of colours other than black are used in exposed conditions, then the pipes may need to be protected from sunlight. PVC pipes all have 1.5PHR of Titanium Dioxide to act as a UV absorber. 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.

6.14.1 Support Spacing

The spacing of supports for a uPVC 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 8 below, shows the support spacing in metres for uPVC pipe carrying water at 20°C. These spacings do not allow for additional extraneous loading.

Recommended Support Spacing

- for PVC pipes

SIZE	MAXIMUM SUPPORT SPACING	
	HORIZONTAL (m)	VERTICAL (m)
15	0.60	1.20
20	0.70	1.40
25	0.75	1.50
32	0.85	1.70
40	0.90	1.80
50	1.05	2.10
65	1.20	2.40
80	1.35	2.70
100	1.50	3.00
125	1.70	3.40
150	2.00	4.00
175	2.20	4.40
200	2.30	4.60
225	2.50	5.00
300	3.00	6.00

- 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.

6.14.2 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.

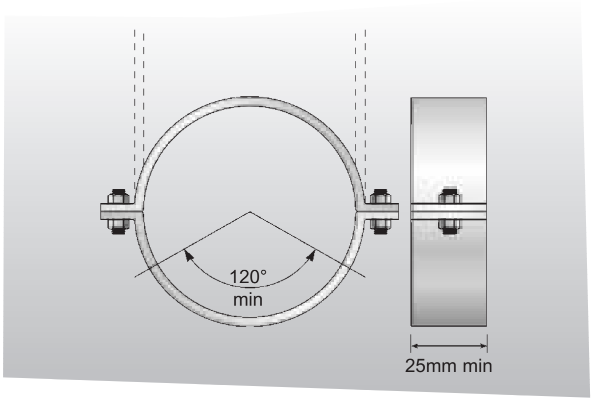
6.14.3 Brackets and Clips

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, either plastic coated or wrapped in a protective material such as nylon, PE, PVC or rubber sheet. 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 fee support allows the pipe to move without restraint along its axis while still being supported. To prevent the support from scuffing or damaging the pipe as it expands and contracts, a 6mm thick layer of felt or lagging material is wrapped around the support. Alternatively, a swinging type of support can be used and the support strap, protected with felt or lagging, must be securely fixed to the pipe.

Fixed Supports

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.
For solvent cement jointed pipe any expansion coupling must be securely clamped with a fixed support. Other pipe clamps should allow for movement due to expansion and contraction. Rubber ring jointed pipe should have fixed supports behind each pipe socket.

6.15 INSTALLATION CONSIDERATIONS

6.15.1 Expansion and Contraction

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.
Will MDPE lines 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.
For solvent cemented systems, the lines should be free to move until a strong bond has been developed (see solvent cement jointing procedures) and installation procedure should ensure that contraction does not impose strain on newly made joints.
For rubber ring jointed pipes, if contraction accumulates over several lengths, pull out of a joint can occur. To avoid this possibility the preferred technique is to back fill each length, at least partially, as laying proceeds. (It may be required to leave joints exposed for test and inspection.)
It should be noted that rubber ring joint design allows for contraction to occur. Provided joints are made to the witness mark in the first instance, and contraction is taken up approx. evenly at each joint, there is no danger of loss of seal. A gap between witness mark and socket of up to 10 mm after contraction is quite acceptable.
Further contraction may be observed on pressurisation of the line (so-called Poisson contraction due to circumferential strain). Again this is anticipated in joint design and quite in order.

6.15.2 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.

6.15.3 Vibration

Direct connection to sources of high frequency such as pump outlet falnges should be avoided. Allfabricated 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 flexible joint such as a repair coupling, expansion joint, or wire reinforced rubber bellows joint. When used above ground such joints may need to be restrained to prevent pipe end pullout.

6.15.4 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.

6.15.5 Fire Rating

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

6.15.6 Ploughing In

MDPE pipe may be ploughed directly into the ground.
The pipe must be stationary in relation to the surrounding soil and care must be taken to ensure that the pipe is not excessively tensioned during the ploughing activities.
Ploughing should not be attempted where the soil contains rock or sharp stones or shale outcrops.

6.16 PNEUMATIC DESIGN

6.16.1 Pneumatic Flow

Marley MDPE 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.

I. Compressed air may be at a higher temperature than the ambient air and PE pipes require temperature re-rating accordingly.
   For air cooled compressors the air temperature averages 15ºC above the surrounding air temperature.
   For water cooled compressors the air temperature averages 10ºC above the cooling water temperature.

II. For underground applications the surrounding temperature may reach 30ºC and the pipe properties require adjustment accordingly.

III. High pressure lines must be protected from damage, especially in exposed installations.

IV. Valve closing sped must be reduced to prevent a build up of pressure waves in the compressible gas flow.

V. 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.

VI. 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.

VII. Dry gases and gas/solids mixtures may generate static electrical charges and these must be dissipated to prevent the possibility of explosion.

VIII. Compressed air must be dry and filters installed in the line to prevent stress cracking in the PE pipe.

IX. The fitting systems used must be pressure compatible with the pipe and pressure compatible with the pipe and where meta; 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.

6.16.2 Compressed Air Formula

It is customary to find the inside Diameter of the pipe by using formulas such as those 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 apprixmation through the following equation.

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

Where

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

The values are specific to each fluid type and the properties should be available from testing.
It is not permitted under the New Zealand Health and Safety Act to use PVC for compressed air lines.

6.17 TRENCHLESS INSTALLATION

Marley's plastic pipes are a versatile material and particularly through their toughness and flexibility, they are able to be used with a range of cost effective "no dig" methods for the pressure pipelines installation.

In particular:

- Guided drilling - directional drilling
- Pipe cracking
- Close-fit lining - Slip lining

7. JOINTING SYSTEMS

RETURN TO CONTENTS

- **PVC Pipe Jointing**
  - **Rubber Ring Jointing**
  - **Solvent Cement Jointing**

- **PE Pipe Jointing**
  - **PE Electrofusion**
  - **Butt Welding**

- **Mechanical Jointing**
  - **Mechanical Joints**
  - **Tapping Systems**

PVC PIPE JOINTING SYSTEMS

PVC pipes employ two jointing systems:

1. Rubber Ring Joint (“Z” Joint)
A rubber ring joint system providing a flexible joint with capability of axial and angular movement. Simple, error free installation makes this joint suited to larger diameter underground work. Sizes 50 and larger.

2. Solvent Cement Joint
A chemically “welded” joint with capability of supporting axial thrust. Available in sizes to 300 but especially suited to smaller diameter systems.

7.1 RUBBER RING JOINTING

One end of the PVC pipe is accurately pressure formed to provide a purpose designed socket and groove into which is fitted a purpose made rubber sealing ring. The socket is strengthened by increasing its wall thickness in both socket and groove zone, to accommodate the increased Hoop Stress.

7.1.2 Specification

The “Z” joint socket and ring seal are designed to conform with the requirements of AS/NZS 1477.
The performance test in AS/NZS 1477 requires that the spigot side of a completed joint be flattened by 7.5% of the pipe diameter. While distorted the joint must withstand a negative pressure of 25 kPa for one hour without leaking.
Performance tests not required by the Standard show that the undistorted joint will not leak when a negative pressure of 100 kPa is applied.
These tests ensure that a Marley PVC water supply system, even under extreme conditions will neither leak nor admit contaminated ground water.

Cutting

PVC is notch sensitive and care should be taken when cutting.
During manufacture pipes are cut to standard by cut off saws. These saws have carbide-tipped circular blades which produce a neat cut without burrs.
However, pipes may be cut on site with a variety of cutting tools. These are:

1. Proprietry cutting tools
These tools can cut, deburr and chamfer the pipe in one operation. They are the best tools for cutting pipe.

2. Portable electric circular saw with cut off wheel
This is quick and easy to use and produces a neat clean cut requiring little deburring. It does, however, require a power supply and the operator has to be skilled in using it to produce a square cut.

3. A fine tooth hand saw and mitre box
This saw produces a square cut but requires more deburring. It takes comparatively more time and effort and requires a stand.
The use of roller cutters is not recommended because of the large burr resulting.

7.1.3 Rubber Ring Joints

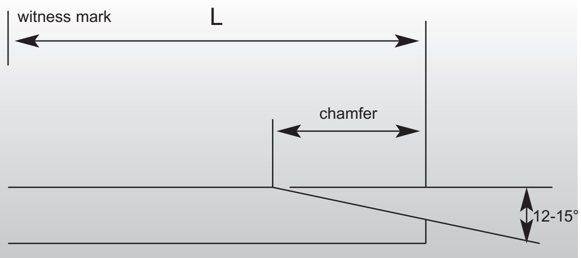
Jointing rings are supplied with the pipe. We recommend the use of a lubricant approved for use with potable water supply lines. Other lubricants may not be suitable for potable water contact and may affect the ring. They should not be substituted without specific knowledge of these effects.
The ring provides a fluid seal in the socket of a pipe or fitting and is compressed when the spigot is passed into the socket. Rings from other manufacturers cannot be interchanged.

7.1.4 Chamfering

If the pipe is to be used for making a rubber ring joint, a chamfer is required. Special chamfering tools are available for this purpose, but in the absence of this equipment a flat file can be used provided it does not leave any sharp edges which may cut the rubber ring. Do not make an excessively sharp edge at the rim or the bore and do not chip or break this edge. As a guide, cut the chamfer to 15° to the pipe surface to approx. half the wall thickness at the pipe end.
When a pipe is cut, a witness mark should be pencilled in and care should be taken to mark the correct position in accordance with Table 6.

Rubber Ring Spigot Dimensions

Size DN	Approx length of chamfer (mm)	Witness mark L (mm)
50	6	103
65	8	110
80	10	116
100	13	126
125	13	137
150	14	145
200	20	162
225	22	174
300	28	213



Pipe Chamfer

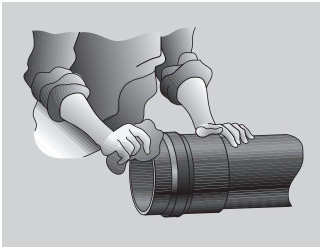
7.1.5 Procedure

Pipes may be jointed out of the trench but it is preferable that connections be made in the trench to prevent possible "pulling" of the joint.

Clean the socket, especially the ring groove and the rubber seal ring. Do not use a rag with lubricant on it - to prevent dust and grit adhering to these surfaces.

Check that the spigot end, if cut in the field, has a chamfer of approximately 12° to 15° (see Table 6).

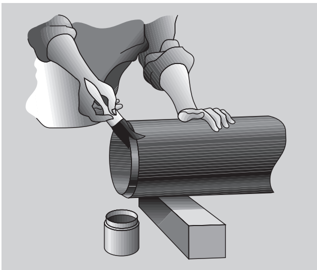
Insert the rubber ring into the groove. The rubber ring is correctly fitted when the thickest cross section of the ring is positioned towards the outside of the socket and the groove in the rubber ring is positioned inside the socket i.e. the flap should point into the pipe.



Run your finger around the lead-in angle of the rubber ring to check that it is correctly seated, not twisted, and that it is evenly distributed around the ring groove.

Remove dirt and dust from the spigot end of the pipe as far back as the witness mark.

Apply Marley jointing lubricant to the spigot end as far back as the witness mark and especially to the chamfered section.



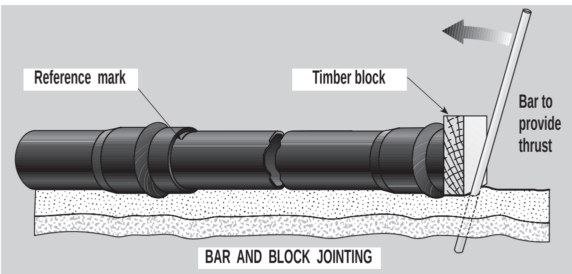
NOTE: Keep the rubber ring and ring groove free of jointing lubricant until the joint is actually being made.

Align the vertical and horizontal pipes and apply a firm, even thrust to push the spigot into the socket. Ensure allowance in the pipe bed for the socket shape. It is possible to joint 100 mm and 150 mm diameter pipes by hand. However, larger diameter pipes such as 200 mm and above may requre the use of a bar and timber block as illustrated. Alternatively, a pipe puller may be used to joint the pipe.

Brace the socket end of the joint so that previously jointed pipes are prevented from closing up.

Inspect each joint to ensure that the witness mark is visible at the face of each socket.

Pipe joints must not be pushed home to the bottom of the socket. They must go no further than the witness mark. This is to allow for possible expansion of the pipe, and ground movement.



BAR AND BLOCK JOINTING

NOTE: If excessive force is required to make a joint, this may mean the rubber ring has been displaced. To check placement of the ring without having to dismantle the joint, a feeler gauge can be inserted between the socket and the pipe to check even placement of the ring, or use a torch to check the pipe joint.

Details of the construction of a pipe puller are available.

7.1.6 How to make a Rubber Ring Joint

Check Spigot End
Ensure pipe spigot has full 15°chamfer and entry depth mark.

Clean Socket
Clean socket and ring groove of dirt and loose gravel.

Clean Rubber Ring

Fit Rubber Ring
Place rubber Z ring in groove and check for proper sealing. Fin must point into pipe.

Align Pipes
Align pipes horizontally and vertically. Do not try to insert pipe at an angle to socket.

Lubricate Spigot
Clean of dust and dirt and apply jointing lubricant to chamfer. Keep end free from dirt.

Insert Pipe
Insert spigot into socket to the marked distance. Do not use undue force. If force is required, check ring seating, using a torch to look up the pipe.

DO NOT LEAVE SOLVENT CEMENT ON YOUR SKIN.

Jointing Lubricant

This lubricant is a specially formulated organic preparation enabling easy jointing of rubber ring joint pressure pipe. The use of petroleum based greases or other substitutes may affect the ring or potability of the water supply and cannot be recommended.

This lubricant dries after a short period of time and the joint cannot be easily dismantled. For situations where it may be necessary to dismantle the rubber ring joint after assembly, the use of silicone based jointing lubricant is recommended. Where it is necessary to joint in wet conditions, it may also be advantageous to use silicone lubricant. If dismantled, joints should be fitted with new rings.

7.2 SOLVENT CEMENT JOINTING

Solvent cement pressure pipe joints require an interference fit between the spigot and socket in pipes and fittings. Solvent cement jointing is a welding and not a glueing process. It is very important that the spigot achieve an interference fit in the socket. Do not attempt to make a joint that does not achieve an interference fit when dry. The actual area of contact between the spigot and the socket may only be a few millimetres. The ends must therefore be square to make a good joint. Before proceeding make sure that the spigots and sockets are not cracked or damaged. A pipe with minor damage to the spigot end may be cut back and used as a shorter pipe.

7.2.1 Procedure (NZS 2032)

Before jointing, check that the spigot has been cut square and all burrs removed from the inside and outside pipe edge. Remove all dirt, swarf, and moisture from spigot and socket. Chamfer the spigot end on pipes over 80 mm diameter.

Mark the pipe spigot with a pencil line at a distance equal to the internal depth of the socket. Other marking methods may be used provided that they do not damage or score the pipe.

Dry fit the spigot into the socket. The spigot should interfere in the socket before it is fully inserted to the pencil line.

Dry and degrease each spigot and socket with a cloth dampened with Methylated Spirits. Prepare the pipe spigot and socket with Marley primer fluid. Wipe the surfaces firmly, to remove all dirt and the glossy surface on both the spigot and socket. (Do not paint surfaces with primer. Primed areas will be slightly tacky.) Prime the surface just before applying the solvent.

Using a suitably sized brush, apply a thin, even coat of solvent cement to the internal surface of the socket first. Then apply a thin, even coat of solvent cement up to the mark on the spigot.

Do not use excess solvent cement, and do not dilute or add anything to the solvent cement.

As a guide, the brush should be approximately one third to one half the pipe diameter and large enough to apply the solvent cement to the joint in about thirty seconds.

Make the joint immediately. In one movement insert and twist the spigot into the socket so that it rotates to about a 1/4 turn. The spigot should be fully homed in the socket. Mechanical force will be required for larger joints, over 100 mm. Pipe pullers are commercially available for this purpose. Hold for a minimum of 30 seconds.

With a clean rag, wipe off any excess solvent cement which may have built up externally on a pipe or fitting socket.

Once the joint is made, do not disturb it for five minutes or rough handle it for at least one hour.

Do not pressurise the line for at least 24 hours.

7.2.2 Health

Marley Solvent Cement has been specially formulated for jointing Marley PVC pipe. It releases flammable and toxic vapours. Forced ventilation should be used in confined spaces. Do not bring a naked flame within the vicinity of solvent cement operations.

After using solvent cement wash the hands thoroughly before eating or smoking. Do not eat or smoke while using solvent cement.

Spillage onto the skin should be washed off immediately with soap and water. Should the solvent cement affect the eyes, wash them in clean water for at least 15 minutes. If solvent cement is accidentally swallowed induce vomiting and seek medical advice immediately.

7.2.3 Precautions

Make sure that the end of each pipe is square in its socket and in the same alignment and grade as the preceding pipes or fittings.

While applying solvent cement, support the spigot and socket clear of the ground to avoid contaminating joint with sand or soil.

Take care not to spill solvent cement onto pipes or fittings. Accidental spillage should be wiped off immediately.

The process of curing is a function of temperature, humidity and time. Joints cure faster when the humidity is low and the temperature is high. The higher the temperature the faster the joints will cure. Avoid making solvent cement joints when the temperature is more than 35°C and provide some form of protection when jointing in windy and dusty conditions.

When jointing under wet and very cold conditions, make sure that the mating surfaces are dry and free from ice, as moisture may prevent the solvent cement from obtaining its maximum strength.

At temperatures over 16°C, joints will require 24 hours to cure. When the temperature is between 0°C and 15°C 48 hours should be allowed. See also the precautions in NZS 2032.

Do not fill the pipe with water for at least one hour after making the last joint.

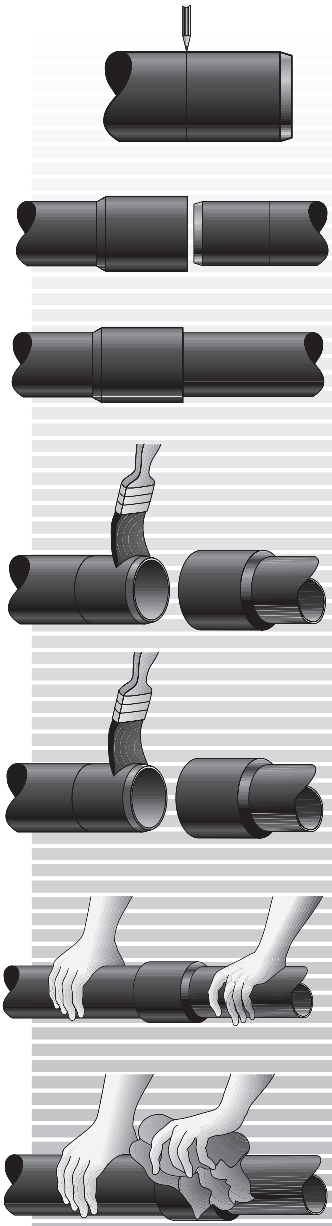
Keep the containers of solvent cement tightly sealed when not in use to prevent evaporation of the solvent and consequent loss of bond strength.

Do not use solvent cement that has gone cloudy or has started to gel in the can.

When applying solvent cement to a pipe or fitting socket take special care to prevent excessive solvent cement from entering the joint as this can cause future “solvent cracking” of the joint. Wipe excess solvent cement from the outside and where possible, from the inside of the joint.

An unsatisfactory solvent cement joint cannot be re-executed, nor can previously solvented spigots and sockets be re-used. To effect repairs, cut off the spigot and socket and use a solvent cement coupling, or use mechanical fittings.

7.2.4 How to make a Solvent Cement Joint



Mark & Chamfer
Mark the socket depth on the pipe end.
Cut a 15° chamfer on larger pipes.

Clean
Clean, dry and degrease the sock and spigot.

Check the Fit
Insert the spigot into the socket (without solvent cement). An interference fit should occur between 1/3 and 2/3 of full entry.

Apply Primer
Prepare the pipe spigot and socket with Marley primer fluid.

Apply Solvent
Apply an even coat of solvent to the socket and then the spigot to the full marked length.

Joint
Insert the spigot the full marked depth in the socket and HOLD for a minimum of 30 seconds, depending on temperature.

Clean Off
Remove surplus solvent cement.

Solvent Cement

Marley Solvent Cement is designed for solvent welding uPVC pipe joints. IT IS NOT AN ADHESIVE. It is a blend of three aggressive solvents and sufficient resin to provide a brushing consistency.

When applied to the pipe surface these solvents cause the uPVC to soften and swell. When two such surfaces are placed in close contact (as in a spigot and socket joint) the softened surfaces mix and on hardening produce a chemically welded joint. Oil, grease, water or dust on the uPVC surface prevents the softening: dust or similar material prevents the intimate contact between the surfaces thus preventing the making of a full strength joint.

Solvent which has thickened in the can through evaporation of the solvents should not be used as it will not soften the pipe surface sufficiently.
The solvents attack the natural oils in human skin eventually causing serious dermatitis.

7.3 JOINTING MATERIALS

7.3.1 Solvent Cement and Jointing Lubricant Coverage

The approximate number of joints that may be jointed with one litre is as follows:

SIZE DN	SOLVENT CEMENT	JOINTING LUBRICANT
15	600	
20	350	
25	260	
32	190	
40	140	
50	85	170
65	70	150
80	60	120
100	50	100
125	40	75
150	30	60
155	25	60
195	17	50
200	25	50
225	15	45
300	10	30
375	10	25

7.4 PE ELECTROFUSION

7.4.1 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 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.

7.4.2 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 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 there weight from twisting the welding socket.
During the welding process including the total cooling time the clamps should remain in place

7.4.3 Fusion Welding Pipe Spigot Ends

Successful electrofusion jointing depends 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” or 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 a non depositing 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 scraper.
All rough edges and swarf from the pipe ends must be removed.

7.4.4 Fusion Welding Fusion Cycle

Only the recommended fusion and cooling times recommended by the manufacture 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

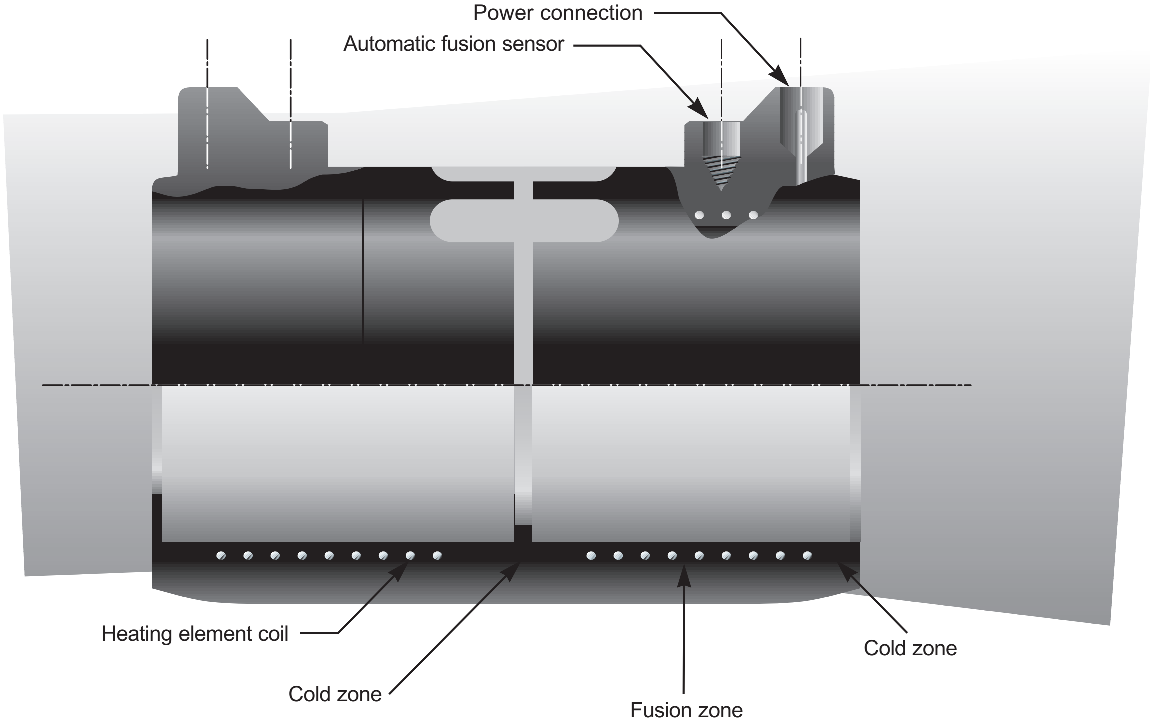
7.4.5 Fusion Welding Coupling Storage

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 not be removed before 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.

Fusion Welding Minimum Cooling Times

Size (mm)	Cooling Time (minutes)
OD20-63	6
OD75-110	11
OD 125-160	16
OD180-225	20
OD250-355	30

Electrofusion Coupling Section



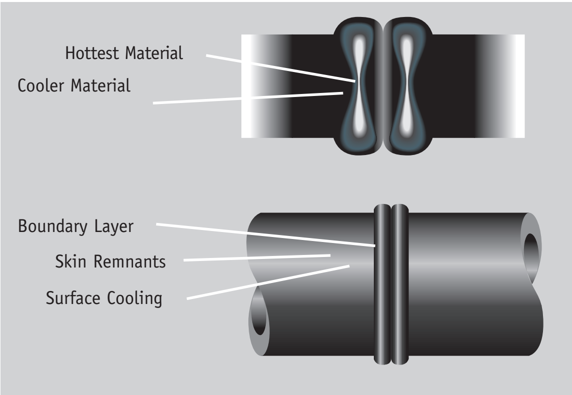
7.5 BUTT WELDING

BUTT WELDING

7.5.1 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.

7.5.2 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.

7.5.3 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.

7.5.4 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.

7.5.5 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

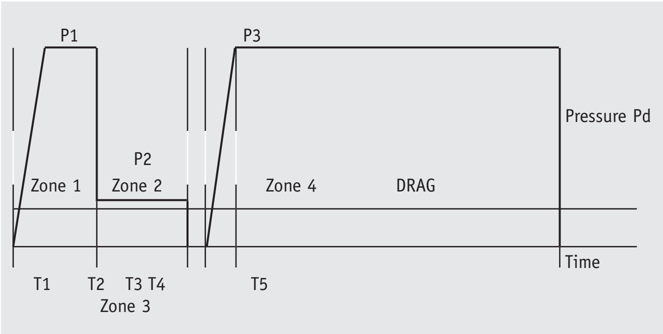
v) Weld Time & Cooling Time (t<15mm)
= 10 + (0.5 x 11.8) = 15.9 minutes

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

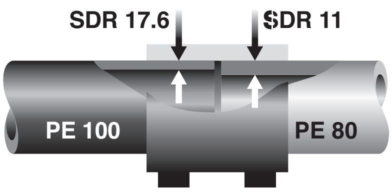
Where finished gaps exceed these values, the pipe ends should be re trimmed, or the pipes rotated in the in the welding machine frame.

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

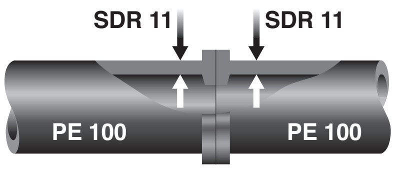
* Drag Pressure measured for each joint must be added to give the final applied pressure, eg. P = Pi + Pd. P = Pinterface + Pdrag

7.5.6 Polyethylene Fusion Jointing Compatibility

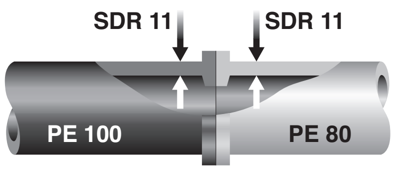
CORRECT



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

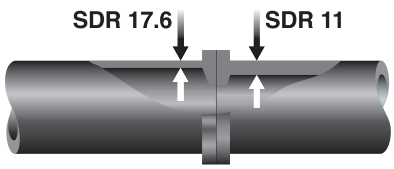


(b) Only similar materials and wall thicknesses may be jointed by butt fusion



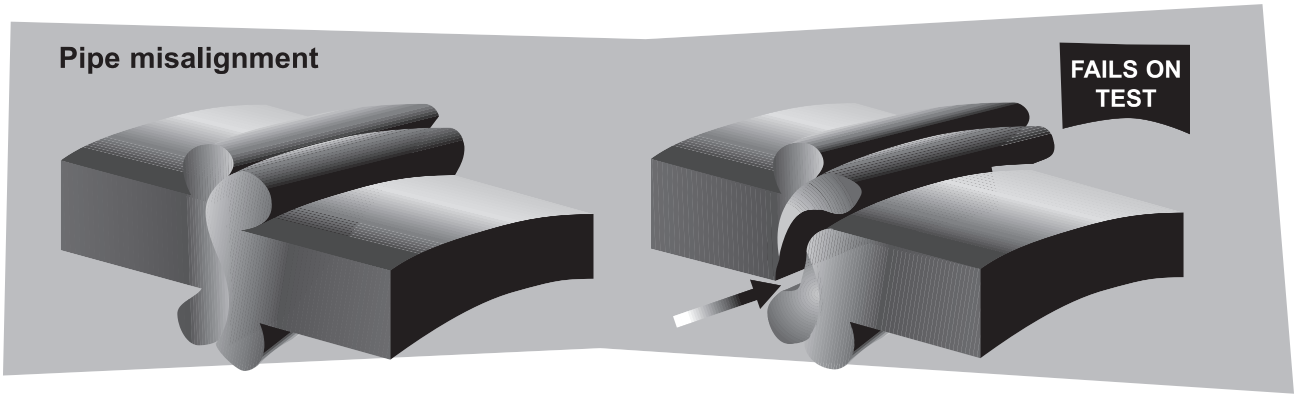
(c) Dissimilar materials may be jointed by butt fusion. However, care is required to ensure a ductile weld is produced.

WRONG

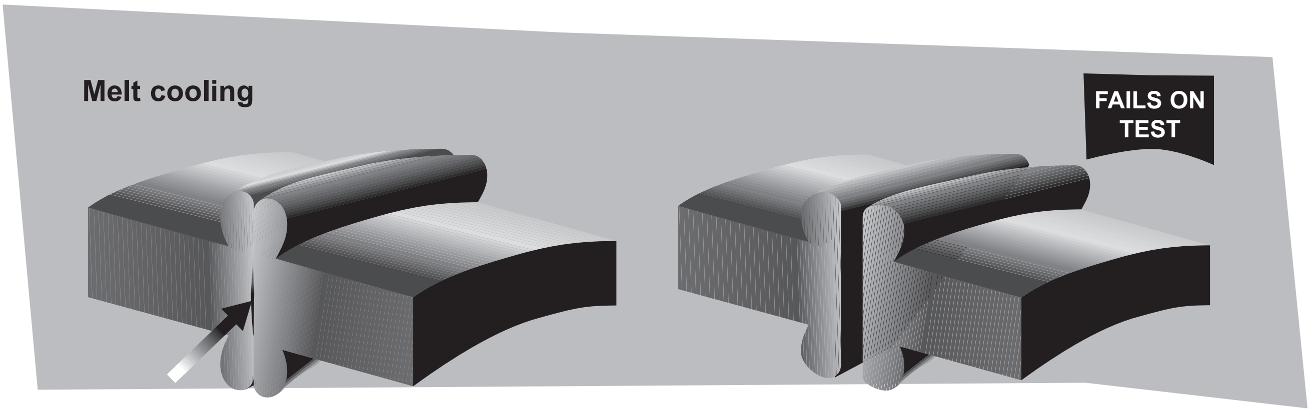


(d) Dissimilar wall thicknesses must not be jointed by butt fusion

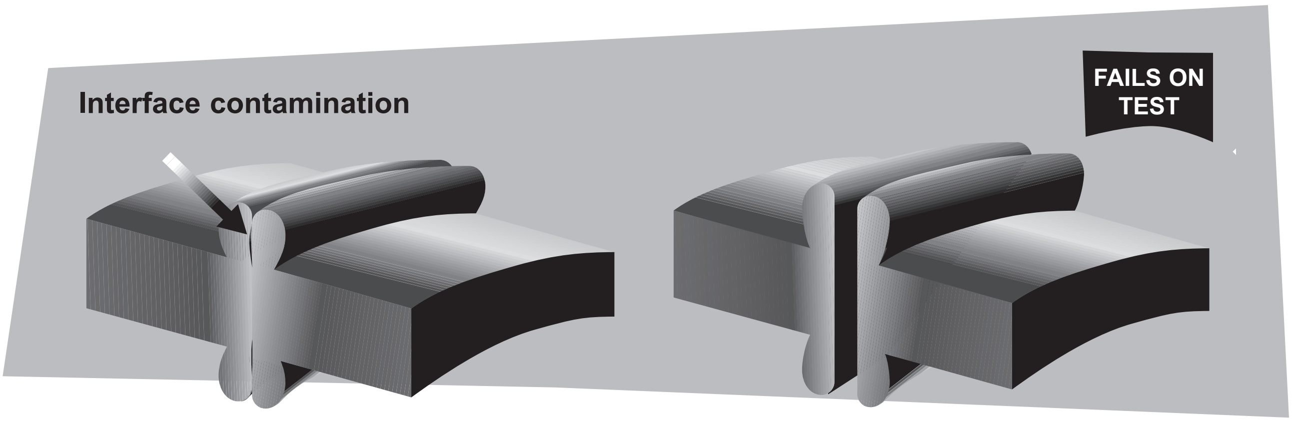
7.5.7 Pipe Misalignment



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.



Re-crystallisation of melt surface, due to excess cooling before 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.



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.

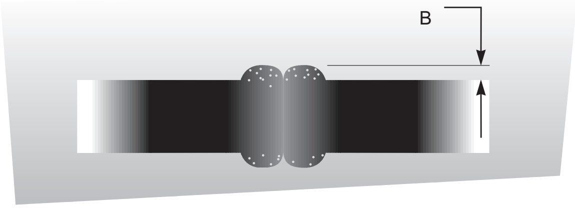
Butt Weld Bead Appearance

The size, shape and surface appearance of the completed weld bead is 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 even sized on both sides of the weld line.

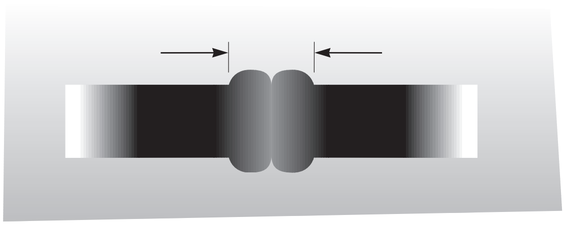
The weld bead must project above the outside diameter of the pipe at all times and be smooth and free from all voids and pitting.

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 width should be a 1mm with a **maximum** set-up bead width 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.

7.5.8 Butt Weld QA Recording

All jointing procedures performed on site must be recorded and identified to the numbered joints.

The procedures which have been demonstrated as being suitable before field construction is suitable. 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 specification test stipulations.

7.5.9 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 due to 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 1.3 times the maximum working pressure in the line, for a period of 15 minutes.

A hydrostatic pressure test of 1.3WP 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.

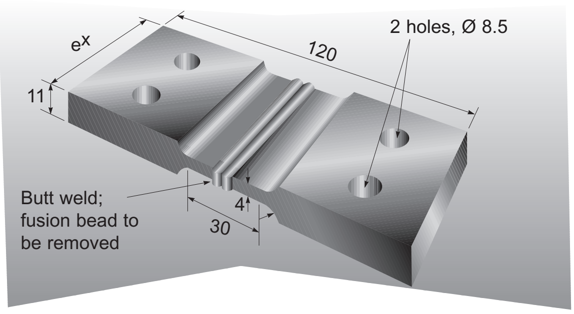
Hydrostatic pressure testing is not adequately evaluate of weld strength.

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 using crosshead speeds around 10mm per minute, are useful to detect extremely 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 generally 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 will behave in a brittle manner.

This **does not** mean the welds are brittle.

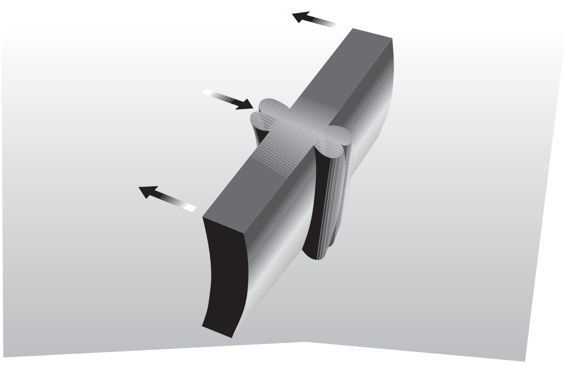
No evidence of contamination, or dislocations should be present on the weld plan fracture surfaces. Any such appearance is sufficient to reject the welds.

d) Long Term Creep Testing

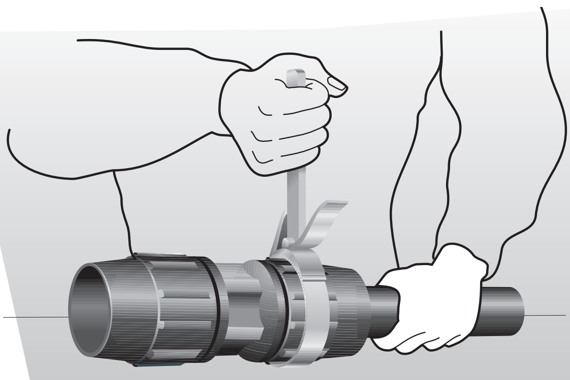
The long term behavior of the weld strength may be evaluated by constant load creep testing at an elevated temperature using an accelerating medium, typically this means using a tensile specimen immersed in a water/detergent mixture around 5% concentration and applying a static load.
The test proceeds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



7.6 MECHANICAL JOINTS



Mechanical jointing utilises compression of elastomeric seals with the pipe being restrained with a gripper ring, either locked by a mechanical locking nut or a self wedging lock onto the pipe. They are available in pipe diameters from 20mm to 110mm. The fittings are all demountable.

The elastomeric seal ring material requires consideration. In addition, the temperature of the fluids and the environment must be taken into account. Sealing rings supplied are produced in nitrile rubber.

Compression fittings may be assembled by directly pushing the PE pipes into the coupling ends. When using fittings with a compression nut care needs to be taken to ensure that the nuts are not damaged in installation. The fitting should not be disassembled, loosen and insert the chamfered pipe fully home before tightening. Only tightening by hand, strap wrench or specialised assembly spanner. Serrated teeth spanners, or wrenches must not be used.

7.6.1 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 and the sealing carried out with an elastomeric gasket being compressed within the mating surfaces. Metal backing plates are bolted together to provide the compression in the gasket material.

The thickness and the bolt dimensions of the back up plate, need to be sized on the operating pressures of the specific pipeline. The guidelines contained within AS/NZS2129 need to be followed for plate thickness.

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. Sealing gasket materials may be the limiting feature in 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 back up plates and bolts needs to have appropriate protection, such as sacrificial anodes, applied.

7.6.2 Repair Joints

Repairs to PE pipelines may be carried out using electrofusion jointswith the centre register removed or with compression couplings.

7.6.3 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 be only assembled by hand, strap wrench, flat face tools. Serrated jaw spanners, or wrenches must not be used.

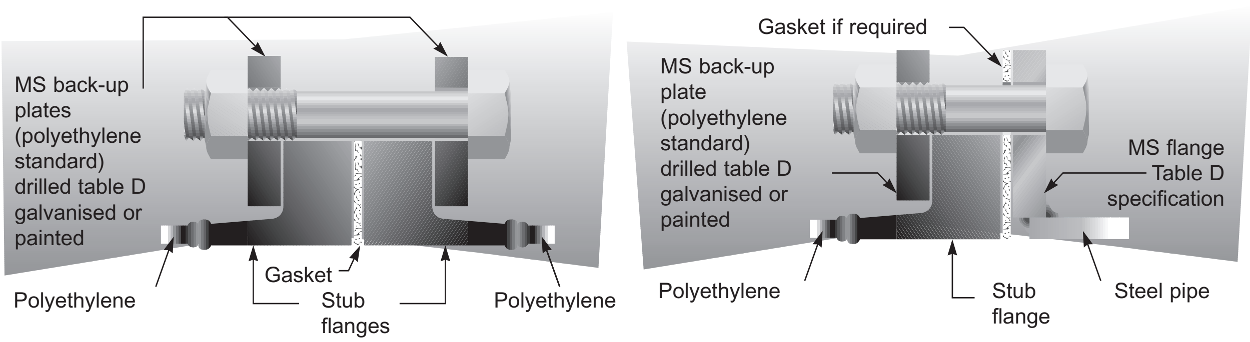
Damage to the moulding can easily occur.

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.

Stub Flanges and Backup Plates

(a) Polyethylene to Polyethylene

(b) Polyethylene to Steel



7.7 TAPPING SYSTEMS

7.7.1 General Considerations

PVC/PE pipelines may be tapped using specialist tapping saddles or tees connected to the PE main by either thermal welding methods or compressed rubber seals.
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 PVC/PE pipes used in both the service and main lines.

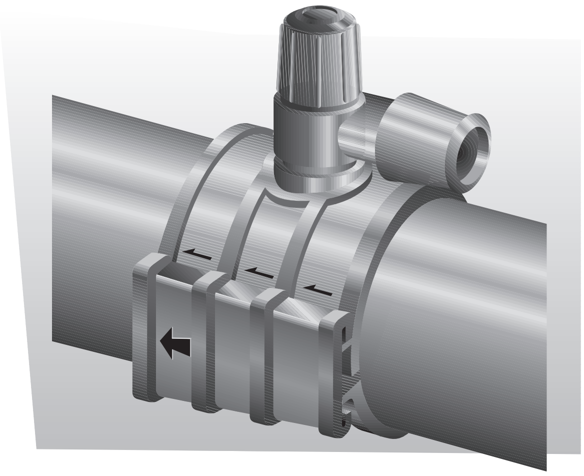
7.7.2 PVC/PE pipes must not be direct tapped using ferrules threaded into the PVC/PE pipe wall section.

Only those tapping systems which have been authorised by the relevant Local Authority shall be used for potable water installations and the standard details for tapping need to be followed.
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 a appropriate hole saw.
Multiple Tapping Saddles may be use on a service line but these should not be installed at no closer than 5 times the pipe Diameter
All tapping activities and service connections in PVC/PE pipes should be made where practical before backfilling is completed. So the service line is not stress 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 PVC/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 PVC/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 thermal fusion tapping saddles or tees are used, then tapping must not take place until the welded joints have fully cooled. Any attempt at tapping before this occurs may cause debonding of the joint area and subsequent leakage at the tapping point. Thermal fusion tapping saddles must not be used for PE main line pipes with a pressure class rating of PN6.3 and below, unless they have been designed to prevent localised collapse of the PE main line pipe at the heat applied area.
Where PVC/PE pipes are tapped, the tapping system should contain a cutter which removes the tapping plug material from the PVC/PE main pipe as a single piece and either retains the plug in the cutter or allows the plug to be removed.
Once the tapping and service connections are completed and if thermal welding has been adopted the adequate cooling time allowed, then the standard pressure testing procedures can be applied .

7.7.3 Mechanical Jointing and Service Connections

7.7.4 Tapping Saddles

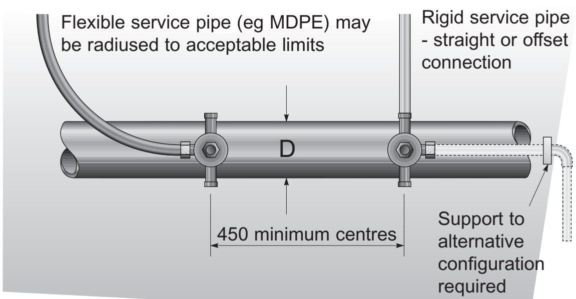
Only tapping saddles designed for use with PVC /PEpipe should be used. These saddles should:
• Be contoured to fit around the pipe and not have lugs or sharp edges that dig in.
• Have a positive stop to avoid overtightening of the saddle around the pipe.



Talbot plastic self tapping ferrule strap

The maximim hole size that should be drilled in a PVC/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 generally, a tee is preferred.
When moving crates of pipes with a forkhoist ensure sockets are not scuffed on hard surfaces.

Holes should not be drilled into PVC/PE pipe:
- Less than 300 mm from a spigot end.
- Closer than 450 mm to another hole on a common parallel line.
- Where significant bending stress is applied to the pipe.



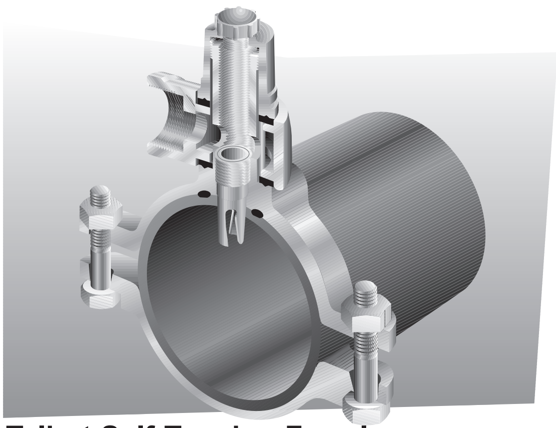
NOTE: Straight connections are considered the norm in most cases

7.7.5 Live Tapping

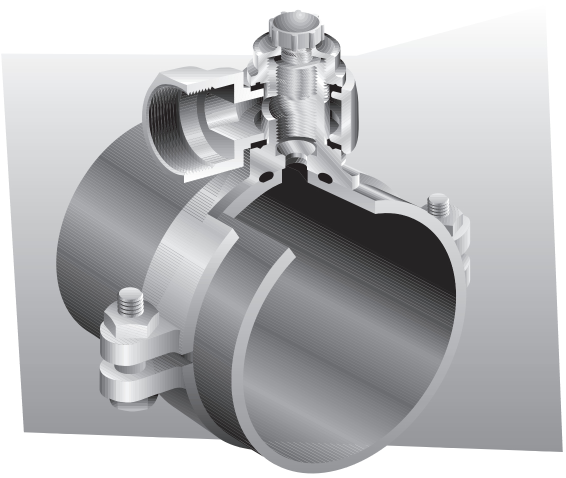
Various tools are available to allow live tapping of a line using a specially adapted tapping band.
The tapping band should be fitted to the pipe and correctly tightened. A specially adapted main cock for live tapping should be fitted to the tapping saddle using PTFE tape and a drilling machine fitted 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.

7.7.6 Dry Tapping

The procedure is the same as above except that the hole can be drilled before the main cock is fitted. It is also possible to dry tap using a twist drill with razor sharp cutting edges ground to an angle of 80°. Removal of the swarf, however, is more difficult and wherever possible the use of a hole saw is recommended.



Talbot Self-Tapping Ferrule



Swivel Ferrule/Strap

7.7.7 Direct Tapping

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

7.7.8 Self Tapping Ferrule

Live mains may be tapped for service connections using the Talbot self tapping ferrule, available with 20mm male outlet.
The ferrule should be screwed into the threaded boss (20 mm) of the tapping band so that the base of the ferrule is within 5 mm of the pipe surface. The cutter is then wound down using a 6mm square drive until fully down. When wound back the cutter will retain the 10 mm diameter uPVC plug and when fully up allows the water to flow to the connections.

8. HANDLING & STORAGE

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8.1 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 whenever possible.

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 pies and fittings become slippery in wet or frosty weather. Particular attention should be given to effective securing and storage under such conditions.
3. As far as practicable the protective packaging (pallets, strapping, bags etc) should be kept intact until the material is required for use.
4. Pipes likely to be stored outside for periods longer than 12 months should be covered to prevent degradation from sunlight. Electrofusion fittings should be stored under cover and in their protective packaging.
5. 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. After sufficient pipe has been cut from the coil the protective end cap must be replaced on the remainder. The outer end of the pipe should be suitably re-marked as such.

   When removed from the coil or drum, the pipe will be oval and curved. The extent 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 hardware is available to facilitate handling and jointing.

8.2 HANDLING

Pipes

MDPE pipes are lighter in weight than other commonly used pipeline materials, and are relatively robust and resistant to damage. Notwithstanding these features, care must be exercised at all times to prevent damage to the pipes.

Pipes should be inspected on delivery to ensure that the packing has not come loose, allowing pipes to move over each other. Where pipes are damaged they must be removed from the remainder of the pipes and the supplier notified.

Damaged pipes must not be used in the installation.

PE pipes are supplied in either coils from smaller diameters (up to 125mm) or in straight lengths. The straight lengths may be up to 15 metres long , depending on transport and site conditions.

Coiled pipes may be supplied either on pallets, or as individual coils. These may be handled with a fork lift truck, using protected tines. The tines must not be forced into the layers of the coils, as this will damage the pipe walls.

Do not roll the coils off the back of trucks as this can lead to damage.

Only webbing slings should be used these must be passed fully through the complete coil layers.

Wire slings must not be used.

Straight length pipes can be handled either with a fork lift, or slings passed around the pipe. Bundled pipes can be handled under the timber packaging using the complete packaging to help protect the pipes.

For larger diameter pipes, a spreader bar may be required to help distribute the load and up to four sling points may be needed.

Pipes must not be dragged from trucks, or trailers, as this will cause scoring along the walls of the pipes, and damage ends of the pipes, or pre welded end fitting assemblies.

8.3 STORAGE

Pipes

All pipes and fittings should be inspected prior to storage and any damage items isolated and removed from stock. The supplier should be notified immediately of any defective product.

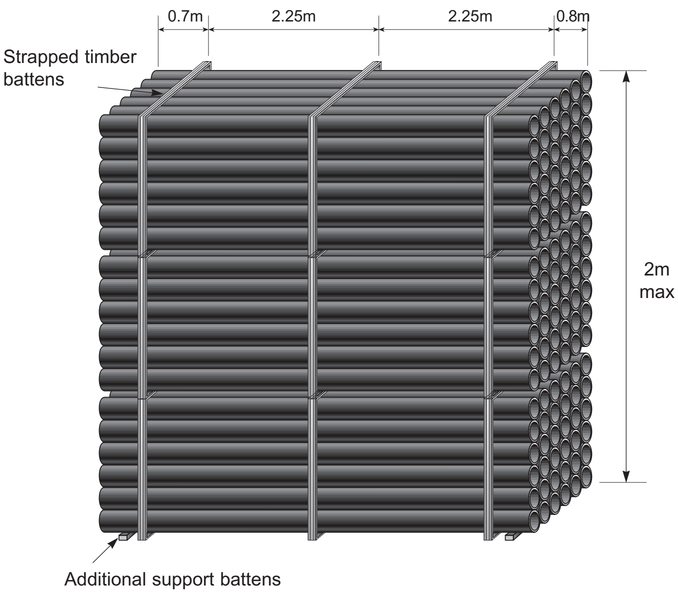
As PE pipes are date stamped at the time of manufacture, stocks should be arranged so that the earliest date production is used first in installation.

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 kept away from combustible materials and potential contaminants.

Any product over 25 kilos needs to be lifted mechanically.

Full colour pipes must be covered when stored in direct sunlight for any extended period (12 months). Where covers are used, these should allow free air movement between pipe stacks to prevent temperature build up. Black pipes may be stored for extended periods without covers.
Stack sites should be selected to allow ready access around, and between any stacks by handling equipment and staff. Care must be taken to ensure security and site safety of any stack sites.
In principle, stack heights should be kept to a minimum.
Different grades of PE and different pressure classes should be segregated to prevent confusion in selection at the time of installation.
Coiled pipes should be store flat to prevent distortion and where coils are stacked on top of each other, the maximum number of stacked coils should be limited to 5 for pipe diameters up to 32mm. 4 for pipe diameters 50mm and 63mm and 2 for pipe diameters 90mm and 110mm.
Crated pipes may be stacked on top of each other, if the timber frames bear on each other. The maximum stack height under these circumstances should be limited to 2 metres.



Individual straight pipes may be stored in either pyramid shape stacks, or side supported stacks.
For pyramid stacks, the bottom pipes must be securely supported to prevent any movement. The pipes can then be stacked neatly on the lower layer up to a maximum stack height of 1.5 metres.
Pipes should be supported with timber spacers 75mm wide, located at 1.5 metre gaps along the length of the pipes. Care must be taken to ensure localised distortion does not take place. The maximum stack heights should not exceed 2 metres.
Large diameter pipes should not be stacked on top of each other.

Where flanges, or other end fittings are pre assembled on the pipe ends, these must not be allowed to bear directly on each other, the pipe barrels, or directly on the ground as a point load.

Pipe Strings

Where pipes are strung out along the proposed pipeline alignment, they should be located at a distance to allow free access to excavation equipment. The pipes should be restrained to prevent any possibility of the pipes rolling.

Fittings

Fittings should be stored in original packaging until required for actual installation. The containers should be stored under cover at all times.
Large diameter fittings should be stored on an even base, and not subject to other loads. Fittings should not be stacked on top of each other.
End fittings, and gasket sealing surfaces must be protected at all times to prevent distortion, or gouging of the surfaces.
All sealing gaskets and rings must be stored in light proof containers, and kept away from heat sources and contaminants such as petrol and oils.

8.4 TRANSPORT

Where pipes are transported by road, or rail, they must be evenly supported at all times.
Coiled pipes should be transported laid flat on the bed of the tray.
For transporting, vehicles should be provided with a clean flat bed, free from nails or other projections which may cause damage. If high sided lorries are used, special care must be taken to prevent slippage or excessive bowing of the pipes and extra protection given at all sharp edges.
Coils may be stacked on top of each other, provided that they are evenly placed on top of each other and firmly secured to prevent movement. If coils are transported vertically, then they must be secured to prevent movement, and any distortion at the bottom of the coils. Other materials must not be placed on top of the coils.
Care should be taken to avoid positioning pipes and fittings near or adjacent to exhaust systems or other head sources and to avoid possible contamination from materials such as diesel oil.
Straight length pipes must be stacked evenly along the length of the truck trays, and evenly supported using timber spacers 75mm wide, and spaced at gaps of 3 metres. All end fittings must be protected and raised up above the tray floors, and not allowed to bear directly on any pipes, or other surfaces. Large diameter, or low pressure class, pipes can be subject to localised distortion and should have internal supports placed in the ends of the pipes.
All pipes should be covered by tarpaulins during transport to prevent road film contamination, and the pipes must be kept away from all heat sources and other sources of contamination.

Only webbed slings of polyethylene or nylon are recommended. Straight pipes should be fully supported and bound together. Pipes must not rest on the integral socket, if one is incorporated.
When transporting fabricated fittings, these should not be loaded in a way that could distort the end, or left exposed to direct sunlight.
Both vertical and horizontal deliveries of coiled pipes are permissible, although in the case of horizontal transportation special notification may be required for highway authorities in respect of wide load regulations.
No other cargo, or loads, should be placed on top of PE pipes during transport.

8.5 PVC PIPE HANDLING

8.5.1 Handling and Storage

PVC pipe is very robust, but still can be damaged by rough handling. Pipes should not be thrown from trucks or dragged over rough surfaces. Plastic piping becomes more susceptible to damage in very cold weather so extra care should be taken when the temperature is low.
Since the soundness of any pipe joint depends on the condition of the spigot and the socket, special care should be taken not to allow them to come into contact with sharp edges or protruding nails or made oval by poor storage.

8.5.2 Transportation of PVC Pipes

While in transit pipes should be well secured and supported. Chains or wire ropes may be used only if suitably padded to protect the pipe from damage. Care should be taken that the pipes are firmly tied so that the sockets cannot rub together.
Pipes may be unloaded from vehicles by rolling them gently down timbers, care being taken to ensure that the pipes do not fall onto one another or onto any hard or uneven surface.

8.5.3 Storage of PVC Pipes

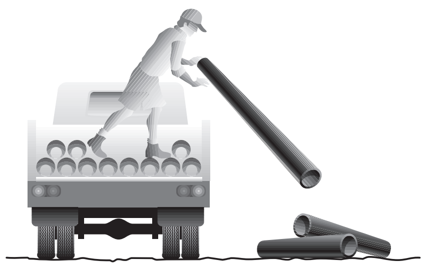
Pipes should be given adequate support at all times. Pipes should be stacked in layers with sockets placed at alternate ends of the stack and with the sockets protruding.
Horizontal support of about 75 mm wide should be spaced not more than 1.0m centre-to-centre beneath the pipes to provide even support. Vertical side supports should also be provided at intervals of 2m along rectangular pipe stacks.
For long term storage (longer than 3 months) the maximum free height should not exceed 1.0m. The heaviest pipes should be on the bottom. The crates used for delivery are adequate for long term storage provided additional bearers (approx. 75mm wide) are placed under the pipes between the crate frames.
If it is planned to store pipes in direct sunlight for a period in excess of one year, then the pipes should be covered with a material such as hessian. Coverings such as black plastics must not be used as these can greatly increase the temperatures within the stack (see Weathering).

NOTE: Many pipe failures can be traced to faults in handling and storage. Refer to AS/NZ 2032 and 2033

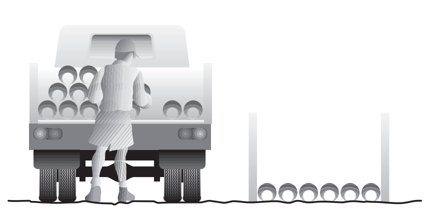
Handling and storing on site

Incorrect way to load pipes

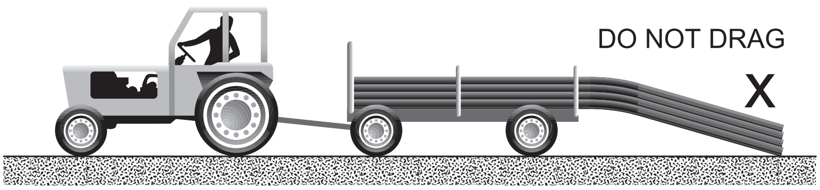
Correct way to load pipes



Incorrect way to off-load



Correct way to off-load



On-site transport

Individual pipe stacks on site

8.6 ABOVE GROUND INSTALLATION (refer to AS/NZ 2566.1, AS/NZ 2032, AS/NZ 2033)

8.6.1 General Conditions

In above ground installation, pipes should be laid on broad, smooth bearing surfaces wherever possible to minimise stress concentration and to prevent physical damage e.g. cable trays.

PVC pipe should not be laid near steam lines or in proximity to other high temperature surfaces.

Where PVC pressure pipeline is used to supply cold water to a hot water cylinder, the last two metres of pipe should be made of copper and a non return valve fitted between the PVC and copper line to prevent pipe failure.

If a pipeline is subjected to continuous vibration such as the connection with a pump, it should be connected by a flexible joint or, if possible, the system should be redesigned to eliminate the vibration.

PVC pipe must not be used to reticulate compressed air.

The pipe must be adequately supported in order to prevent sagging and excessive distortion. Clamp, saddle, angle, spring or other standard types of supports and hangers may be used where necessary. Pipe hangers should not be over tightened. Metal surfaces should be insulated from the pipe by plastic coating, wrapping or other means.

9. TESTING & COMMISSIONING

RETURN TO CONTENTS

- **PVC Pipeline Testing**
- **Polyethylene Pipeline Testing**

PVC Pipeline Testing

Testing and Commissioning

The pipeline may be tested as a whole or in sections, depending on the diameter and length of the pipe, the spacing between sectioning valves or blank ends and the availability of water.

Pipelines should be bedded and backfilled, but with the joints left uncovered for inspection before and after testing.

All thrust supports for fittings and valves must be finished and the concrete properly cured (the minimum time is seven days). Blank ends installed temporarily should be adequately supported to take the pressure thrust.

Fill the pipeline with water and remove air from the system as far as possible. Pressurise the system. Additional water will be required to bring the line up to pressure because the pipe expands slightly. For example, to reach 1.5 times working pressure requires about 1% additional volume.

After reaching test pressure, note the drop in pressure over time. It is normal for a pressure drop to occur as the remaining air goes into solution, and some further expansion of the pipe (around 0.1%) will also occur.

The expansion due to temperature rise of 1°C will decrease the pressure by about 3.4 kPa.

Re-pressurise and again note the drop in pressure over the same time period. A diminished pressure drop indicates a satisfactory test. A similar pressure drop may indicate a leak. It may be necessary to repeat the procedure several times to be sure.

An absolute maximum test pressure of 1.5 times the design pressure should be applied to the pipe test section. This pressure should be measured at the lowest point in the system. When using pressures higher than the design pressure, ensure that the thrust blocks, valves or other fittings have been designed to take these higher pressures. The procedure is specified in AS/NZ 2032 and 2033.

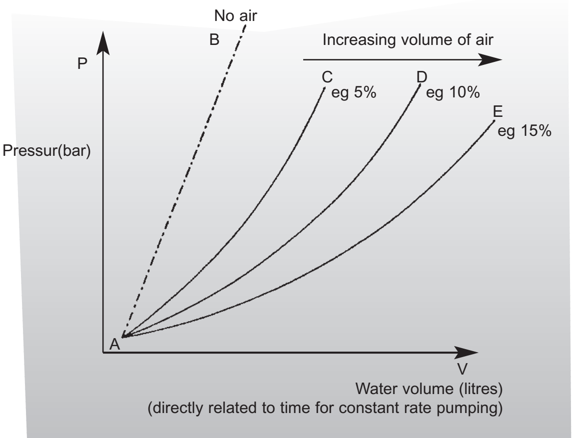
Flushing

Following successful testing, the line should be thoroughly flushed and dosed with a sterilising agent such as chlorine. Local authority requirements should be followed.

Polyethylene Pipeline Testing

9.1 INTRODUCTION

All completed PE pipelines should be tested to ensure that all joints, fittings, anchorage blocks are installed correctly and that there are no defects in the pipes causing leakage 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, PE80 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 reduced 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 may 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.

9.2 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 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 back-filling with soil or loaded with sandbags to pre-vent movement and possible mechanical seal joint displacement. Where PE pipes are partially backfilled over the entire length, leaving open only the joints at the start and end of the pipe run.
- 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 form 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.

9.3 PE 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.

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 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 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 800 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
- relative movement of ‘mechanical’ fittings
- efficiency of the bedding and compacted surround to resist pipe movement.
- accuracy and efficiency of testing apparatus.

9.3.1 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.

9.3.2 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 due to the joints, the plug can be sized to the maximum diameter reduction allowed in the design.

For butt welded PE pipes, unless the internal beads are removed, the plug needs to be sized to account for the weld bead presence.

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

9.4 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 test 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

9.5 PRESSURE TEST

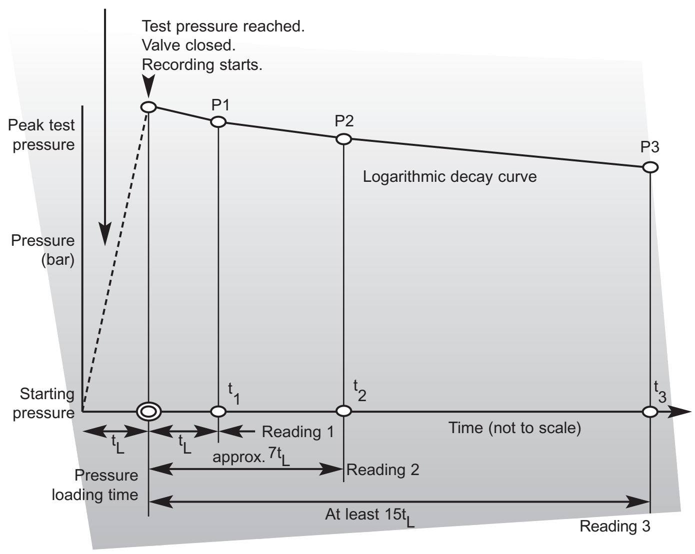
9.5.1 Large Bore Commissioning

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 movement 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.



9.6 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.

9.6.1

Take a first reading of pressure P_1 at t_1, where t_1 is equal to the pressure loading time (t_L).

9.6.2

Take a second reading of Pressure P_2, at a time approximately $7t_L$; Let this be t_2.

To allow for the stress relaxation behavior of PE pipelines, calculate the corrected values of t_1 and t_2.

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

9.6.3

The measure of the slope of the pressure decay curve between t_1 and t_2 is then calculated as the ratio n_1.

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

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) 0.04 – 0.05 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.

9.6.4

Take a further reading of pressure P_3 at a decay time not less than $15t_L$. Let this be t_3. Again to allow for the stress relaxation behavior of PE pipelines, calculate the correct value for t_3.

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

9.6.5

The measure of the slope of the pressure decay curve between t2 and t3 is then calculated as the ratio of n_2.

Calculate $n_2 = \dfrac{\log P_1 - \log P_2}{\log t_{3c} - \log t_{2c}}$

For a pipe system with no leakage and bearing in mind the identified compaction, then the ratio of n_2 should be:

a) 0.08 – 0.10 for pipes without soil constraint,

b) 0.04 – 0.05 for pipes in compacted backfill.

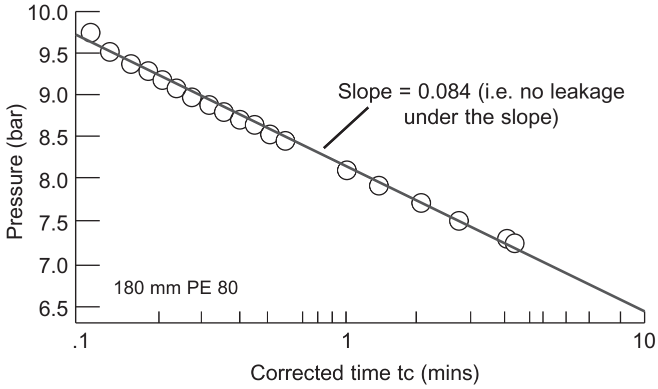
The figure below shows the results of test (using graphical analysis with multiple results from a data logger) on mains without leaks in unconstrained and constrained situations respectively.
The sensitivity of the test can be increased by extending the value of t_3 ie extending the test duration.

9.6.6

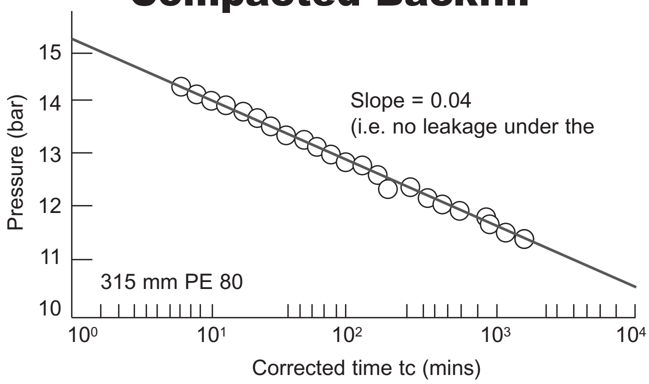
The procedure detailed above identifies the principle. However it is strongly advised that the slopes n1 and n2 are obtained from more than three points.

PRESSURE REGRESSION

- Unrestrained



- Compacted Backfill



9.7 PRESSURE TEST ANALYSIS
– Predicted Pressures

9.7.1

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.

9.7.2

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

9.7.3

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.

9.7.4

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.

9.8 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.

10.0 PIPELINE LOCATION, MARKING, RECORDING AND DETECTION

10.1

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.

10. CHEMICAL RESISTANCE

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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 conveyed 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 material 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
- 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)	$CH_3CO_2CH_2CH_2CH_2CH_3$	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	$Ca(OHl)_2$	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

Chemical Resistance

	FORMULA	CONC %	TEMP (°C)	PVC	PE
DIOCTYLPHTHALATE		all	25 60	3 3	1 2
DISTILLED WATER		100	25 60	1 1	1 1
DRINKING WATER		100	25 60	1 1	1 1
ETHERS		all	25 60	3 3	
ETHYL - ACETATE (ACETIC ETHER)	$CH_3CO_2C_2H_5$	100	25 60	3 3	1 3
- ALCOHOL	CH_3CH_2OH	nd	25 60	1 2	1 2
(ETHANOL) - CHLORIDE	CH_3CH_2Cl	all	25 60	3 3	2
- ETHER	$CH_3CH_2OCH_2CH_3$	all	25 60	3 3	
ETHYLENE - CHLOROHYDRIN	$ClCH_2CH_2OH$	100	25 60	3 3	
- GLYCOL (ETHANEDIOL OR GLYCOL)	$HOCH_2CH_2OH$	comm	25 60	1 1	1 3
FATTY ACIDS		nd	25 60	1 1	
FERRIC - CHLORIDE	$FeCl_3$	10	25 60	1 2	
		sat	25 60	1 1	1 1
- NITRATE	$Fe(NO_3)_3$	nd	25 60	1 1	1 1
- DEXTRINE (BRITISH GUM OR STARCH GUM)	$C_6H_{12}OCH_2O$	nd	25 60	1 2	1 1
- SULFATE	$Fe(SO_4)_3$	nd	25 60	1 1	1 1
FERROUS - CHLORIDE	$FeCl_2$	sat	25 60	1 1	1 1
- SULFATE	$FeSO_4$	nd	25 60	1 1	1 1
FERTILIZER		≤ 10 sat	25 60 25 60	1 1 1 1	1 1 1 1
FLUORINE GAS DRY	F_2	100	25 60	2 3	2 3
FLUROSILICIC ACID	H_2SiF_6	32	25 60	1 1	1 1
FORMALDEHYDE	HCOH	-	25 60	1 2	1 1
FORMIC ACID	HCOOH	50 100	25 60 25 60	1 2 1 3	1 1 1 1
FRUIT PULP AND JUICE		comm	25 60	1 1	1
FUEL OIL		100 comm	25 60 25 60	1 1 1 1	 - 2
FURFUROLE ALCOHOL	$C_5H_3OCH_2OH$	nd	25 60	3 3	2 2
GAS EXHAUST - ACID		all	25 60	1 1	
- WITH NITROUS - VAPOURS		traces	25 60	1 1	1 1
GAS PHOSGENE	ClCOCl	100	25 60	1 2	2 2
GELATINE		100	25 60	1 1	1 -
GLUCOSE (DEXTROSE)	$C_6H_{12}O_6$	all	25 60	1 2	1 1
GLYCERINE AQ.SOL(GLYCEROL)	$HOCH_2CHOHCH_2OH$	all	25 60	1 1	1 1
GLYCOGLUE AQUEOUS		10	25 60	1 1	1 1
GLYCOLIC ACID	$HOCH_2COOH$	37	25 60	1 1	1 1
HEPTANE	C_7H_{16}	100	25 60	1 2	1 3
HEXANE	C_6H_{14}	100	25 60	1 2	1 2
HYDROBROMIC ACID	HBr	≤10 48	25 60 25 60	1 2 1 2	1 1 1 1
HYDROCHLORIC ACID (MURIATIC ACID)	HCl	≤25	25 60	1 2	1 1
		≤ 37	25 60	1 1	1 2
HYDROCYANIC ACID (PRUSSIC ACID OR HYDROGEN CYANIDE)	HCN	deb	25 60	1 1	1 1
HYDROFLUORIC ACID	HF	10	25 60	1 2	1 1
HYDROGEN	H_2	all	25 60		
HYDROGEN - PEROXIDE (BLEACH)	H_2O_2	30 50	25 60 25 60	1 1 1 1	1 1 2 -
- SULFIDE DRY		sat	25 60	1 2	1 1
- SULFIDE WET		sat	25 60	1 2	1 1
HYDROSUPHITE		≤10	25 60	1 2	
HYDROXYLAMINE SULPHATE	$(H_2NOH)_2H_2SO_4$	12	25 60	1 1	1
ILLUMINATING GAS		100	25 60	1	1
IODINE - DRY AND WET	I_2	3	25 60	2 3	
- TINCTURE		≤3	25 60	2 3	2 3
ISOCTANE	C_8H_{18}	100	25 60	1	2
ISO-OCTANE	$(CH_3)_3CCH_2(CH_3)_2$				
ISOPROPYL -ETHER	$(CH_3)_2CHOCH(CH_3)_2$	100	25 60	2 3	2 3
- ALCOHOL (ISOPROPANOL)	$(CH_3)_2CHOH$	100	25 60	 2	
LACTIC ACID	$CH_3COHCOOH$	≤28	25 60	1 2	1 1
LANOLINE		nd	25 60	1 2	 1
LEAD ACETATE	$Pb(CH_3COO)_2$	sat	25 60	1 1	1 -
LINSEED OIL		comm	25 60	1 2	 2
LUBRICATING OILS		comm	25 60	1 1	3
MAGNESIUM - CARBONATE	$MgCO_3$	all	25 60	1 1	
- CHLORIDE	$MgCl_2$	sat	25 60	1 1	1 1
- HYDROXIDE	$Mg(OH)_2$	all	25 60	1 1	
-NITRATE	$MgNO_3$	nd	25 60	1 1	1 1
- SULFATE	$MgSO_4$	dil sat	25 60 25 60	1 1 1 1	1 1 1 1
MALEIC ACID	COOHCHCHCOOH	nd	25 60	1 1	1 1
MALIC ACID (HYDROXYSUCCINIC ACID)	$CH_2CHOH(COOH)_2$	nd	25 60	1 -	1 -
MERCURIC - CHLORIDE	$HgCl_2$	sat	25 60	1 1	1 1
- CYANIDE	$HgCN_2$	all	25 60	1 1	
MERCUROUS NITRATE	$HgNO_3$	nd	25 60	1 1	1 1
MERCURY	Hg	100	25 60	1 2	1 1
METHYL - ACETATE	CH_3COOCH_3	100	25 60	- -	- -
- ALCOHOL (METHANOL OR WOODSPIRIT)	CH_3OH	nd	25 60	1 1	 1
- BROMIDE (BROMOMETHANE)	CH_3Br	100	25 60	3	3
- CHORIDE (CHLOROMETHANE)	CH_3Cl	100	25 60	3 3	1
- ETHYLKETONE	$CH_3COCH_2CH_3$	all	25 60	3 3	1 2
METHYLAMINE	CH_3NH_2	32	25 60	2 3	1 2

Chemical Resistance

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

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

11. DISCLAIMER

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