المُنى
almona

PE100 & PE80 SYSTEMS FOR WATER AND GAS NETWORKS

Technical Manual

almona INFRASTRUCTURE

DVGW SKZ SASO NSF WRAS APPROVED PRODUCT

An ISO 9001:2015 certified company

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"WE DESIGN, DEVELOP, MANUFACTURE AND PROVIDE INNOVATIVE PIPE SOLUTIONS THAT BEST MEET THE NEEDS OF OUR CUSTOMERS"

ABOUT US

Almona is a leading Saudi Arabian plastic pipe manufacturing company and since our establishment in 2008 we have constantly evolved to meet the requirements of our most demanding customers. Our aim is to provide sophisticated and diverse pipe solutions for hot and cold water applications, telecommunication networks, sewage and drainage systems together with water and gas infrastructure.

We are a certified to ISO 9001:2015 Quality Management Systems organization and all our products comply with the appropriate Saudi (SASO), German (DIN) and International (ISO) Standards. Our pipe systems for drinking water applications are NSF-61, WRAS and DVGW certified and all almona products are tested extensively in our state-of-the-art laboratory, to ensure that the quality and performance are continuously maintained.

Almona's success is the result of the company's persistent commitment to continuous innovation and investment in technology, in the relentless pursuit of providing quality products and services. Today, we are pleased to offer a wide range of plastic products, divided into four categories:

BUILDINGS

SEWAGE AND DRAINAGE

INFRASTRUCTURE

TELECOMMUNICATION DUCTING

CONTENTS

This manual is intended for civil designers, engineers, contractors and installers of PE80 and PE100 infrastructure pipe systems. It is divided into ten sections as follows:

Section I

1. General Information

1.1 Introduction

Almona offers a wide product range of polyethylene (PE) pipe systems, which are specially designed, developed and manufactured for rigorous applications in the most demanding infrastructure projects. Our PE80 and PE100 products offer the significant advantages of PE for constructing cost-effective, reliable, high performance and low maintenance systems with a service lifetime of at least 50 years.

Due to their outstanding properties, features and benefits, almona PE80 and PE100 products have a long success track record of being used for both above ground and underground installations across a wide range of applications. The high level of chemical resistance, durability, light weight, impact resistance and flexibility, make almona PE 80 and PE100 the pipe systems of choice for water and natural gas distribution networks, industrial, drainage, mining and many other pressure and non-pressure (gravity) applications.

Almona PE systems are manufactured in our ISO 9001:2015 accredited production facilities that comprise industry leading manufacturing and testing facilities and make use of only the highest quality raw materials from leading international suppliers. Our products are approved to the most stringent internal, national and international standards and can be used with confidence, whatever the application.

1.2 Advantages of almona PE Pipe System

Almona PE systems are engineered to offer the significant advantages of PE, over the traditional pipeline materials such as steel, copper and cement. A number of important performance criteria account for the widespread adoption of PE systems worldwide. These are summarized below:

- Long lifetime in excess of 50 years
- Excellent cost - performance ratio
- Highly corrosion resistant
- Proven low levels of leakage
- Excellent abrasion resistance
- High impact strength
- High resistance to pressure
- Superior flow characteristics

- Low water permeability
- Low coefficient of friction
- Resistant to chemicals such as acids, alkalis and salts
- Resistant to flames and fire propagation
- Outstanding flexibility and resistance to ground movement, vibration and earthquakes
- Weather/ UV resistance in above ground applications
- Fast, easy and cost-effective handling and installation
- Safe and easy jointing by welding
- Can be manufactured in long lengths, including coils and drums
- Produced from non-toxic, halogen free material
- Low maintenance
- Environmentally friendly

For more detailed information on the key characteristics of almona PE systems refer to Sections II to XI of this document.

1.3 Characteristics of the System

Almona PE80 and PE100 pipes are produced as a single layer solid wall pipe with integral colour coded outer stripes denoting the pipe's material and application.

1.3.1 Medium Density Polyethylene (MDPE) PE80

Almona PE80 pipe systems are made of Medium Density Polyethylene (MDPE), offer high flexibility, resistance to internal pressure and high impact resistance. The systems are widely used for smaller diameter pipe systems including water and gas building connections, main lines for drip irrigation systems and some industrial applications.

1.3.2 High Density Polyethylene (HDPE) PE100

Almona PE100 systems are made of High-Density Polyethylene (HDPE) and offer high resistance to internal pressure together with high impact and abrasion resistance. The systems have been widely used in both pressure and non-pressure applications in pipe sizes of up to 2,500mm diameter.

Principal applications include water and gas supply, cooling water, pressure pipelines carrying sewage and stormwater and protective ducting systems. PE100 pipes are also used for industrial and chemical pipelines, the lining of steel pipes, submarine pipelines, compressed air systems, mining slurry pipelines and aquaculture.

Almona PE80 and PE100 pipes are classified in accordance with the joint ISO and European Standard, EN ISO 12162, according to their 50-year design strength at 20°C, also referred to as the Minimum Required Strength (MRS). To be classified as a PE80 pipe the MRS at a temperature of 20°C should be at least 8.0 MPa and at least 10.0 MPa for the pipe to be classified as a PE100. These values, together with the Standard Dimensional Ratio (SDR) are used as the basis of the pressure pipe design, but there are other important parameters that must be taken in to account when designing a PE pipeline. For more information on MRS, pressure resistance and other parameters, please refer to Section III, Design Considerations.

> "ALMONA OFFERS A WIDE PRODUCT RANGE OF POLYETHYLENE PIPE SYSTEMS, WHICH ARE SPECIALLY DESIGNED, DEVELOPED AND MANUFACTURED FOR RIGOROUS APPLICATIONS IN THE MOST DEMANDING INFRASTRUCTURE PROJECTS"

Section II

2. Technical Specifications

2.1 Pipe Colour, Striping Options and Dimensions

Almona offers a complete range of PE80 and PE100 pipes and fittings with the following characteristics:

- Potable water supply networks: Black PE80 and PE100 pipes with and without blue stripes.
- Gas distribution networks: Yellow PE80 pipes, orange PE100 pipes, black PE80 pipes with yellow stripes and black PE100 pipes with orange stripes.
- Irrigation networks: Black PE63, PE80 or PE100 pipes with and without green stripes.
- Dimensions are summarized in the following table.

Pipe diameter in mm	almona pipes product range overview																							
	16	20	25	32	40	50	63	75	90	110	125	140	180	200	225	250	280	315	355	400	450	500	560	630
Water transportation networks																								
PE100 SDR41 (S20) PN4							●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE100 SDR41 (S20) PN3,2							●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE100 SDR33 (S16) PN4						●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE100 SDR26 (S12,5) PN6					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE100 SDR17 (S8) PN10				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE100 SDR13,6 (S6,3) PN12,5			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE100 SDR13,6 (S6,3) PN9,9			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE100 SDR11 (S5) PN16		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE100 SDR9 (S4) PN20	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
PE100 SDR9 (S4) PN15,6	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
PE100 SDR7,4 (S3,2) PN19,2	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
PE80 SDR41 (S20) PN3,2																		●	●	●	●	●	●	●
PE80 SDR41 (S20) PN4							●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Pipe diameter in mm	almona pipes product range overview																						
	16	20	25	32	40	50	63	75	90	110	125	140	180	200	225	250	280	315	355	400	450	500	560	630

Water transportation networks

Pipe diameter in mm	16	20	25	32	40	50	63	75	90	110	125	140	180	200	225	250	280	315	355	400	450	500	560	630
PE80 SDR33 (S16) PN4						●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR33 (S16) PN3,1						●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR26 (S12,5) PN5						●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR26 (S12,5) PN4					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR22 (S10,5) PN6					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR17 (S8) PN8					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR13,6 (S6,3) PN8			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR13,6 (S6,3) PN10			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR11 (S5) PN12,5		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR11 (S5) PN10		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR9 (S4) PN16	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
PE80 SDR9 (S4) PN12,5	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
PE80 SDR7,4 (S3,2) PN15,3	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		

PE63 for irrigation systems

Pipe diameter in mm	16	20	25	32	40	50	63	75	90	110	125	140	180	200	225	250	280	315	355	400	450	500	560	630
PE63 SDR26 (S12,5) PN4					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE63 SDR21 (S10) PN3,9					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE63 SDR17,6 (S8,3) PN6				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE63 SDR13,6 (S6,3) PN6,2		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE63 SDR11 (S5) PN10		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE63 SDR9 (S4) PN9,8	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE63 SDR7,4 (S3,2) PN15,9	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
PE63 SDR6 (S2,5) PN15,7	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		

Pipe diameter in mm	almona pipes product range overview																							
	16	20	25	32	40	50	63	75	90	110	125	140	180	200	225	250	280	315	355	400	450	500	560	630
Gas Distribution Networks																								
PE100 SDR17,6	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE100 SDR11	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR17,6	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
PE80 SDR11		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

2.2 Jointing technologies

Butt fusion and electrofusion are the preferred methods of jointing almona PE pipe systems as these effectively create pipelines with no joints. In particular circumstances, such as when connecting to valves and pipes made of other materials, mechanical jointing systems such as compression fittings, mechanical couplings and flanges can be used.

2.3 Raw Materials and Pipe Specifications

Almona products are manufactured using only the highest quality raw materials supplied by leading international suppliers. The raw material physical properties are tested by independent international laboratories to ensure compliance with ISO 4427 and ISO 4437, together with the SASO 1402 national standard (methods of testing PE pipes for general purposes). In addition, prior to processing raw materials, almona conducts quality control tests in our own state-of-the-art laboratory to ensure compliance to the specified physical properties.

The PE compound used for striping the pipes comprises a colour masterbatch together with the same base resin used to produce the parent pipe compound. Striping compounds are pre-compounded and are UV-stabilized with a minimum of 0.2% of a hindered amine light stabilizer (HALS). They also contain sufficient antioxidant to ensure that when tested in accordance with ISO 11357-6 using oxygen, the oxidation induction time is longer than 40 min at a test temperature of 200°C, twice the requirement of the standard.

The typical psysical properties of raw materials used for manufacturing almona PE80 and PE100 pipe systems are summarized in the following table.

Property	Test Method	Unit	PE80	PE100
Melt Flow Rate (MFR) 190°C / 2.16kg	ISO 1133	g/10 min	< 0.1	< 0.1
Melt Flow Rate (MFR) 190°C / 5.0kg	ISO 1133	g/10 min	0.3	0.25
Density (Compound)	ISO 1183	kg/m³	950	959
Tensile Stress at Yield 50mm/min	ISO 527	MPa	22	25
Elongation at Break	ISO 527	%	> 600	> 600
Tensile Modulus 50mm/min	ISO 527	MPa	800	1100
Charpy Impact Notched at (0°C)	ISO 179/1eA	Kj/m²	14	16
Hardness, Shore D	ISO 868	-	59	60
Carbon Black Content	ASTM D 1603	%	> 2	> 2
Carbon Black Dispersion	ISO 18553	-	≤ Grade 3	≤ Grade 3
Brittleness Temperature	ASTM D 746	°C	< - 70	< - 70
Notched Pipe Test	ISO 13479	hours	≥ 500	≥ 500
Thermal Stability (210°C)	EN 728	minutes	> 20	> 20
Total Volatiles	EN 12009	mg/kg	≤ 350	≤ 350
Water Content	EN 12118	mg/kg	≤ 300	≤ 300
Coefficient of Linear Thermal Expansion	ASTM D 696	mm/mm/ °C	2.0 x 10-4	2.0 x 10-4
Thermal Conductivity	DIN 52612	W/km	0.41	0.41

Almona PE100 and PE80 pipes exceed the minimum required strength (MRS).

PE class	MRS [MPa]	Operating life [years]
PE100	10	50
PE80	8	50
PE63	6,3	50

2.4 Fire resistance

All almona pipe system components comply with the requirements of DIN 4102 and EN 13501-1 (fire classification B2 - normally flammable) for building and construction materials.

The self-ignition temperature is 350°C. Suitable fire-fighting agents are water, foam, carbon dioxide or powder. In case of fire with PE Pipes, any fire extinguisher may be used.

Powder extinguishers are very effective in quenching flames. Water sprays are especially effective in rapid cooling and damping down a fire but are not recommended in the early stages of a fire since they may help to spread the flames. Other factors will also influence the selection of fire extinguishers e.g. proximity of live electrical equipment. Please refer to specific classifications of firefighting extinguishers.

In multiple storey buildings PE systems penetrating floor cavities must be enclosed in fire rated service ducts appropriate to the Class of the building concerned or devices such as intumescent fire stoppers should be installed in accordance with the manufacturer's instructions (refer to Section V).

2.5 Chemical Resistance

The outstanding chemical resistance of almona PE 80 and PE 100 pipes to a variety of chemicals and solvents, allows their use in a wide range of applications. Our PE pipe systems offer high level of resistance to most corrosive acids, alkaline solutions, solvents, fuels, alcohol and salts than any traditional piping systems.

In broad terms, PE80 and PE100 system do not rot, rust, pit, corrode or lose wall thickness through chemical or electrical reaction with the surrounding soil. Also, polyethylene does not normally support the growth of, nor is affected by, algae, bacteria or fungi.

Nevertheless, special care is required in some applications where effluents contain harmful chemicals such as oxidizers, cracking agents and certain solvents. The degree of resistance to a specific chemical will depend on the concentration, temperature, length and type of exposure (i.e. intermittent or continuous) and working pressure, each of which may affect the long-term life of any system. The chemical resistance list provided in Section X: Appendix shall be used as a guide for evaluating the suitability of our products with the chemical agent that is intended to be used.

2.6 Temperature resistance

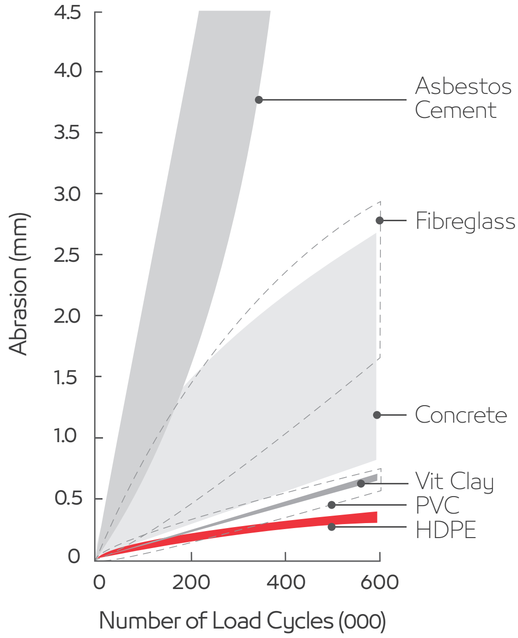
Almona PE80 and PE100 pipes are suitable for temperatures ranging between -50°C and +60°C. At higher temperatures the tensile strength and stiffness of PE are reduced and the material loses it strength at a higher rate. Hence if a minimum 50 year service is desired, PE pipe system should not be used for continuous pressure operation at temperatures above +40°C.

The tables given in section 3.2.3 of this catalogue are taken from DIN 8074: 2011-12 and give clear guidance on the expected service life of PE 80 and PE 100 pipe systems for a range of pipe SDRs base on their operational pressures and temperatures. The tables demonstrate how the service life of pipe systems can be significantly extended by reducing the operational pressure and hence the hoop (circumferential) stress in the pipe wall.

For temperatures below 0°C designers shall ensure that the fluid will not freeze, which can cause damage to the pipe system.

2.7 Abrasion resistance

In several documented studies, PE has been shown to have excellent abrasion resistance, with considerably reduced wear rates compared to the traditional pipe materials. Average abrasion values for pipes made of different materials are shown in the figure below.



Almona PE80 and PE100 pipes offer outstanding abrasion resistance, making them the first choice for applications where high internal resistance to abrasion is required e.g. for transporting solids in liquid or gaseous forms such as particulate slurry at low velocity and various other industrial effluents. The abrasion rates of our pipe systems increase depend on several factors including:

- flow turbulence
- fluid velocity
- size, shape and hardness of debris/particles

The interaction of these parameters shall be taken into consideration in the design of new pipelines. In practice, the transmission of solids in both liquid or gaseous forms results in abrasion of the internal PE pipe walls, especially at points of high turbulence such as bends or junctions. The effective lifetime of the PE pipeline can be increased by using demountable joints which allow periodic rotation of the PE pipe sections to distribute the abrasion wear evenly around the circumference of the pipe.

In projects where the exact abrasion wear rate is required to be known during the design phase, testing of wear rates shall be performed using the specific medium under the proposed operational conditions. For more information, refer to Chapter III: Design Considerations and Chapter V: Installation.

2.8 Permeability

Almona PE80 and PE100 pipes can be shown to be permeable to certain gases and liquids under extreme conditions, the rate of permeation being mainly dependent upon the nature of the gas or liquid, thickness of the pipe wall, internal pressure, time and temperature.

The ingress of hydrocarbons in to the plastic matrix can have a negative impact on two important aspects associated with a pipeline's construction and operation, namely the quality of fusion joints and the reduction in pipe strength and stiffness. The magnitude of the impact depends on the amount of contamination and the point in time at which it occurs.

Should the pipes and fittings be contaminated with a hydrocarbon prior to fusion jointing, for example, as a result of being laid on soil contaminated with gasoline, then the strength of the joint may be significantly weaker than a properly prepared and fused joint.

Hydrocarbon permeation in to the pipe wall either before or after installation, perhaps as a result of the pipeline being laid in contaminated ground, will significantly reduce the strength of the PE material and hence reduce the pressure which the pipe can sustain. The same contamination will soften the PE material, meaning that it will creep more under pressure. This can result in collapse of the pipeline when emptied or the loss of water tightness at flanges.

Permeation of hydrocarbons in to the pipe wall can also lead to contamination of the liquid being carried by the pipeline. If that liquid is potable water this can have very serious consequences for the health of consumers. Hence whenever a PE pipeline is to be laid through contaminated ground, multilayer barrier pipe systems should be used.

2.9 Electrical conductivity & static charge

Almona PE80 and PE100 pipes are non-conductive and cannot be used for electrical earthing purposes. Since, PE pipes are good insulators, they also tend to accumulate a static charge as result of friction during handling, laying and operation. These charges could potentially be a safety hazard if there is a possibility of a combustible leaking gas or of explosive, dry and dusty atmospheres. Such potential hazards shall be evaluated and dealt with through the adoption of safe static dissipation measures prior to working on the pipeline. Where PE pipes are used to replace existing metal water pipes, the project Engineers shall take into consideration any existing systems used for earthing or corrosion control purposes. Accordingly, the concerned authorities shall be consulted to determine their requirements.

2.10 Weathering

The presence of between 2 and 2.5% carbon black, by mass, in accordance with the international standards, enables almona PE80 and PE100 pipes to resist degradation by ultraviolet (UV) rays. almona yellow PE80 pipes and orange PE100 pipes are effectively stabilized against UV rays for a minimum period of 4 months under the conditions found in the Arabian Peninsula. All types of PE are also impervious to the effects of wind and rain.

Where yellow and orange pipes are to be stored in the sun for periods of longer than 1 month it is recommended that they should be protected with an opaque UV resistant covering and that they are not laid down beside the trench for extended periods of time, prior to being jointed and installed.

2.11 Sustainability

During the production of PE systems, almona focus on sustainable practices including the minimizing of energy consumption and the 100% recycling of all PE80 and PE100 scrap material from the manufacturing process.

Compared to other materials, the energy expenditure required for the production of almona PE systems is significantly lower than that required to produce, for example, metallic pipes and the process does not produce any environmentally hazardous substances. At the end of their operational life all PE pipe systems can be recycled to produce new products such as cable ducts or can be incinerated to recover their energy content. TEPPFA, the European Plastic Pipes and Fittings Association has undertaken extensive work on the Life Cycle Assessment of plastic pipe systems to demonstrate their relatively low environmental impact.

2.12 Quality Assurance

Almona systems provide the highest levels of quality and our target is to exceed the requirements of national and international standards. This is achieved through highly controlled manufacturing processes and the implementation of a state-of-the-art quality control system which covers raw material, pipe and fittings, packing, storage, supply chain and post-sales support.

Our pipe and fittings are produced using the latest generation of machinery operated by trained skilled professionals that are supported by a continuous research and development programme. Deviations on product quality are avoided through stringent quality control checks undertaken by our inhouse quality control laboratory.

2.13 Applicable Standards

Almona PE80 and PE100 meet the stringent requirements given in the following standards:

ISO 4427	Plastics piping systems. Polyethylene (PE) pipes & fittings for water supply
ISO 4437	Plastics piping systems for the supply of gaseous fuels – Polyethylene (PE)
EN 12201	Plastics piping systems for water supply, and for drainage and sewerage under pressure. Polyethylene (PE)
EN 1555	Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE)
DIN 8074	Polyethylene (PE) - Pipes PE80, PE100 - Dimensions
DIN 8075	Polyethylene (PE) - Pipes PE80, PE100 - General quality requirements, testing
SASO 1402	Methods of testing polyethylene pipes for general purposes
DIN 4102	Fire behaviour of building materials and building components
EN 13501-1	Fire classification of construction products and building elements Part 1: Classification using data from reaction to fire tests

"ALMONA SYSTEMS PROVIDE THE HIGHEST LEVELS OF QUALITY AND OUR TARGET IS TO EXCEED THE REQUIREMENTS OF NATIONAL AND INTERNATIONAL STANDARDS"

Section III

3. Design Considerations

Internationally, the design of pipelines is covered by different national and local standards or accepted practices. The design considerations presented in Section III of this document aim only to provide guidance on critical parameters that may impact on the performance or lifetime of a PE pipeline.

For the design of a new PE pipeline, it is first necessary to establish the basic operating parameters for the desired performance of the system, generally for at least 50 years lifetime. The main design parameters to be considered can be grouped into four categories:

1. Pipe characteristics
2. Operating temperature and pressure
3. Flow
4. Installation type (under or above ground)

After establishing the above parameters, to which the pipeline will be subjected, the best suited pipe and fittings material type i.e PE80 or PE100 can be determined and the pipe dimensions determined.

The procedure for piping system design is frequently an iterative process. For pressure liquid flows, an initial choice of pipe pressure rating and internal diameter can be used to undertake hydraulic calculations to accurately estimate the pipeline operating pressure and hence determine if the initial estimate can be improved on by changing either or both of the initial estimates. This iterative process is repeated until the most efficient combination of pressure rating and internal diameter is determined.

For non-pressure (gravity) systems, the only head available is that due to the change in pipe invert level from upstream to downstream. The design process needs to meet the requirement for a minimum flushing velocity to be achieved on a regular basis, which is required to remove sediments and for the sewer or drain to deal with very large variations in flow at different times of the day and during storm conditions. The iterative design process also needs to select an economic wall thickness or profile design that can sufficiently resist the anticipated static and dynamic earth and traffic loads.

The design equations, relationships and parameters of PE pipes are well-established in the literature. A recommended reliable source of information on design of PE piping systems is the Handbook of Polyethylene Pipe published by the Plastics Pipe Institute of the USA and which is free to download from their website (https://plasticpipe.org/publications/pe-handbook.html).

Other sources of information include the HR Wallingford tables and charts for the hydraulic design of pipes, sewers and channels and the HDPE pipe technical guidance section of the PE100+ Association website (https://www.pe100plus.com).

3.1 Pipe characteristics

Almona offers a broad series of PE80 and PE100 pipes with nominal diameters (DN) ranging from 16 to 630mm. Nominal pipe diameter refers to the outside diameter (d) of the pipe. Almona PE80 and PE100 pipes are classified in accordance to:

- Standard Dimension Ratio (SDR)
- Pipe series (S)
- Nominal Pressure (PN)

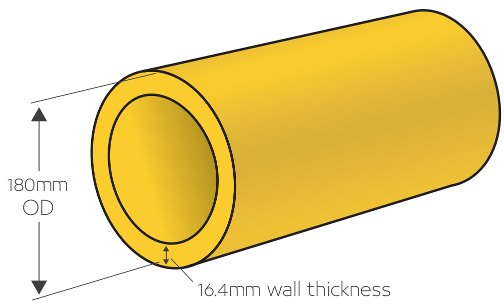
3.1.1 Standard Dimension Ratio (SDR)

The Standard Dimension Ratio (SDR) refers to the ratio of outside diameter, d, to the minimum specified wall thickness, t and is for pipe systems, such as PE, where the pipe size is determined by the outside diameter (OD).

$$SDR = \frac{d}{s_{min}}$$

Where: **d** is the nominal outer pipe diameter, mm
s_{min} is the minimum wall thickness, mm

Example: $SDR\ 11 = \frac{180}{16.4}$



The pressure rating of any homogenious material pipe, regardless of the material, is determined by the SDR and the strength of the material in resisting the hoop stress generated by the internal pressure. The holds true, regarless of the pipe diameter.

Hence specifying PE pipes with a given SDR, regardless of their diameter, ensures that all pipes of the same PE material will have the same pressure rating.

The higher strength of PE100 permits thinner pipe walls than PE80 for the same operating pressure (see below figure). PE100 uses less polymer and provides for a larger bore and increased flow capacity for a given nominal pipe size. This can result in significant cost savings, but this has to be balanced against the higher flexibility and more forgiving welding characteristics of MDPE PE80 material. This has lead some utilities to continue specifying PE 80 material for small diameter pipes of up to 63mm.

3.1.2 Pipe series (S)

Pipe series (S) is a dimensionless number indicative of the pipe pressure resistance, related to the pipe nominal outside diameter and wall thickness. Pipe series (S) can be defined as:

$$S = \frac{SDR - 1}{2}$$

3.1.3 Nominal pressure (PN)

PN is the maximum operating pressure of a pipe determined by the material design stress and SDR. almona PE pipes are produced in different pressure ratings (PN ratings), which indicate the maximum continuous internal pressure, measured in bar, that the pipe can withstand at a temperature of 20°C. PN can be expressed as:

$$PN = \frac{20\sigma}{SDR - 1}$$

Where σ is the maximum permitted stress of the pipe, explained in the following section of this manual.

As previously explained, almona PE80 and PE100 pipes are not recommended for continuous pressure operation at temperatures above 40°C if a 50 year design life is required, though they can operate at higher temperatures if a shorter design life is acceptable.

Almona offers a wide range of PE80 and PE100 pipe sizes designated by SDR, S and PN ratings. The designer can refer to Section VI of this technical manual or to our Infrastructure Products catalogue: Polyethylene PE100 and PE80 Pipes System. Selection of the above pipe characteristics shall be based on the design considerations described in that section.

The following table gives the maximum operating pressures at 20ºC for almona PE80 and PE100 pipes having a range of SDRs, when used for either water or gas network applications.

PIPE OD	SDR11				SDR17.6 (GAS)/ SDR17 (WATER)		SDR17	SDR21 (GAS)/ SDR21 (WATER)		SDR26 (GAS)/ SDR26 (WATER)	
	PE80		PE100		PE80		PE100	PE100		PE100	
	GAS	WATER	GAS	WATER	GAS	WATER	WATER	GAS	WATER	GAS	WATER
20mm	5.5	12.5									
25mm	5.5	12.5									
32mm	5.5	12.5									
50mm	5.5	12.5									
63mm	5.5	12.5	7.0	16.0	3.0	8.0					
90mm	5.5	12.5	7.0	16.0	3.0	8.0	10.0				
110mm		12.5		16.0	3.0	8.0	10.0				
125mm	5.1	12.5	7.0	16.0	3.0	8.0	10.0				
160mm	5.1	12.5		16.0	3.0	8.0	10.0		8.0		6.0
180mm	4.1	12.5	7.0	16.0	3.0	8.0	10.0		8.0		
225mm		12.5		16.0		8.0	10.0		8.0		6.0
250mm	4.0	12.5	7.0	16.0	3.0	8.0	10.0	2.0	8.0	2.0	6.0
280mm		12.5		16.0		8.0	10.0	2.0	8.0	2.0	6.0
315mm	3.4	12.5	7.0	16.0	2.7	8.0	10.0	2.0	8.0	2.0	6.0
355mm	3.1	12.5	7.0	16.0	2.5	8.0	10.0	2.0	8.0	2.0	6.0
400mm		12.5	7.0	16.0	2.3	8.0	10.0	2.0	8.0	2.0	6.0
450mm		12.5	7.0	16.0	2.2	8.0	10.0	2.0	8.0	2.0	6.0
500mm		12.5	7.0	16.0	2.1	8.0	10.0	2.0	8.0	2.0	6.0
560mm			7.0	16.0	2.0		10.0		8.0		6.0
630mm			7.0	16.0	1.8		10.0		8.0		6.0

3.2 Operational Pressures

3.2.1 Definition of Minimum Required Strength (MRS)

A key factor in the design of any pipe system is determining the internal hydrostatic pressure that a pipe can sustain for a given temperature and time period without failure of the pipe. This pressure-time-temperature behaviour of the pipe depends on the long-term hydrostatic strength of the pipe material in resisting the circumferential (hoop) stress generated by the internal pressure.

As the long-term hydrostatic strength of PE varies with time and temperature it needs to be determined at a set time and temperature for classification purposes, in accordance with ISO 9080 and EN ISO 12162. When determined in accordance with these standards the long term hydrostatic strength is referred to as the Minimum Required Strength (MRS). This corresponds to the lower confidence limit of the predicted circumferential (hoop) stress which the pipe is able to withstand at a continuous ambient temperature of 20°C for a period of 50 years.

Water is used as the internal test medium and the outside environment is taken to be either water or air. The MRS values for almona PE63, PE80 and PE100 pipe systems are shown in the following table:

Material Designation	MRS MPa
PE63	6.3
PE80	8.0
PE100	10.0

3.2.2 Maximum permitted stress (σ)

It is recognized that most pipe systems will not operate at constant temperatures and pressures and that many will be installed below ground and possibly be filled with mediums other than pure water. It is important to ensure that an allowance is made for these aspects together with others such as variations in pipe manufacture, material properties, jointing, installation and minor surface damage when determining the nominal pressure rating of the pipe (PN).

As explained in section 3.1.3 of this catalogue, the following is the equation used for determining the PN of a PE pipe.

$$PN = \frac{20\sigma}{SDR - 1}$$

An allowance for taking account of the above conditions needs to be applied to the material's MRS in order to calculate the maximum permitted stress (σ), which is used in the above equation. almona recommends to follow the procedures described in EN ISO 12162 which uses a minimum design coefficient (c) which is applied to the MRS, as shown in the following equation:

$$\sigma = \frac{MRS}{C}$$

EN ISO 12162 designates the minimum service design coefficient (c) for PE pipe systems at 20°C shall be 1.25. ISO 4427 and EN 12201 state that this value shall be used for water applications, whilst ISO 4437 and EN 1555 state that a value of 2.0 should be used for natural gas applications. The value used for gas applications is very conservative, but reflects the catastrophic impact that can result from the failure of a gas distribution pipeline.

Based on these service design coefficient values, the maximum permitted stress of PE80 and PE100 pipes, depending on their application, is given in the following table.

Classification (ISO 12162)	MRS value [MPa]	50 year, 20°C Design Strength Range [MPa]	Maximum permitted stress σ	
			Water [N/mm²]	Gas [N/mm²]
PE80	8.0	$8.0<\sigma_{LPL}<9.99$	6.40	4.00
PE100	10.0	$10.0<\sigma_{LPL}<11.19$	8.00	5.00

The service design coefficients and maximum permitted stresses given above are applicable for regular water and gas distribution networks. Where PE pipe systems are to be used in more challenging applications, such as when being used to transport mining slurries, designers should look at increasing the coefficients.

3.2.3 Effects of operational temperature on pipe pressure ratings

As explained in section 2.6 of this manual, at higher temperatures the tensile strength and stiffness of PE are reduced and the material loses it strength at a higher rate.

The following table, which is taken from DIN 8074: 2011-12, gives the maximum continuous working pressure for almona PE80 pipes used for water supply applications depending on the operational temperature and service life required.

Temperature °C	Years of service	Pipe Series (S)										
		25	20	16	12.5	10.5	10	8.3	8	6.3	5	4
		Standard Dimension Ratio (SDR)										
		51	41	33	26	22	21	17.6	17	13.6	11	9
		Allowable Working Pressure (bar)										
10	5	3.2	4.0	5.1	6.4	7.7	8.1	9.7	10.1	12.8	16.1	20.3
	10	3.1	4.0	5.0	6.3	7.6	8.0	9.5	10.0	12.6	15.9	20.0
	25	3.1	3.9	4.9	6.1	7.4	7.8	9.3	9.8	12.3	15.5	19.5
	50	3.0	3.8	4.7	6.0	7.2	7.6	9.1	9.5	12.0	15.1	19.0
	100	2.9	3.7	4.7	5.9	7.2	7.5	8.9	9.4	11.8	14.9	18.8
20	5	2.7	3.4	4.2	5.4	6.5	6.8	8.1	8.5	10.7	13.5	17.0
	10	2.6	3.3	4.1	5.2	6.3	6.6	7.9	8.3	10.4	13.1	16.5
	25	2.5	3.2	4.1	5.1	6.2	6.5	7.7	8.1	10.3	12.9	16.3
	50	2.5	3.2	4.0	5.0	6.0	6.4	7.4	8.0	10.0	12.5	16.0
	100	2.4	3.1	3.9	4.9	5.9	6.2	7.4	7.8	9.8	12.3	15.5
30	5	2.2	2.8	3.5	4.5	5.4	5.7	6.8	7.1	9.0	11.3	14.3
	10	2.2	2.8	3.5	4.4	5.3	5.6	6.7	7.0	8.8	11.1	14.0
	25	2.1	2.7	3.4	4.3	5.2	5.5	6.5	6.9	8.7	10.9	13.8
	50	2.1	2.7	3.4	4.2	5.1	5.4	6.4	6.7	8.5	10.7	13.5
40	5	1.9	2.4	3.0	3.8	4.7	4.9	5.8	6.1	7.7	9.7	12.3
	10	1.9	2.4	3.0	3.8	4.6	4.8	5.7	6.0	7.6	9.5	12.0
	25	1.8	2.3	2.9	3.7	4.5	4.7	5.6	5.9	7.4	9.3	11.8
	50	1.8	2.3	2.9	3.6	4.4	4.6	5.5	5.7	7.2	9.1	11.5
50	5	1.6	2.1	2.6	3.3	4.0	4.2	5.0	5.2	6.6	8.3	10.5
	10	1.6	2.0	2.5	3.2	3.9	4.1	4.9	5.1	6.4	8.1	10.2
	15	1.6	2.0	2.5	3.2	3.9	4.1	4.9	5.1	6.4	8.1	10.2
60	5	1.4	1.8	2.3	2.9	3.5	3.7	4.4	4.6	5.8	7.3	9.2
70	2	1.3	1.6	2.0	2.6	3.1	3.3	3.9	4.1	5.2	6.5	8.2

Safety factor C = 1.25
Reference DIN 8074: 2011-12

The following table gives the maximum continuous working pressure for almona **PE80** pipes used for water supply applications depending on the operational temperature and service life required.

Temperature °C	Years of service	Pipe Series (S)						
		20	12.5	8.3	8	6.3	5	4
		Standard Dimension Ratio (SDR)						
		41	26	17.6	17	13.6	11	9
		Allowable Working Pressure (Bar)						
10	5	5.0	7.9	11.9	12.5	15.8	19.9	25.1
	10	4.9	7.7	11.7	12.3	15.5	19.5	24.6
	25	4.8	7.6	11.5	12.0	15.2	19.1	24.1
	50	4.7	7.5	11.3	11.9	15.0	18.9	23.8
	100	4.6	7.3	11.1	11.7	14.7	18.5	23.3
20	5	4.2	6.6	10.0	10.5	13.3	16.7	21.0
	10	4.1	6.5	9.9	10.4	13.1	16.5	20.8
	25	4.0	6.4	9.7	10.1	12.8	16.1	20.3
	50	4.0	6.3	9.6	10.0	12.5	16.0	20.0
	100	4.9	6.1	9.4	9.8	12.3	15.5	19.5
30	5	3.5	5.6	8.5	8.9	11.2	14.1	17.8
	10	3.5	5.5	8.3	8.8	11.0	13.9	17.5
	25	3.4	5.4	8.2	8.6	10.9	13.7	17.3
	50	3.4	5.4	8.1	8.5	10.7	13.5	17.0
40	5	3.0	4.8	7.3	7.6	9.6	12.1	15.3
	10	3.0	4.7	7.1	7.5	9.5	11.9	15.0
	25	2.9	4.6	7.0	7.4	9.3	11.7	14.8
	50	2.9	4.6	6.9	7.3	9.1	11.5	14.5
50	5	2.6	4.2	6.3	6.6	8.3	10.5	13.3
	10	2.6	4.1	6.2	6.5	8.2	10.3	13.0
	15	2.6	4.1	6.2	6.5	8.2	10.3	13.0
60	5	2.3	3.6	5.5	5.7	7.2	9.1	11.5
70	2	2.1	3.3	5.0	5.2	6.6	8.3	10.5

Safety factor C = 1.25
Reference DIN 8074: 2011-12

For other applications designers are recommended to follow the guidelines given in section 3.4.1 of this catalogue.

3.2.4 Transient Internal Pressures (Pressure Surges)

Transient internal pressures, commonly referred to as surge pressures, are transient (short term) fluctuations of the pressure within a pipeline that occur due to operational changes in the system. They may be occasional and severe, in which case they normally occur as a result of system malfunction or frequently recurring less intense events that are a result of an operational change in the system.

3.2.4.1 Occasional Pressure Surges

Occasional pressure surges are typically sudden peaks and troughs in pressure due to rapid velocity changes in the flow of a liquid or gas along a pipeline or within a closed network. The rapid change in velocity leads to the formation of a pressure wave (surge) that propagates back and forth along a pipeline oscillating in both directions from the point of origin. The phenomenon is commonly referred to as water hammer.

Occasional pressure surges are usually caused by equipment malfunction or very fast incorrect operation. The most common cause is a power failure to a pumping system that results in the rapid deceleration of all pump sets. Other causes are typically associated with the failure of a system, but in exceptional cases can be caused by operational mistakes, such as the rapid closure of a large diameter butterfly valve.

Such severe fluctuations in pressure can, in extreme cases, lead to the rupturing of pipes and failure of fittings. Fortunately, the visco-elastic nature of PE means that the initial magnitude of the pressure wave tends to be less than along metallic pipelines and that the pressure variations die down quickly. Nevertheless, in the case of severe surge pressures it may be necessary select a higher pressure rating for the pipeline.

Accurate calculation of pressure wave profile is therefore essential, especially in the case of long distance larger diameter pipelines and such calculations are normally undertaken using specialised computer simulation packages. Simple conservative estimates of the pressure surge can be calculated using the Joukowsky equation.

The Handbook of Polyethylene Pipe advices that PE pipes produced using modern materials can withstand occasional pressure surges of up to twice the pipes pressure rating. For example, an almona SDR17 PE100 pipe that has a nominal pressure rating of 10 bar can cope with occasional pressure surges of up to 20 bar.

3.2.4.2 Recurring pressure surges

Recurring pressure surges can be caused by the starting and stopping of pumps, operation of valves and other changes in the steady-state operation of a pipeline or network.

Depending on the frequency and magnitude of the surges, together with the pipe material properties such recurring changes in pressure may cause gradual and cumulative fatigue damage of the pipe system. Fortunately modern PE pipe materials, such as the ones used by almona in the production of our pipe systems, are highly resistant to fatigue and can cope with many changes pressure each hour without suffering from fatigue.

The Handbook of Polyethylene Pipe advices that modern PE materials can cope with up to 50 pressure variations per hour with no negative effects, providing that the magnitude of the variations does not exceed 50% of the pipe's pressure rating i.e. that the total pressure (steady-state pressure plus surge pressure) in a pipe shall not exceed 1.5 times the pipe's pressure rating.

3.3 Flow

3.3.1 Estimation of average internal pipe diameter

The flow of fluids and gases along a pipeline and the associated hydraulic losses largely depend of the cross sectional area of the pipe bore and the hydraulic (head) losses that are due to friction between the fluid or gas and the pipe wall inner surface. As PE pipes are produced using an extrusion process that controls the outside diameter of the pipe and varies the wall thickness, depending on which SDR is required, there can be some variation in the pipe wall thickness.

In most cases this variation, in pipe wall thickness is ignored, but when the hydraulic calculations have to be undertaken to a high level of accuracy then an estimate of the average pipe wall thickness and hence the actual internal diameter of the pipe needs to be made.

The following equation, which is taken from The Handbook of Polyethylene Pipe, estimates the inside diameter by deducting twice the average wall thickness from the average outside diameter. The average wall thickness is taken as typically 6% greater than minimum wall thickness. As a result, the inside diameter of the pipe is determined as:

$$D_i = Do - 2.12 \left(\frac{DO}{SDR} \right)$$

Where

Di: average inside pipe diameter, mm

Do: average outside pipe diameter, mm

SDR: standard dimension ratio

3.3.2 Flow rate

A basic design parameter in designing a pipe system is its conveyance capacity or flow rate. For pressure pipe systems, where the pipes flow full, flow rate can be calculated based on the following equation:

$$Q = V \times \frac{\pi \times D_i^2}{4}$$

Where

Q: volumetric flowrate (m3/s)
V: flow velocity (m/s)
Di: inside pipe diameter (m)
π: 3.142 (circle circumference/diameter)

The above equation assumes the pipe maintains a round profile. It is often the case that PE pipes are subject to deformation due to external loads and a certain degree of ovality is expected. Although such deformation may slightly affect the hydraulic characteristics of the pipe, in practice it can safely be regarded as negligible.

In the case of sewers, groundwater and stormwater drains where the pipes are laid at a shallow angle and the pipe generally does not flow full, open channel flow conditions exists. For open channel flow, under constant grade (slope] and uniform flow conditions, the Manning equation may be used to calculate the flowrate. The Manning equation is limited to water or liquids with a kinematic viscosity equal to water.

$$Q = \frac{1}{n} A_c R_h^{2/3} S_0^{1/2}$$

Where

n: manning's coefficient, typically 0.009 for PE pipes
A_c: cross-sectional area of flow (m^2)
R_h: hydraulic radius (m)
S_0: hydraulic slope (m/m)

3.3.3 Head losses due to fluid flow

When a fluid flows through a pipeline there is a reduction in the total head (energy) of the fluid due to viscous sheer stresses developed between the fluid and the pipe wall.

Head losses due to flow in straight pipes are called major, linear or friction losses (h_f) while head losses due to flow through pipeline system components, such as fittings, are called the minor, dynamic or local losses (h_m). For relatively short pipe systems, with a relatively large number of bends and fittings, minor losses can easily exceed major losses.

Compensation for static head (h_s) due to elevation differences between pipe inlet and outlet should also be considered. As such, the total head loss (h_L) of pipe is expressed as:

$$h_L = h_f + h_m + h_s$$

3.3.3.1 Major head losses

Major head losses are due to friction between the fluid flowing through the pipe and the pipe walls. For incompressible fluids, there are several equations that can be used for calculating the head loss, with the most popular being the Darcy-Weisbach equation.

$$h_f = f \times \frac{LV^2}{d_i\, 2g}$$

Where

h_f: head loss due to friction (m)

f: friction factor (dimensionless)

L: pipeline length (m)

d_i: inside pipe diameter (m)

v: flow velocity (m/s)

g: gravitational acceleration (9.81 m/s^2)

The calculation is easy to use, with the exception of the determining the friction factor (f). this can be calculated using the iterative Colebrook- White equation which is shown below.

$$\frac{1}{\sqrt{f}} = -2 \log\left(\frac{k}{3.7d_i} + \frac{2.51}{Re\sqrt{f}}\right)$$

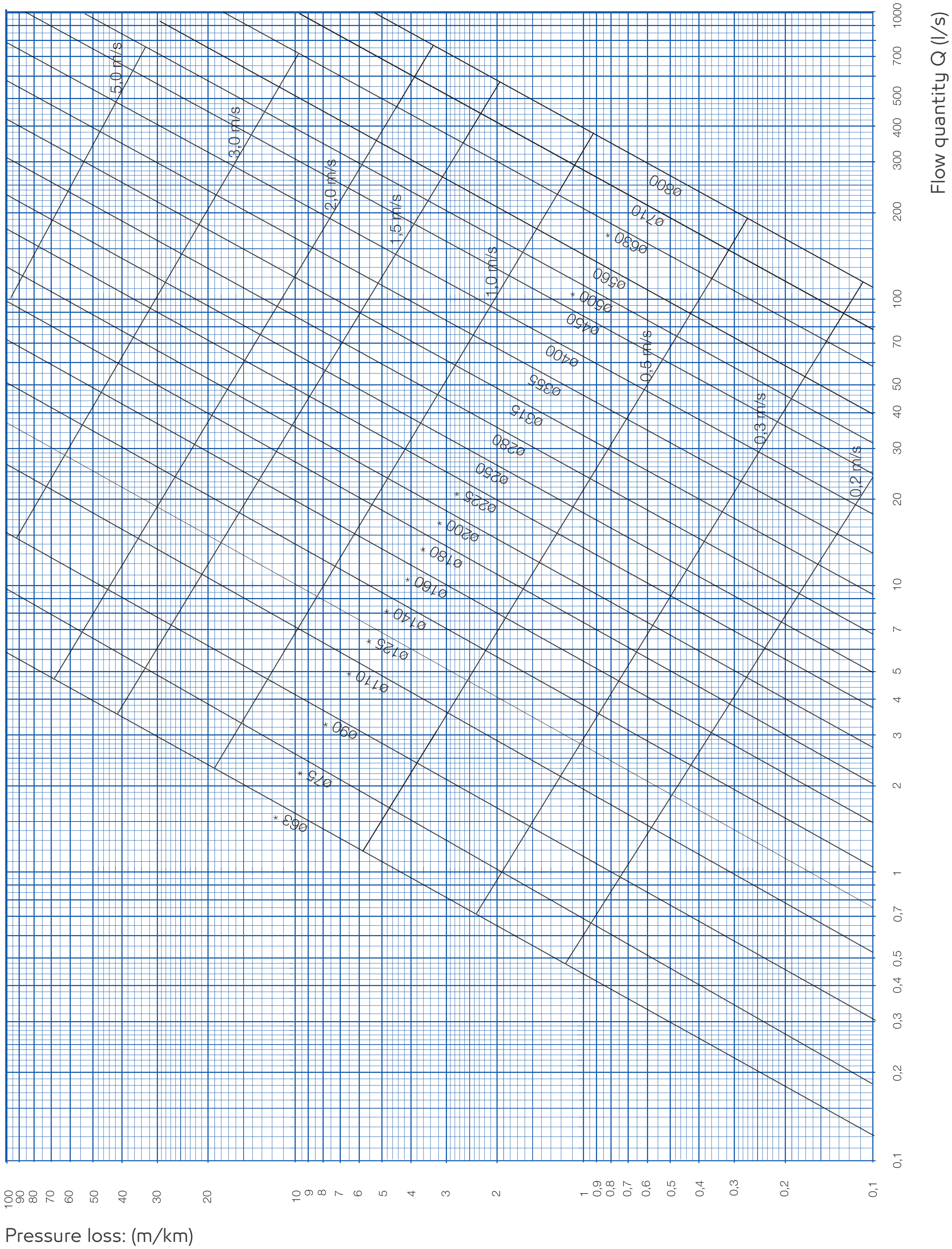
Where

k: pipe roughness value (m)

Re: Reynold's Number (dimensionless)

The complexities of having to calculate the faction factor using an iterative equation, together with having to calculate the Reynold's Number, which itself has four elements means that many engineers settle for an alternative and calculate hf using small computer apps that can run on a mobile phone, tables of head loss figures for different pipe diameters, flow and pipes materials or design charts as shown below.

Whilst most flow charts refer to the pipe inner diameter, those for PE pipe systems refer to the nominal (outside) pipe diameter and pipe SDR in order to simplify the design process. Flow characteristics of almona SDR17 and SDR11 PE100 pipes are shown in the following charts.


Flow quantity Q (l/s)
1000
700
500
400
300
200
100
70
50
40
30
20
10
7
5
4
3
2
1
0,7
0,5
0,4
0,3
0,2
0,1
5,0 m/s
3,0 m/s
2,0 m/s
1,5 m/s
1,0 m/s
0,5 m/s
0,3 m/s
0,2 m/s
ø800
ø710
ø630 *
ø560
ø500 *
ø450
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ø355
ø315
ø280
ø250
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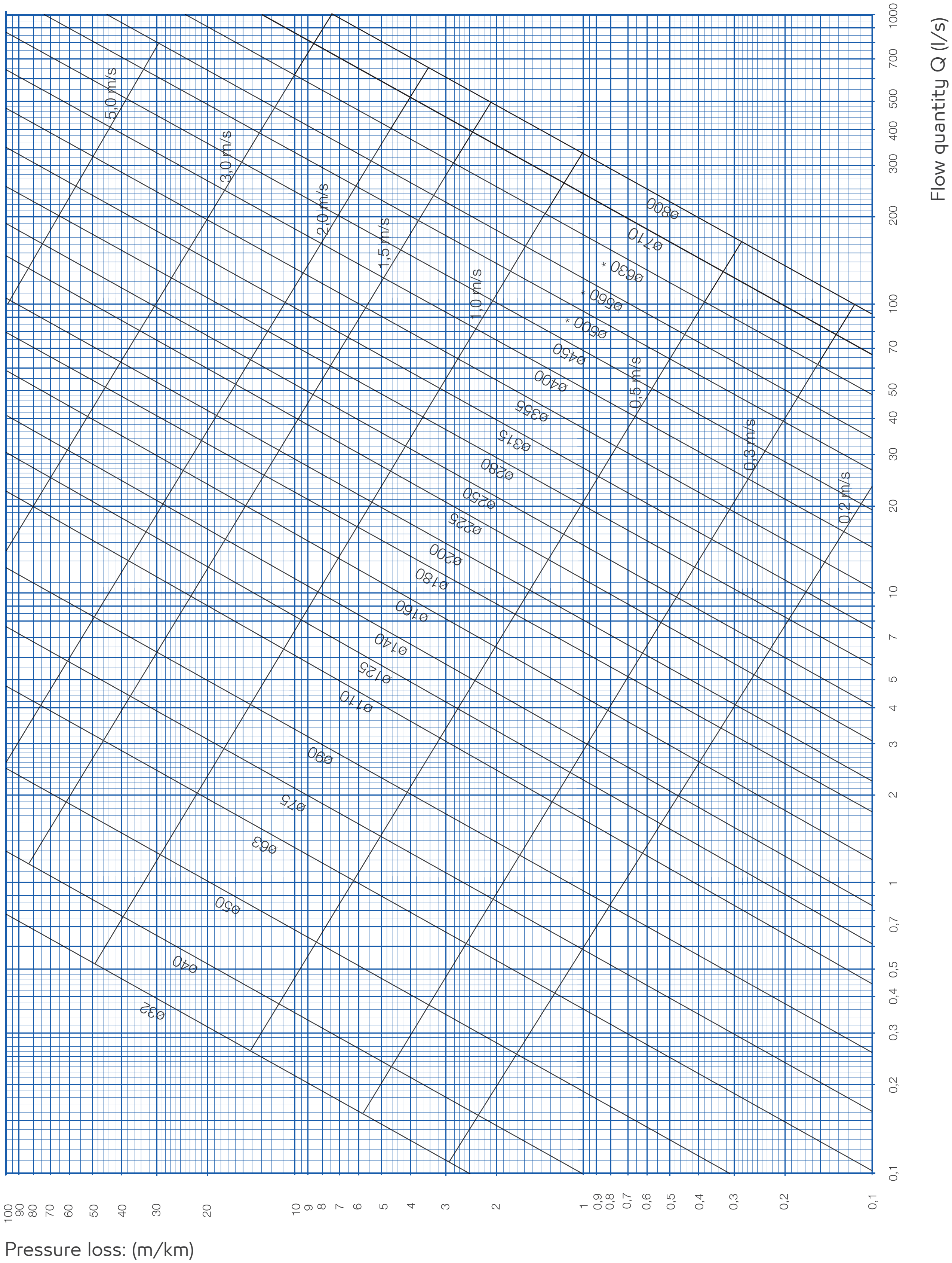
ø200 *
ø180 *
ø160 *
ø140 *
ø125 *
ø110 *
ø90 *
ø75 *
ø63 *
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
Pressure loss: (m/km)


Flow quantity Q (l/s)
Pressure loss: (m/km)
5,0 m/s
3,0 m/s
2,0 m/s
1,5 m/s
1,0 m/s
0,5 m/s
0,3 m/s
0,2 m/s
ø32
ø40
ø50
ø63
ø75
ø90
ø110
ø125
ø140
ø160
ø180
ø200
ø225
ø250
ø280
ø315
ø355
ø400
ø450
ø500 *
ø560 *
ø630 *
ø710
ø800
1000
700
500
400
300
200
100
70
50
40
30
20
10
7
5
4
3
2
1
0,7
0,5
0,4
0,3
0,2
0,1
100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3 2 1 0,9 0,8 0,7 0,6 0,5 0,4 0,3 0,2 0,1

3.3.3.2 Minor head losses

Minor head losses occur when a fluid flows through fittings such as valves, bends and tees that make up a pipeline or network. These losses represent additional energy dissipation in the flow, usually caused by turbulence induced by the shape of the fitting. Minor head losses can be estimated by means of a loss coefficient (K) as shown below:

$$h_m = \Sigma K \frac{V^2}{2g}$$

Where

h_m: total minor head losses due to system components (m)
ΣK: the sum of all of the loss coefficients (K) in the length of pipe
V: flow velocity (m/s)
g: gravitational acceleration (9.81 m/s^2)

Flow loss coefficient (K) of some of the almona fittings are given in the following table

Angle	Fitting	K
90°	Elbow (L/d=1)	0.25
45°	Elbow (L/d=1)	0.15
90°	Tee (straight through)	0.1
90°	Tee (side branch)	0.3
90°	Long Radius bend	0.15
45°	Long Radius bend	0.07
N/A	Open gate valve	0.2

3.3.4 Flow velocity limitations

Limitations regarding flow velocities in almona PE pipe systems arise from system specific requirements. The operational performance, but also the economics of a pipe system should be taken into account when determining the range of flow velocities. For instance, high velocities lead to increased head losses while low velocities result to longer residence times in the pipeline which may affect water quality. However, in general, maximum velocities in PE pipes are limited by the surge pressure capacity whilst the minimum velocity is determined by the self-cleansing velocity, at least in those pipelines carrying particles.

Acceptable flow velocities in PE pipe systems depend on the specific details of the system. In pressure pipe systems, the maximum operating velocity is usually dictated by the surge pressure allowance of the pipe. The magnitude of a pressure surge is directly related to the velocity of flow in the systems and so very high velocities should be avoided if possible.

As a generally guideline, from an economic perspective, the maximum velocity is smaller diameter pipelines and networks is normally limited to approximately 2 m/s though in the case of larger diameter transmission pipelines this could rise to around 3 m/s.

In the case of gas pipelines, flow velocity in compressible gas lines tends to be self-limiting. Compressible gas flows in PE pipes are typically laminar or transitional. Fully turbulent flows are possible in short pipelines, but difficult to achieve in longer transmission and distribution lines because the PE pipe pressure rating limits the flow capacity and hence the velocity.

In pipe systems carrying liquid slurries, minimum flow velocities should be determined to ensure that the solids remain in suspension and so prevent sediment build up. Very high velocities should also be avoided to minimise abrasion of the pipe wall. In general, flow velocities that lead to Reynold's numbers greater than 4,000 ensure that fully turbulent flow, and thus, suspension of solids is maintained.

The design of slurry pipelines depends on the particle size distribution and density of the slurry together with the alignment, size and material of the pipeline itself. The accurate design of slurry pipelines is therefore best undertaken by special designers, though some guidance on PE slurry pipeline design is given in Chapter 6 of the Handbook of Polyethylene Pipe.

3.3.5 Compressible gas flow

Gases are compressible fluids, however, when the pressure drop and therefore density change is limited, the Darcy-Weisbach equation still applies with adequate accuracy and can be used in gas distribution networks.

Equations such as the Mueller equation, Weymouth equation, Panhandle equations are simplified equations used to model gas flows along high pressure transmission pipelines, typically at pressures above 40 bar. As PE pipes can only be used to carry natural gas at pressures of up to 10 bar they are not applicable.

For the design of PE gas pipelines and distribution networks designers are advised to use the General Flow Equation, of which there are several variations. The following example is taken from IGEM/TD/3 Gas Distribution Guide, published by the UK Institution of Gas Engineers and Managers. The guide also provides advice and guidance on many aspects of designing PE gas pipelines and networks.

$$Q = 7.574 \times 10^{-4} \cdot \left[\frac{T_s}{P_s}\right] \cdot \left[\frac{(P_1^2 - P_2^2) \cdot d^5}{STZL}\right]^{0.5} \cdot \left[\frac{1}{f}\right]^{0.5}$$

Where

Q: gas flow rate at base conditions ($m^3 h^{-1}$)

T_s: standard temperature (288K)

P_s: pressure at standard conditions (1.013 bar)
f: friction factor
P_1: upstream absolute pressure (bar)
P_2: downstream absolute pressure (bar)
d: internal diameter (mm)
S: specific gravity (0.6 for Natural Gas; 1.5 for propane, 2.0 for butane)
Z: average compressibility factor
T: average temperature of flowing gas (K) (normally taken as 278K)
L: pipe lenght (m)

3.3.6 Effect of air pockets and installation of air valves

Formation of air pockets in liquid carrying pipe systems occurs when air accumulates at local high spots along the pipeline. Such air pockets limit the effective hydraulic capacity of the pipe by restricting flow and may amplify the effects of pressure surges. Therefore air valves should be placed along the pipeline at high points, significant changes in grade and at sufficient intervals so that air can be evacuated or, if the line is drained, air can enter the pipeline.

3.3.7 The Poisson effect and unrestrained mechanical joints

When a tensile stress is applied to almona PE pipes, the pipes elongates in the direction of the applied stress and contracts perpendicular to the direction of the applied stress. Therefore when a section of pipe is pressurized, it tends to increase in diameter and reduce in length. The relationship between expansion in the radial direction and contraction in the longitudinal direction is given by Poisson's ratio. This point needs to be taken in to account whenever pipes and fittings are joined using unrestrained mechanical joints as it can lead to the pipe being pulled out of the joint.

For a given PE pipe diameter and SDR, the Poisson "pull out" force may be determined by multiplying the end area of the PE pipe by the product of the internal pressure hoop stress and the appropriate Poisson ratio.

The hoop stress, σ_H, acting on the longitudinal cross-section area of the pipe is given by:

$$\sigma_H = p \times \frac{d - s}{2\,s}$$

Where
σ_H: hoop stress (MPa)
f: internal pressure (MPa)
d: external pipe diameter (mm)
s: pipe wall thickness (mm)

The pull out force, F_R, acting at the pipe ends is:

$$F_R = v \times A \times \sigma_H$$

Where

F_R: Poisson tensile forces, N

v: Poisson's ratio (typically 0.4-0.5 for PE materials)

A: pipe wall cross-sectional area (mm^2)

Designers should calculate the pullout forces for the particular application and determine the appropriate anchoring techniques to protect any unrestrained in-line mechanical connections from the effect of pullout forces.

It should be highlighted that many specialist fittings manufacturers produce fully restrained (full end-load resistant) couplings, flange adaptors and other types of flexible mechanical joints that comply with ISO 17885–2015 "Plastics piping systems - Mechanical fittings for pressure piping systems–Specifications". Designers are advised to use such fittings whenever possible in order to maintain the continuous nature of PE pipelines and eliminate the risk of joint pull out due to the poisson effect.

3.4 Temperature

The physical properties of almona PE pipes can be significantly affected by temperature variations. In general, PE displays good chemical resistance and offers strength and rigidity within a temperature range of between –40°C and +80°C. Designers however need to take account of the effect of temperature on the strength of PE material and on pipe dimensions due to thermal expansion and contraction.

3.4.1 Effect on material strength

The standard physical properties of PE pipes are determined under laboratory conditions that generally involve measurement at a temperature of 20°C or, in the case of hydrostatic testing, under conditions that are used to determine the material's performance at 20°C. Hence a pipe's pressure rating (PN) or maximum operating pressure (MOP) is determined based on standardized conditions related to the material's maximum permitted stress at 20°C.

As previously explained in sections 2.6 and 3.2.3 of this catalogue, these physical or engineering material properties vary in relation to operational temperatures and this is why section 3.2.3 contains the tables detailing the effects of operational temperature on pipe pressure ratings.

The tables given in section 3.2.3 only apply to water applications and give values for set temperatures and years of service. Should designers need to consider other operational conditions or applications then they should apply the guidance given in ISO 13761 : 2017. This is applicable for temperatures between 20°C and 50°C, provided that the fluid being carried by the pipe does not adversely affect the long term material properties. The following is a copy of the table 1 given in the standard.

Temperature (°C)	Pressure reduction factor
20	1.00
25	0.93
30	0.87
35	0.80
40	0.74
45	0.67
50	0.61

For other temperatures between 20°C and 50°C, the pressure reduction factor with respect to temperature can be determined with linear interpolation from the above points, or using the following formula:

$$K = 1.260 - 0.013 \times T$$

Where

K: Pressure reduction factor

T: Operating temperature of the liquid (°C)

For temperatures up to 40°C a pipe's corrected maximum operating pressure (MOP) with regards to temperature to achieve a 50-year service time is:

$$MOP = PN \times K$$

Where

MOP: Temperature corrected Maximum operating pressure (bar)

PN: Pressure rating of the pipe (bar)

K: Pressure reduction factor

For sustained temperatures above 40°C almona should be consulted concerning the service life of the pipe system.

It should be noted that almona PE pipes exhibit similar opposite behaviour for temperatures lower than 20°C. In these situations, the pressure resistance of the pipe may actually exceed the design pressure class ratings. However, a decrease in flexibility and an increase vulnerability to impact damage will also occur at significantly lower temperatures. Please note that even when the operational temperatures are less than 20°C the international standards do not allow designers to take account of the enhanced pressure resistance.

3.4.2 Effects on pipe dimension

PE has a high coefficient of thermal expansion, almost ten times that of steel and so Almona PE pipes, unless restrained, will linearly expand and contract as their temperature varies. In case of unconstrained pipes, a change in temperature results in a change to the length of the pipe.

It should be pointed out that after a pipe is buried, the effects of temperature variations are significantly reduced as there is less variation in temperature and any pipe thermal movement is restrained by the friction between the surrounding soil and the pipe wall.

For unconstrained pipes laid on a frictionless surface, the change in length in response to a change in temperature can be expressed as:

$$\Delta L = L \times a_L \times \Delta_L$$

Where

ΔL: pipe length change (m)

L: pipe length change (m)

aL: coefficient of linear thermal expansion (0.0002 m/m/°C)

ΔT: temperature change (°C)

Almona HDPE pipe length variation due to temperature change is shown in the below table:

ΔT temperature change (°C)	ΔL Length variation (mm/m)
5	1
10	2
15	3
20	4
25	5
30	6

If a section of pipe is restrained at fixed points so that it cannot expand or contract, then internal longitudinal stresses will develop between the points of restraint. These need to be determined in order to ensure that the restraining points are strong enough to take such stresses and to ensure that the pipe itself will not be damaged. The stresses are determined according to the following equation:

$$\sigma_T = E \times a_L \times \Delta_T$$

Where

σT: longitudinal stress due to temperature change (MPa)

E: pipe apparent modulus of elasticity at average temperature (MPa)

aL: coefficient of linear thermal expansion (0.0002 m/m/°C)

ΔT: temperature change (°C)

Pipe deformation is a relatively slow process. As such, the apparent modulus (creep modulus) of elasticity is used to determine the generated stress. Creep modulus values for almona PE pipes vary depending on the temperature and duration of the deformation due to temperature change. Guidance on such values is given in Chapter 3, Appendix B of the Handbook of Polyethylene Pipe.

The force experienced at the restraint points such as puddle flanges, line anchors and fittings at each end of the pipe section can be determined from the following equation:

$$F_T = \sigma_T \times A$$

Where

FT: longitudinal force on pipe end due to temperature change (N)

σT: longitudinal stress due to temperature change (MPa)

A: pipe wall cross sectional area (mm^2)

Whilst most designers take account of the compressive force that will be applied to restraints as temperatures rise and the pipe tries to expand, account should also be taken of the tensile forces that will be applied when temperatures fall and the pipe section tries to contract.

3.5 Structural design pipes considering external load considerations

The design of a pipes to resist external loads and pressures in generally referred to as the pipe structural design and takes account of external loads due to:

- Buried installation or installation under water
- Traffic or other surcharge loads both during construction and operation
- Applications that may be subject to partial vacuum conditions

Almona PE pipes can be designed to withstand both internal pressures, referenced in the previous sections of this catalogue and external pressures such as those listed above. Any internal pressure will assist the pipeline in resisting external loads, so when designers consider the worst case, they generally assume that the pipe is empty or that the fluid being conveyed by the pipe is not under pressure.

External loads develop ring bending (deflection) and ring compressive stresses in the pipe wall. Excessive deflection may cause loss of stability and flow restriction, whilst excessive compressive stress may cause ring buckling of the pipe.

3.5.1 Buried installations

There are several types of underground installation of almona PE pipes that affect the external load conditions the pipe is subjected to. This section is limited to installation in trenches or embankments.

Trenchless installation technologies such as directional drilling or pipe bursting fall outside the scope of this section as these pipes may not develop the same soil support as conventional trench installed pipes. In such cases, the specialist installer should provide information on the loads that the pipe will be subjected to during and after installation. The main parameters to be considered in the design of buried pipes in trenches and embankments, aside from the pipe characteristics itself, are the surface loading, the depth of installation and the groundwater level.

There are many national and international standards and guides concerning the structural design of buried pipelines, which follow different approaches. In North America PE pipelines generally follow the guidance given in Chapter 6 of the Handbook of Polyethylene Pipe, whilst in Europe most designers follow EN 1295 or the various national standards and guides. For plastic pipe systems a buried pipe design tool and design guidelines have been developed by The European Plastic Pipes and Fittings Association (TEPPFA) and details can be found at https://www.teppfa.eu/

3.5.2 Underwater installation

For PE pipes intended to be used in an underwater installation, additional considerations should be taken into account. These include weighting against flotation, anchoring to prevent drifting of the pipe due to currents and stresses due to different installation methods. Generally the installation stresses are higher than those that the underwater pipeline will experience during operation. Chapter 10 of the Handbook of Polyethylene Pipe provides guidance on the design and installation of PE marine pipelines, whilst the book "Marine Wastewater Outfalls and Treatment Systems", published by the International Water Association is a standard work on the subject.

3.5.3 Applications that may be subject to partial vacuum conditions

Depending on their application and design many pipes may be subjected to temporary partial vacuum (negative pressure) conditions and in the case of suction pipes this can be a permanent operational condition. Designers should ensure that pipes are capable of sustaining negative pressures in addition to any external loads in order to prevent the pipe buckling or collapsing when subject to such conditions.

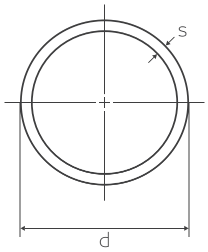
Except in the case of suction pipework, short term negative pressures can occur as a result of pressure surges in the system and the scale of such transient can be calculated as part of the analysis. In the case of suction pipework the negative pressure will depend on the performance of the suction pump.

In all cases, the theoretical maximum negative pressure that can occur in any system is full vacuum, which is 1 Atmosphere. This is equivalent to 1 bar or 0.1 MPa and can simply be taken account of in the structural design of by increasing the external pressure or load by the same amount.

Section IV

4. Product Range

4.1 PE100 and PE80 pipes for gas supply networks



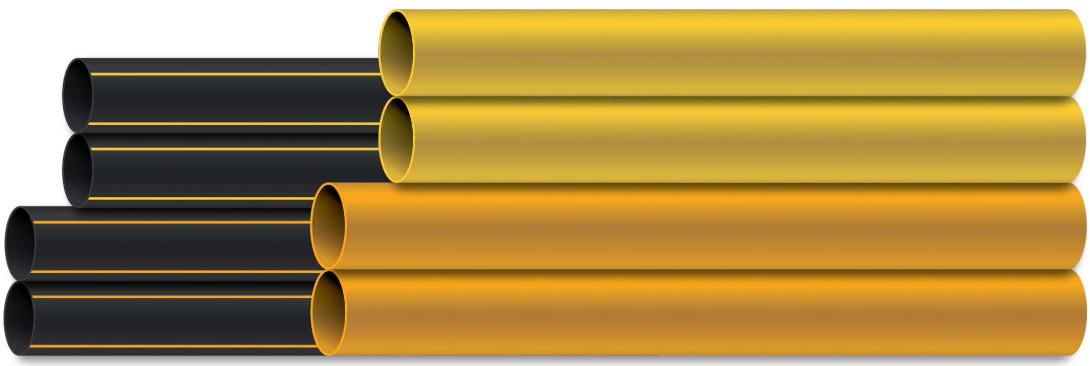
almona PE100 and PE80 pipes for gas supply networks according to ISO4437

Material	PE100	PE80
Minimum required strength	MRS = 10,0 MPa	MRS = 8,0 MPa
Design stress	σs = 5,0 MPa	σs = 4,0 MPa
Design safety factor	C = 2,0 for gas Black with orange stripes	C = 2,0 for gas Black with yellow stripes
Color	Orange	Yellow
Length	Sizes from 16mm to 32mm are available in coils of 100, 200 and 300 up to 1500 meters. Sizes from 40mm to 160mm are available in coils of 100 meters. larger diameters are available in straight lengths of 12 meters. Different lengths can be supplied on request.	

Nominal Outside Diameter d (mm)	SDR17.6 PE100 PN6 PE80 PN4.8		SDR11 PE100 PN10 PE80 PN8	
	Wall Thickness s (mm)	Weight (kg/m)	Wall Thickness s (mm)	Weight (kg/m)
16	2,3	0,10	3,0	0,12
20	2,3	0,13	3,0	0,16
25	2,3	0,17	3,0	0,21
32	2,3	0,22	3,0	0,28
40	2,3	0,36	3,7	0,43
50	2,9	0,46	4,6	0,67
63	3,6	0,69	5,8	1,06
75	4,3	0,98	6,8	1,50
90	5,2	1,40	8,2	2,14
110	6,3	2,09	10,0	3,17
125	7,1	2,68	11,4	4,10
140	8,0	3,36	12,7	5,15
160	9,1	4,38	14,6	6,71
180	10,3	5,51	16,4	8,47
200	11,4	6,83	18,2	10,45
225	12,8	8,60	20,5	13,22
250	14,2	10,62	22,7	16,31

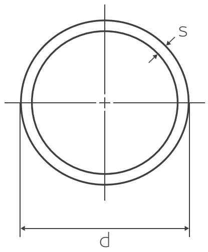
280	15,9	13,27	25,4	20,44
315	17,9	16,80	28,6	25,86
355	20,2	21,29	32,3	32,80
400	22,8	27,03	36,4	41,63
450	25,6	34,16	40,9	52,69
500	28,4	42,12	45,5	64,95
560	31,9	53,10	50,9	81,55
630	35,8	67,20	57,3	102,90

" ALMONA PROVIDES THE HIGHEST QUALITY POLYETHYLENE PE100 AND PE80 PIPE SYSTEMS FOR THE MOST DEMANDING GAS TRANSMISSION AND DISTRIBUTION NETWORKS "



4.2 PE100 and PE80 pipes for water supply networks

almona PE100 and PE80 pressure pipes for water supply networks according to ISO 4427-2

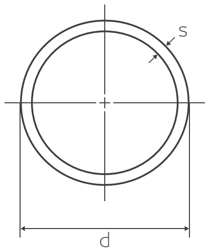


Material	PE100	PE80
Minimum required strength	MRS = 10,0 MPa	MRS = 8,0 MPa
Design stress	σs = 8,0 MPa	σs = 6,4 MPa
Design safety factor	C = 1,25 for water	C = 1,25 for water
Color	Black Black with blue stripes	Black Black with blue stripes
Length	Sizes from 16mm to 32mm are available in coils of 100, 200 and 300 up to 1500 meters. Sizes from 40mm to 160mm are available in coils of 100 meters. larger diameters are available in straight lengths of 12 meters. Different lengths can be supplied on request.	

	SDR41 S20	SDR26 S12,5	SDR17 S8	SDR13,6 S6,3	SDR11 S5	SDR9 S4
			Nominal pressure (PN)			
PE80 PE100 Nominal Outside Diameter d (mm)	PN3,2 PN4 Wall Thickness s (mm)	PN5 PN6 Wall Thickness s (mm)	PN8 PN10 Wall Thickness s (mm)	PN10 PN12,5 Wall Thickness s (mm)	PN12,5 PN16 Wall Thickness s (mm)	PN16 PN20 Wall Thickness s (mm)
16	-	-	-	-	-	2,0
20	-	-	-	-	2,0	2,3
25	-	-	-	2,0	2,3	3,0
32	-	-	2,0	2,4	3,0	3,6
40	-	-	2,4	3,0	3,7	4,5
50	-	2,0	3,0	3,7	4,6	4,6
63	-	2,5	3,8	4,7	5,8	7,1
75	-	2,9	4,5	5,6	6,8	8,4
90	-	3,5	5,4	6,7	8,2	10,1
110	-	4,2	6,6	8,1	10,0	12,3
125	-	4,8	7,4	9,2	11,4	14,0
140	-	5,4	8,3	10,3	12,7	15,7
160	-	6,2	9,5	11,8	14,6	17,9
180	-	6,9	10,7	13,3	16,4	20,1
200	-	7,7	11,9	14,7	18,2	22,4

225	-	8,6	13,4	16,6	20,5	25,2
250	-	9,6	14,8	18,4	22,7	27,9
280	-	10,7	16,6	20,6	25,4	31,3
315	7,7	12,1	18,7	23,2	28,6	35,2
355	3,5	13,6	21,1	26,1	32,2	39,7
400	9,8	15,3	23,7	29,4	36,3	44,7
450	11,0	17,2	26,7	33,1	40,9	50,3
500	12,3	19,1	29,7	36,8	45,4	55,8
560	13,7	21,4	33,2	41,2	50,8	62,5
630	15,4	24,1	37,4	46,3	57,2	70,3

almona PE100 pressure pipes for water supply networks according to DIN 8074/8075

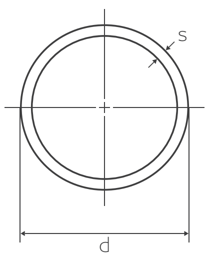


Material	PE100
Minimum required strength	MRS = 10.0 MPa
Design stress	σs = 8,0 MPa
Design safety factor	C = 1,25 for water
Color	Black Black with blue stripes
Length	Sizes from 16mm to 32mm are available in coils of 100, 200 and 300 up to 1500 meters. Sizes from 40mm to 160mm are available in coils of 100 meters. larger diameters are available in straight lengths of 12 meters. Different lengths can be supplied on request.

Nominal Outside Diameter d (mm)	SDR41 S20 PN4		SDR26 S12,5 PN6,3		SDR17 S8 PN10		SDR13,6 S6,3 PN12,5		SDR11 S5 PN16		SDR9 S4 PN20	
	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m
16	-	-	-	-	-	-	-	-	-	-	2,0	0,092
20	-	-	-	-	-	-	-	-	2,0	0,118	2,3	0,134
25	-	-	-	-	-	-	2,0	0,151	2,3	0,173	3,0	0,202
32	-	-	-	-	2,0	0,198	2,4	0,235	3,0	0,282	3,6	0,331
40	-	-	1,8	0,229	2,4	0,299	3,0	0,360	3,7	0,434	4,5	0,514
50	-	-	2,0	0,317	3,0	0,458	3,7	0,555	4,6	0,673	5,6	0,796
63	1,8	0,368	2,5	0,500	3,8	0,728	4,7	0,883	5,8	1,06	7,1	1,27
75	1,9	0,462	2,9	0,683	4,5	1,03	5,6	1,25	6,8	1,48	8,4	1,78
90	2,2	0,647	3,5	0,988	5,4	1,47	6,7	1,79	8,2	2,14	10,1	2,57

110	2,7	0,952	4,2	1,45	6,6	2,19	8,1	2,64	10,0	3,18	12,3	3,82
125	3,1	1,25	4,8	1,86	7,4	2,79	9,2	3,40	11,4	4,12	14,0	4,92
140	3,5	1,56	5,4	2,35	8,3	3,50	10,3	4,26	12,7	5,13	15,7	6,18
160	4,0	2,02	6,2	3,08	9,5	4,57	11,8	5,56	14,6	6,74	17,9	8,04
180	4,4	2,51	6,9	3,83	10,7	5,77	13,3	7,05	16,4	8,51	20,1	10,2
200	4,9	3,08	7,7	4,74	11,9	7,12	14,7	8,65	18,2	10,5	22,4	12,6
225	5,5	3,90	8,6	5,96	13,4	9,03	16,6	11,0	20,5	13,3	25,2	15,9
250	6,2	4,88	9,6	7,38	14,8	11,1	18,4	13,5	22,7	16,3	27,9	19,6
280	6,9	6,04	10,7	9,20	16,6	13,9	20,6	16,9	25,4	20,5	31,3	24,6
315	7,7	7,59	12,1	11,7	18,7	17,6	23,2	21,5	28,6	25,9	35,2	31,1
355	8,7	9,65	13,6	14,8	21,1	22,4	26,1	27,2	32,2	32,9	39,7	39,5
400	9,8	12,2	15,3	18,8	23,7	28,3	29,4	34,5	36,3	41,7	44,7	50,1
450	11,0	15,4	17,2	23,7	26,7	35,8	33,1	43,7	40,9	52,8	50,3	63,4
500	12,3	19,2	19,1	29,2	29,7	44,2	36,8	53,9	45,4	65,2	55,8	78,1
560	13,7	23,9	21,4	36,6	33,2	55,4	41,2	67,6	50,8	81,7	62,5	98,0
630	15,4	30,2	24,1	46,4	37,4	70,2	46,3	85,5	57,2	103	-	-

almona PE100 pressure pipes for water supply networks according to DIN 8074/8075



Material — PE100

Minimum required strength — MRS = 10.0 MPa

Design stress — σs = 6,25 MPa

Design safety factor — C = 1.6 for water

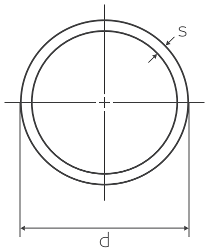
Color — Black
Black with blue stripes

Length — Sizes from 16mm to 32mm are available in coils of 100, 200 and 300 up to 1500 meters. Sizes from 40mm to 160mm are available in coils of 100 meters. larger diameters are available in straight lengths of 12 meters.
Different lengths can be supplied on request.

Nominal Outside Diameter d (mm)	SDR41 S20 PN3,2		SDR33 S16 PN4		SDR13,6 S6,3 PN9,9		SDR11 S5 PN12,5		SDR9 S4 PN15,6		SDR7,4 S3,2 PN19,2	
	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m
16	-	-	-	-	-	-	-	-	2,0	0,092	2,3	0,103
20	-	-	-	-	-	-	2,0	0,118	2,3	0,134	3,0	0,164
25	-	-	-	-	2,0	0,151	2,3	0,173	3,0	0,202	3,5	0,243

32	-	-	-	-	2,4	0,235	3,0	0,282	3,6	0,331	4,4	0,390
40	-	-	-	-	3,0	0,360	3,7	0,434	4,5	0,514	5,5	0,607
50	-	-	1,8	0,290	3,7	0,555	4,6	0,673	5,6	0,796	6,9	0,945
63	1,8	0,368	2,0	0,403	4,7	0,883	5,8	1,06	7,1	1,27	8,6	1,49
75	1,9	0,462	2,3	0,557	5,6	1,25	6,8	1,48	8,4	1,78	10,3	2,12
90	2,2	0,647	2,8	0,800	6,7	1,79	8,2	2,14	10,1	2,57	12,3	3,03
110	2,7	0,952	3,4	1,19	8,1	2,64	10,0	3,18	12,3	3,82	15,1	4,54
125	3,1	1,25	3,9	1,53	9,2	3,4	11,4	4,12	14,0	4,92	17,1	5,84
140	3,5	1,56	4,3	1,09	10,3	4,26	12,7	5,13	15,7	6,18	19,2	7,33
160	4,0	2,02	4,9	2,45	11,8	5,56	14,6	6,74	17,9	8,04	21,9	9,54
180	4,4	2,51	5,5	3,10	13,3	7,05	16,4	8,51	20,1	10,2	24,6	12,1
200	4,9	3,08	6,2	3,88	14,7	8,65	18,2	10,5	22,4	12,6	27,4	14,9
225	5,5	3,90	6,9	4,82	16,6	11,0	20,5	13,3	25,2	15,9	30,8	18,8
250	6,2	4,88	7,7	5,98	18,4	13,5	22,7	16,3	27,9	19,6	34,2	23,3
280	6,9	6,04	8,6	7,47	20,6	16,9	25,4	20,5	31,3	24,6	38,3	29,2
315	7,7	7,59	9,7	9,47	23,2	21,5	28,6	25,9	35,2	31,1	43,1	36,9
355	8,7	9,65	10,9	12,0	26,1	27,2	32,2	32,9	39,7	32,5	48,5	46,8
400	9,8	12,2	12,3	15,2	29,4	34,5	36,3	41,7	44,7	50,1	54,7	59,4
450	11,0	15,4	13,8	19,2	33,1	43,7	40,9	52,8	50,3	63,4	61,5	75,2
500	12,3	19,2	15,3	23,6	36,8	53,9	45,4	65,2	55,8	78,1	68,3	92,8
560	13,7	23,9	17,2	29,7	41,2	67,6	50,8	81,7	62,5	89,0	-	-
630	15,4	30,2	19,3	37,5	46,3	85,5	57,2	103	-	-	-	-

almona PE80 pressure pipes for water supply networks according to DIN 8074/8075

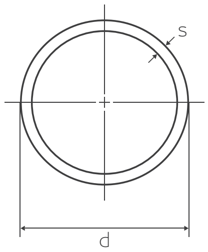


Material	PE80
Minimum required strength	MRS = 8.0 MPa
Design stress	σs = 6,4 MPa
Design safety factor	C = 1.25 for water
Color	Black Black with blue stripes
Length	Sizes from 16mm to 32mm are available in coils of 100, 200 and 300 up to 1500 meters. Sizes from 40mm to 160mm are available in coils of 100 meters. larger diameters are available in straight lengths of 12 meters. Different lengths can be supplied on request.

Nominal Outside Diameter d (mm)	SDR41 S20 PN4		SDR33 S16 PN4		SDR22 S10,5 PN6		SDR13,6 S6,3 PN10		SDR11 S5 PN12,5		SDR9 S4 PN16	
	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m
16	-	-	-	-	-	-	-	-	-	-	1,8	0,084
20	-	-	-	-	-	-	1,8	0,107	1,9	0,112	2,3	0,133
25	-	-	-	-	-	-	1,9	0,144	2,3	0,171	2,8	0,200
32	-	-	-	-	-	-	2,4	0,232	2,9	0,272	3,6	0,327
40	-	-	-	-	1,9	0,238	3,0	0,356	3,7	0,430	4,5	0,509
50	-	-	1,8	0,287	2,3	0,361	3,7	0,549	4,6	0,666	5,6	0,788
63	1,8	0,364	2,0	0,399	2,9	0,563	4,7	0,873	5,8	1,05	7,1	1,26
75	1,9	0,457	2,3	0,551	3,5	0,807	5,6	1,24	6,8	1,47	8,4	1,76
90	2,2	0,643	2,8	0,791	4,1	1,14	6,7	1,77	8,2	2,12	10,1	2,54
110	2,7	0,943	3,4	1,17	5,0	1,67	8,1	2,62	10,0	3,14	12,3	3,78
125	3,1	1,23	3,9	1,51	5,7	2,16	9,2	3,37	11,4	4,08	14,0	4,87
140	3,5	1,54	4,3	1,88	6,4	2,72	10,3	4,22	12,7	5,08	15,7	6,11
160	4,0	2,0	4,9	2,42	7,3	3,54	11,8	5,50	14,6	6,67	17,9	7,96
180	4,4	2,49	5,5	3,07	8,2	4,47	13,3	6,98	16,4	8,42	20,1	10,1
200	4,9	3,05	6,2	3,84	9,1	5,57	14,7	8,56	18,2	10,4	22,4	12,4
225	5,5	3,86	6,9	4,77	10,3	7,00	16,6	10,9	20,5	13,1	25,2	15,8
250	6,2	4,83	7,7	5,92	11,4	8,59	18,4	13,4	22,7	16,2	27,9	19,4
280	6,9	5,98	8,6	7,40	12,8	10,8	20,6	16,8	25,4	20,3	31,3	24,3
315	7,7	7,52	9,7	9,37	14,4	13,6	23,2	21,2	28,4	25,6	35,2	30,8
355	8,7	9,55	10,9	11,8	16,2	17,3	26,1	26,9	32,2	32,5	39,7	39,1

400	9,8	12,1	12,3	15,1	18,2	21,9	29,4	34,1	36,3	41,3	44,7	49,6
450	11,0	15,4	13,8	19,0	20,5	27,7	33,1	43,2	40,9	52,3	50,3	62,7
500	12,3	19,0	15,3	23,4	22,8	34,2	36,8	53,3	45,4	64,5	55,8	77,3
560	13,7	23,6	17,2	29,4	25,5	42,8	41,2	66,9	50,8	80,8	62,5	97,0
630	15,4	29,9	19,3	37,1	28,7	54,1	46,3	84,6	57,2	102	-	-

almona PE80 pressure pipes for water supply networks according to DIN 8074/8075



Material	PE80
Minimum required strength	MRS = 8.0 MPa
Design stress	σs = 5,0 MPa
Design safety factor	C = 1.6 for water Black
Color	Black with blue stripes
Length	Sizes from 16mm to 32mm are available in coils of 100, 200 and 300 up to 1500 meters. Sizes from 40mm to 160mm are available in coils of 100 meters. larger diameters are available in straight lengths of 12 meters. Different lengths can be supplied on request.

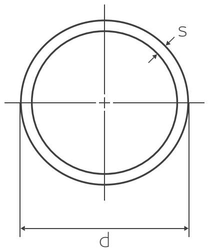
Nominal Outside Diameter d (mm)	SDR33 S16 PN3,1		SDR26 S12,5 PN4		SDR17,6 S8,3 PN6		SDR11 S5 PN10		SDR9 S4 PN12,5		SDR7,4 S3,2 PN15,3	
	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m
16	-	-	-	-	-	-	-	-	1,8	0,084	2,2	0,099
20	-	-	-	-	-	-	1,9	0,112	2,3	0,133	2,8	0,154
25	-	-	-	-	-	-	2,3	0,171	2,8	0,200	3,5	0,240
32	-	-	-	-	1,8	0,179	2,9	0,272	3,6	0,327	4,4	0,386
40	-	-	1,8	0,227	2,3	0,285	3,7	0,430	4,5	0,509	5,5	0,600
50	1,8	0,287	2,0	0,314	2,9	0,440	4,6	0,666	5,6	0,788	6,9	0,936
63	2,0	0,399	2,5	0,494	3,6	0,688	5,8	1,05	7,1	1,26	8,6	1,47
75	2,3	0,551	2,9	0,675	4,3	0,966	6,8	1,47	8,4	1,76	10,3	2,09
90	2,8	0,791	3,5	0,978	5,1	1,39	8,2	2,12	10,1	2,54	12,3	3,0
110	3,4	1,17	4,2	1,43	6,3	2,08	10,0	3,14	12,3	3,78	15,1	4,49
125	3,9	1,51	4,8	1,84	7,1	2,66	11,4	4,08	14,0	4,87	17,1	5,77
140	4,3	1,88	5,4	2,32	8,0	3,34	12,7	5,08	15,7	6,11	19,2	7,25
160	4,9	2,42	6,2	3,04	9,1	4,35	14,6	6,67	17,9	7,96	21,9	9,44
180	5,5	3,07	6,9	3,79	10,2	5,48	16,4	8,42	20,1	10,1	24,6	11,9

200	6,2	3,84	7,7	4,69	11,4	6,79	18,2	10,4	22,4	12,4	27,4	14,8
225	6,9	4,77	8,6	5,89	12,8	8,55	20,5	13,1	25,2	15,8	30,8	18,6
250	7,7	5,92	9,6	7,30	14,2	10,6	22,7	16,2	27,9	19,4	34,2	23,0
280	8,6	7,40	10,7	9,10	15,9	13,2	25,4	20,3	31,3	24,3	38,3	28,9
315	9,7	9,37	12,1	11,6	17,9	16,7	28,6	25,6	35,2	30,8	43,1	36,5
355	10,9	11,8	13,6	14,6	20,1	21,2	32,2	32,5	39,7	39,1	48,5	46,3
400	12,3	15,1	15,3	18,6	22,7	26,9	36,3	41,3	44,7	49,6	54,7	58,8
450	13,8	19,0	17,2	23,5	25,5	34,0	40,9	52,3	50,3	62,7	61,5	74,4
500	15,3	23,4	19,1	28,9	28,4	42,0	45,4	64,5	55,8	77,3	68,3	91,8
560	17,2	29,4	21,4	36,2	31,7	52,5	50,8	80,8	62,5	97,0	-	-
630	19,3	37,1	24,1	45,9	35,7	66,5	57,2	102	-	-	-	-

" ALMONA PROVIDES THE HIGHEST QUALITY POLYETHYLENE PE100 AND PE80 PIPE SYSTEMS FOR THE MOST DEMANDING WATER DISTRIBUTION NETWORKS "

4.3 PE80 and PE63 pipes for irrigation systems

almona PE80 pressure pipes for irrigation systems according to DIN 8074/8075

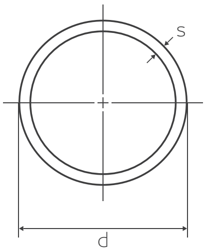


Material	PE80
Minimum required strength	MRS = 8,0 MPa
Design stress	σs = 6,4 MPa
Design safety factor	C = 1,25 for water
Color	Black Black with green stripes
Length	Sizes from 16mm to 32mm are available in coils of 100, 200 and 300 up to 1500 meters. Sizes from 40mm to 160mm are available in coils of 100 meters. larger diameters are available in straight lengths of 12 meters. Different lengths can be supplied on request.

Nominal Outside Diameter d (mm)	SDR41 S20 PN4		SDR33 S16 PN4		SDR22 S10,5 PN6		SDR13,6 S6,3 PN10		SDR11 S5 PN12,5		SDR9 S4 PN16	
	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m
16	-	-	-	-	-	-	-	-	-	-	1,8	0,084
20	-	-	-	-	-	-	1,8	0,107	1,9	0,112	2,3	0,133
25	-	-	-	-	-	-	1,9	0,144	2,3	0,171	2,8	0,200
32	-	-	-	-	-	-	2,4	0,232	2,9	0,272	3,6	0,327
40	-	-	-	-	1,9	0,238	3,0	0,356	3,7	0,430	4,5	0,509
50	-	-	1,8	0,287	2,3	0,361	3,7	0,549	4,6	0,666	5,6	0,788
63	1,8	0,364	2,0	0,399	2,9	0,563	4,7	1,873	5,8	1,05	7,1	1,26
75	1,9	0,457	2,3	0,551	3,5	0,807	5,6	1,24	6,8	1,47	8,4	1,76
90	2,2	0,643	3,4	1,17	5,0	1,67	8,1	2,62	10,0	3,14	12,3	3,78
110	2,7	0,943	4,2	1,43	6,3	2,08	10,0	3,14	12,3	3,78	15,1	4,49
125	3,1	1,23	3,9	1,51	5,7	2,16	9,2	3,37	11,4	4,08	14,0	4,87
140	3,5	1,54	4,3	1,88	6,4	2,72	10,3	4,22	12,7	5,08	15,7	6,11
160	4,0	2,0	4,9	2,42	7,3	3,54	11,8	5,50	14,6	6,67	17,9	7,96
180	4,4	2,49	5,5	3,07	8,2	4,47	13,3	6,98	16,4	8,42	20,1	10,1
200	4,9	3,05	6,2	3,84	9,1	5,57	14,7	8,56	18,2	10,4	22,4	12,4
225	5,5	3,86	6,9	4,77	10,3	7,00	16,6	10,9	20,5	13,1	25,2	15,8
250	6,2	4,83	7,7	5,92	11,4	8,59	18,4	13,4	22,7	16,2	27,9	19,4
280	6,9	5,98	8,6	7,40	12,8	10,8	20,6	16,8	25,4	20,3	31,3	24,3
315	7,7	7,52	9,7	9,37	14,4	13,6	23,2	21,2	28,4	25,6	35,2	30,6

355	8,7	9,55	10,9	11,8	16,2	17,3	26,1	26,9	32,2	32,5	39,7	32,1
400	9,8	12,1	12,3	15,1	18,2	21,9	29,4	34,1	36,3	41,3	44,7	49,6
450	11,0	15,3	13,8	19,0	20,5	27,7	33,1	43,2	40,9	52,3	50,3	62,7
500	12,3	19,0	15,3	23,4	22,8	34,2	36,8	53,3	45,4	64,5	55,8	77,3
560	13,7	23,6	17,2	29,4	25,5	42,8	41,2	66,9	50,8	80,8	62,5	97,0
630	15,4	29,9	19,3	37,1	28,7	54,1	46,3	84,6	57,2	102	-	-

almona PE63 pressure pipes for irrigation systems according to DIN 8074 8075

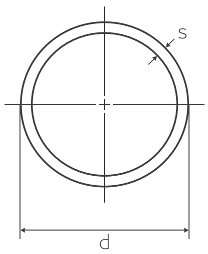


Material	PE63
Minimum required strength	MRS = 6.3 MPa
Design stress	σs = 5,04 MPa
Design safety factor	C = 1.25 for water
Color	Black Black with green stripes
Length	Sizes from 16mm to 32mm are available in coils of 100, 200 and 300 up to 1500 meters. Sizes from 40mm to 160mm are available in coils of 100 meters. larger diameters are available in straight lengths of 12 meters. Different lengths can be supplied on request.

Nominal Outside Diameter d (mm)	SDR26 S12,5 PN4		SDR17,6 S8,3 PN6		SDR11 S5 PN10		SDR7,4 S3,2 PN15,9	
	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m
16	-	-	-	-	-	-	2,2	0,099
20	-	-	-	-	1,9	0,112	2,8	0,154
25	-	-	-	-	2,3	0,171	3,5	0,240
32	-	-	1,8	0,179	2,9	0,272	4,4	0,386
40	1,8	0,227	2,3	0,285	3,7	0,430	5,5	0,60
50	2,0	0,314	2,9	0,440	4,6	0,666	6,9	0,936
63	2,5	0,494	3,6	0,688	5,8	1,05	8,6	1,47
75	2,9	0,675	4,3	0,976	6,8	1,47	10,3	2,09
90	3,5	0,978	5,1	1,39	8,2	2,12	12,3	3,0
110	4,2	1,43	6,3	2,08	10,0	3,14	15,1	4,49
125	4,8	1,84	7,1	2,66	11,4	4,08	17,1	5,77
140	5,4	2,32	8,0	3,34	12,7	5,08	19,2	7,25
160	6,2	3,04	9,1	4,35	14,6	6,67	21,9	9,44

180	6,9	3,79	10,2	5,48	16,4	8,42	24,6	11,9
200	7,7	4,69	11,4	6,79	18,2	10,4	27,4	14,8
225	8,6	5,89	12,8	8,55	20,5	13,1	30,8	18,6
250	9,6	7,30	14,2	10,6	22,7	16,2	34,2	23,0
280	10,7	9,10	15,9	13,2	25,4	20,3	38,3	28,9
315	12,1	11,6	17,9	16,7	28,6	25,6	43,1	36,5
355	13,6	14,6	20,1	21,2	32,2	32,5	48,5	46,3
400	15,3	18,6	22,7	26,9	36,3	41,3	54,7	58,8
450	17,2	23,5	25,5	34,0	40,9	52,3	61,5	74,4
500	19,1	28,9	28,4	42,0	45,4	64,5	68,3	91,8
560	21,4	36,2	31,7	52,5	50,8	80,8	-	-
630	24,1	45,9	35,7	66,5	57,2	102	-	-

almona PE63 pressure pipes for irrigation systems according to DIN 8074 8075



Material	PE63
Minimum required strength	MRS = 6.3 MPa
Design stress	σs = 3,94 MPa
Design safety factor	C = 1.6 for water
Color	Black Black with green stripes
Length	Sizes from 16mm to 32mm are available in coils of 100, 200 and 300 up to 1500 meters. Sizes from 40mm to 160mm are available in coils of 100 meters. larger diameters are available in straight lengths of 12 meters. Different lengths can be supplied on request.

Nominal Outside Diameter d (mm)	SDR21 S10 PN3,9		SDR13,6 S6,3 PN6,2		SDR9 S4 PN9,8		SDR6 S2,5 PN15,7	
	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m	Wall Thickness s (mm)	Weight kg/m
16	-	-	-	-	1,8	0,084	2,7	0,115
20	-	-	1,8	0,107	2,3	0,133	3,4	0,180
25	-	-	1,9	0,144	2,8	0,200	4,2	0,278
32	-	-	2,4	0,232	3,6	0,327	5,4	0,454
40	1,9	0,239	3,0	0,356	4,5	0,509	6,7	0,701
50	2,4	0,374	3,7	0,549	5,6	0,788	8,3	1,09
63	3,0	0,399	2,5	0,494	3,6	0,688	5,8	1,05

75	3,6	0,828	5,6	1,24	8,4	1,76	12,5	2,44
90	4,3	1,18	6,7	1,77	10,1	2,54	15,0	3,51
110	5,3	1,77	8,1	2,62	12,3	3,78	18,3	5,24
125	6,0	2,27	9,2	3,37	14,0	4,87	20,8	6,75
140	6,7	2,83	10,3	4,22	15,7	6,11	23,3	8,47
160	7,7	3,72	11,8	5,50	17,9	7,96	26,6	11,0
180	8,6	4,67	13,3	6,98	20,1	10,1	29,9	14,0
200	9,6	5,78	14,7	8,56	22,4	12,4	33,2	17,2
225	10,8	7,30	16,6	10,9	25,2	15,8	37,4	21,8
250	11,9	8,93	18,4	13,4	27,9	19,4	41,6	27,0
280	13,4	11,3	20,6	16,8	31,3	24,3	46,5	33,8
315	15,0	14,2	23,2	21,2	35,2	30,8	52,3	42,7
355	16,9	18,0	26,1	26,9	39,7	39,1	59,0	54,3
400	19,1	22,9	22,4	34,1	44,7	49,6	66,5	68,9
450	21,5	28,9	33,1	43,2	50,3	62,7	-	-
500	23,9	35,7	36,8	53,3	55,8	77,3	-	-
560	26,7	44,7	41,2	66,9	62,5	97,0	-	-
630	30,0	56,7	46,3	84,6	-	-	-	-

" ALMONA PROVIDES THE HIGHEST QUALITY POLYETHYLENE PE100, PE80 AND PE63 PIPE SYSTEMS FOR IRRIGATION NETWORKS "

Section V

5. Installation

5.1 Installation techniques for buried pipes

Polyethylene pipe systems from almona are designed to make installation faster, easier and more cost effective. One of the main advantages of our systems in installation is their lightness and flexibility, coupled with high durability and totally secure jointing methods. For all modern installation techniques, whether in the rehabilitation or installation of new pipelines and whether the pipelines is to be laid above or below ground, PE80 and PE100 systems from almona often provide the simplest and most economical solution.

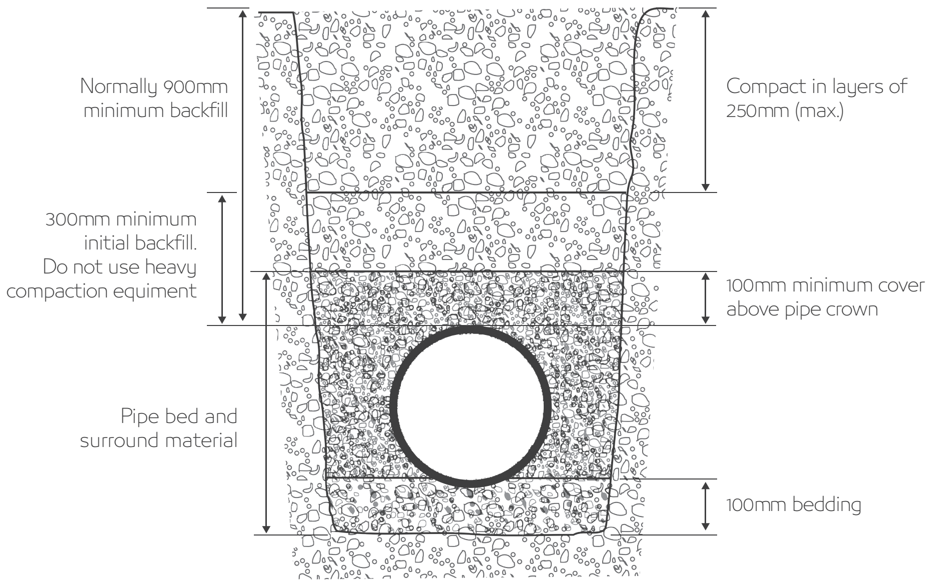
A major advantage of almona PE pipes is that pipe lengths can be butt-fused or electrofusion jointed to form a continuous string of pipe and the need for thrust blocks is eliminated except where connections are made to pipes of other materials. almona PE pipe systems support all methods of conventional and trenchless installation. The most common installation techniques for almona products are described below.

Additional information on all the trenchless technologies in the following text, can be found in the PE100+ Association No - Dig Technical Guide, which can be accessed through the following link.
https://www.pe100plus.com/PE-Pipes/Technical-guidance/r1106.html

5.1.1 Trenching

The dimensions of a trench opening are normally governed by the pipe diameter, method of jointing and site conditions. As previously noted, a major installation advantage of almona PE pipe systems is that lengths can be fused together by butt-fusion to form continuous strings, which usually takes place outside of the trench. Since the need for in-trench jointing is virtually eliminated, the width of excavations can be minimized, resulting in reduced labour cost, less imported backfill material and lower reinstatement costs. The trench shall be dewatered and kept dry during the excavation, pipe laying and backfilling process to ensure that proper installation, placing and compaction of the backfill material takes place.

Normal minimum depth of cover for pipes should be 900mm from ground level to the crown of the pipe, tough this can be reduced to 600mm in exceptional circumstances, where the will be no imposed loads from vehicles. Trench width should not normally be less than the outside diameter of the pipe plus 250mm to allow for adequate compaction of side fill unless specialised narrow trenching techniques are used and/or especially free flowing and easily compacted side materials are employed. Recommended trench dimensions for almona pipe systems are shown below



Where a free flowing rounded single size granular material having a maximum particle size of 10mm and very few fines (pea gravel) is used for the pipe surround trench widths may be reduced to only 100mm greater than the pipe diameter.

Considerable savings in the costs of imported backfill, reinstatement and waste spoil disposal can be made if trench width is minimized. In many cases it may be acceptable to lay PE pipe directly on the bottom of the trench, without a pipe bed, provided that the native soil is a fairly uniform granular material free of any objects having a particle greater than 10% of the pipe outside diameter or 25mm, whichever is smaller. In such cases the bottom of the trench should be levelled off and compacted to a minimum modified Proctor (AASHTO) density of 90% prior to the laying of the pipeline.

In rocky or clay ground conditions the trench should be cut to a depth which will allow for the necessary thickness of imported bedding material to be placed and compacted to a minimum AASHTO density of 90%. A variety of clean dry granular material free from silty and foreign materials may be used for the imported bedding material. These include:

- Freely flowing clean dry sand.
- An evenly graded granular material where the maximum particle size shall not exceed 10% of the pipe outside diameter or 25mm diameter, whichever is the smaller.
- In the case of small diameter pipes such as service connections, an evenly graded granular material with a maximum particle size of 5mm is acceptable.

Once the bed is completed, the pipe, which has generally been welded together beside the trench, shall be laid along its length, taking in to consideration the following points:

- During the laying process the pipe ends should remain covered to prevent the entry of material in to the pipe.
- Care should be taken to ensure that scratching, scoring and abrasion of the pipe surface is kept to a minimum. After installation the pipe should be inspected and any sections having damaged which is deeper than 10% of the pipe wall thickness should be cut out.
- When pipes are pulled as part of the laying process care shall be taken to ensure that the drag force does not exceeding the allowable force as specified in section 6.7 of this document. Pipes should only be pulled when they are supported by roller assemblies and are free of the ground surface to minimise the risk of damage.
- The high flexibility of almona PE pipes allows them to be bent or curved on site down whilst being laid. Such 'cold bending' shall be limited to a minimum bend radius of not be less than 25 times the pipe OD, Where there are space restrictions the bend radius may be reduced down to 20 times the pipe OD, but only with the end users permission.
- No electro-fusion or mechanical joints should be incorporated in the sections of pipework which are to be bent or curved. If such joints need to be used at such points, formed bend or elbows should be included in the pipeline design.

The material placed around the pipe sides and over the crown of the pipe, to a minimum depth of 100mm, is referred to as the pipe surround. After laying of the pipeline the pipe surround material shall be placed evenly on both sides of the pipe, ensuring that no cavities are left between the underside of the pipe and the trench bottom or pipe bed. The pipe surround material shall be placed in layers of no more than 150 mm thick and compacted with hand tools across the width of the trench to achieve a minimum AASHTO density of 90%.

The pipe surround material shall generally meet the same requirements as that for the bed material. The exception shall be in the case of when the pipeline is laid across or allow major roads or when it will be subjected to heavy traffic loads. In this case, imported surround material shall always be used and if possible the compaction shall be to 95% AASHTO density to maximise the support to the pipe and minimise the degree of settlement in the finished surface.

The backfill material above the pipe surround shall generally comprised selected excavated material from which foreign objects such as construction waste and large hard objects have been removed. It shall be compacted in layers having a maximum depth of 250mm to achieve a minimum AASHTO density of 90%. Heavy compaction equipment should not be used until the fill over the crown of the pipe is at least 300mm.

In the case of major road crossings and other heavily trafficked areas, the designer may decide to carry on with the imported pipe surround material to the underside of the pavement, in order to minimise the degree of settlement in the finished surface.

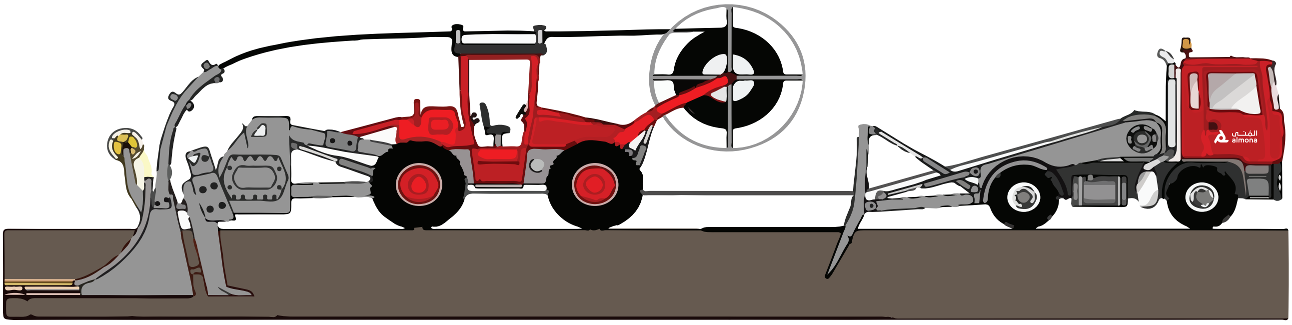
Where the native soil comprises clay, excavated material should be kept as dry as possible after excavation and broken up by rotovating prior to backfilling, to ensure that the maximum particle size is no greater than 10% of pipe diameter or 25mm, whichever is the smaller.

5.1.2 Impact moling

Impact moling is cost efficient method for the trenchless installation of smaller diameter pipes. Traffic restrictions are often unnecessary and the cost of excavation, backfill and reinstatement is virtually eliminated. The only excavation is for launching and reception pits at each end of the installation, in order to accommodate the mole and its ancillary equipment. The impact mole drives a borehole between the two pits, in most cases leaving the ground surface undisturbed. A sacrificial liner is sometimes attached to the mole and pulled along behind it. The PE pipe can be pulled directly behind the mole or through a liner, if this is used. Installation damage to the PE pipe, in the form of scratching and scoring of the outer surface, varies greatly depending on the ground conditions. In the case of rocky conditions it is recommended that a thin walled sacrificial liner is used to minimise the risk.

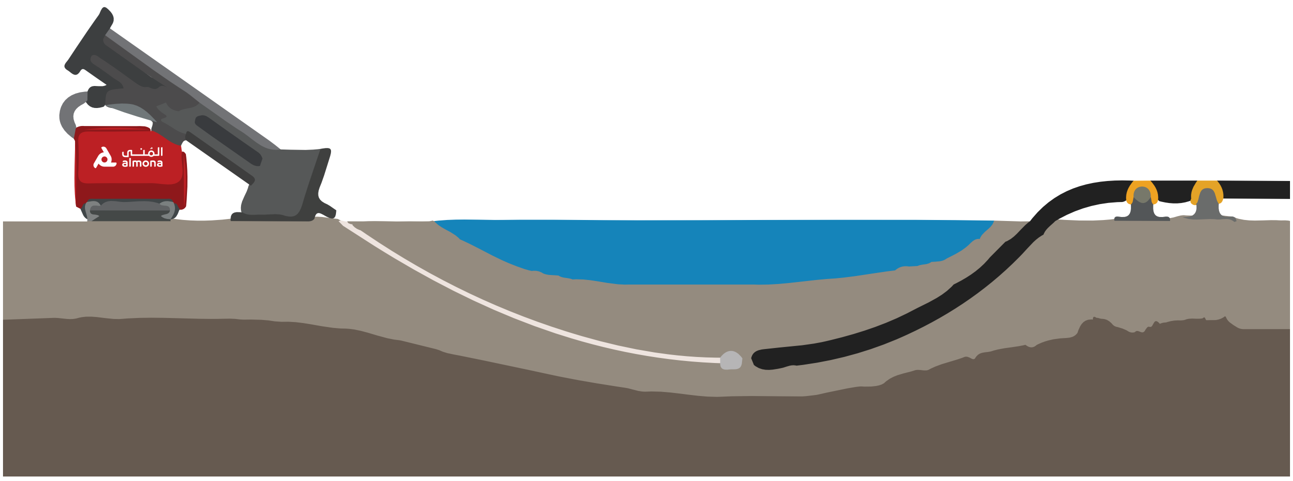
5.1.3 Mole ploughing

This technique was originally developed for laying land drainage and adapted for installation of gas and water pipes in rural areas. It enables pipelines to be laid across rural landscapes with minimum disruption to agriculture, whilst the ground surface can also be quickly reinstated to almost its original condition. The installation equipment generally comprises a winch vehicle that pulls the plough undertaking the installation, though in the case of very small pipes a self powered plough vehicle can be used. A new PE pipe string is literally ploughed into the ground at depths of up to 2m and installation rates can exceed 2km per day, even which laying pipes of up to 355mm OD.



5.1.4 Horizontal Directional drilling

This is an installation technique that was originally developed for the drilling of oil and gas wells; but is now increasingly used for PE pipelines. It allows pipelines to be installed under roads and rivers etc. with minimal excavation work. The technique involves drilling a pilot hole under an obstacle ,reeming the hole to increase the diameter and then pulling the pipeline back through an enlarged hole from the far side.



The installation steps are as follows:

Stage 1. A small diameter 'pilot hole' is drilled from one side of the obstacle to the next by a drill head attached to the pilot string of drill pipes. Depending on the ground conditions a wide variety of pilot heads can be used. Some as designed for silty or granular conditions and primarily use jets of high pressure drilling mud to cut their way through the soil, whilst harder materials may require the use of drill bits driven by mud motors.

The drill head is steered by using a flexible joint close to the head which is moved by manipulation of the jets or by thrust force on the end of the drill string. A transmitter in the head sends signals to the surface and these are received by a hand-held locator which displays both the lateral position and depth of the head, allowing its tracing and guidance.

Stage 2. An enlarged hole is gradually bored using larger and larger reeming tools which use similar cutting and directional control technologies to the pilot drill heads. At all times the drill hole is filled with a constantly circulating bentonite drilling mud solution which provides lubrication, removes cuttings from the drill hole and prevents it from collapsing.

Stage 3. Once the reaming process has been completed and the drill hole has reached the required diameter, a reverse barrel reamer is attached to the dill pipes and this in turn is connected to the PE pipe string. The reamer is then used to pull the PE pipe string through the drill hole whilst ensuring than any debris is removed from in front of the pipe string and that the drill hole is large enough to accommodate the pipe string. In the case of small pipe diameters stages 2 and 3 can sometimes be combined.

One advantage of modern horizontal drilling technologies is that they can be used to install PE pipes of up to 1200mm OD and lengths of up to 2km. One key restriction is the pulling stress that can be applied to the pipe string whilst it is being pulled through the drill hole. Tensile loading measuring devices, fitted to the pipe are however now available to ensure that the pipe is not overstressed during the installation process.

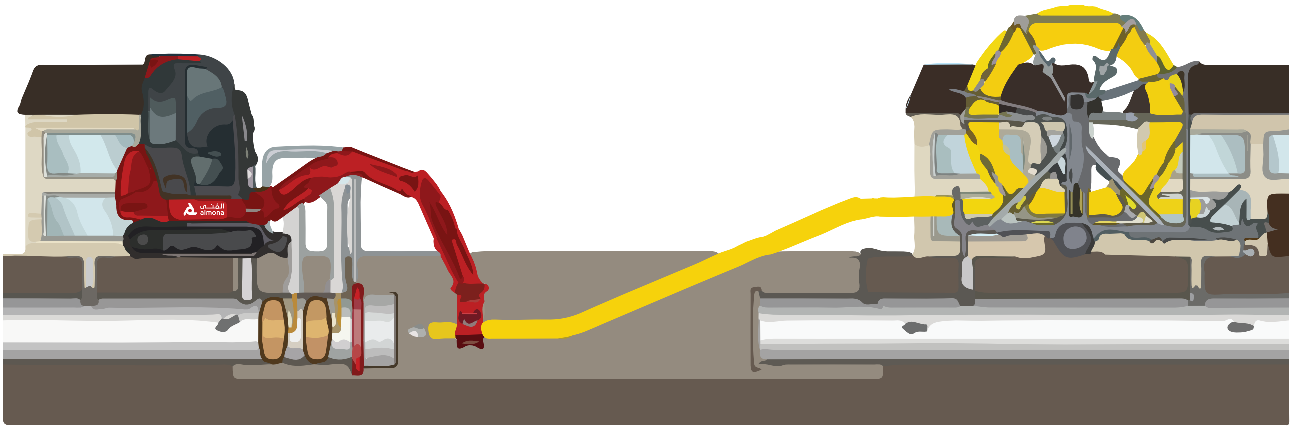
> "ALMONA POLYETHYLENE PIPE SYSTEMS ARE DESIGNED TO MAKE INSTALLATION FASTER, EASIER AND MORE COST EFFECTIVE"

5.2 Rehabilitation and renovation techniques

5.2.1 Slip lining/Insertion

In slip-lining or insertion, a replacement PE pipe string of smaller size is inserted into an existing decommissioned pipeline.

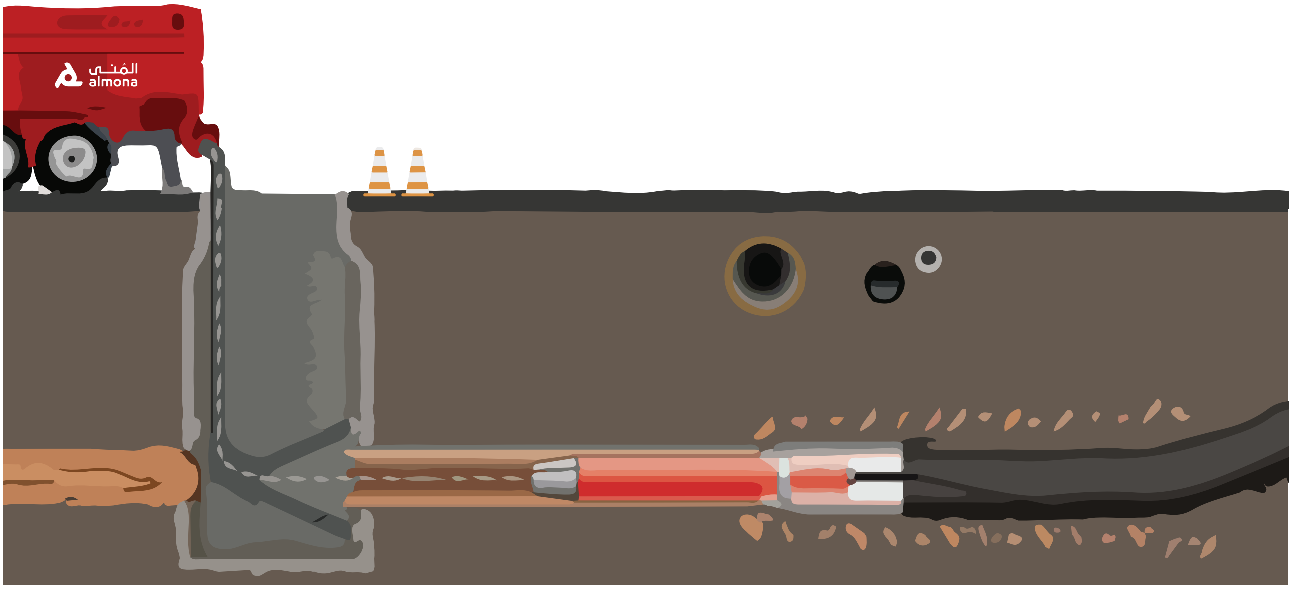
Though some reduction in flow capacity is inevitable, this can be minimised by careful preparation and cleaning of the old pipe so that the largest possible diameter of new PE pipe can be inserted. In many instances an average annular clearance of as little as five per cent of the existing pipe internal diameter, even less still for sizes above 300mm, has proven adequate where pipelines are reasonably straight and of uniform bore. In pressure pipelines the reduction in carrying capacity can also be compensated for by the smooth inner surface and hence improved flow performance of the PE liner. Gravity sewer and storm water drainage applications benefit from the prevention of ground water from entering the system.



5.2.2 Pipe bursting or splitting

This group of techniques is generally used in size-for-size replacement of existing pipelines, though it can be used for some limited upsizing of existing pressure and gravity pipelines. With this technique an existing main is either cracked or split open by a breaking head and the bore simultaneously expanded by a mole, allowing a flexible PE pipe to be pulled in behind the mole.

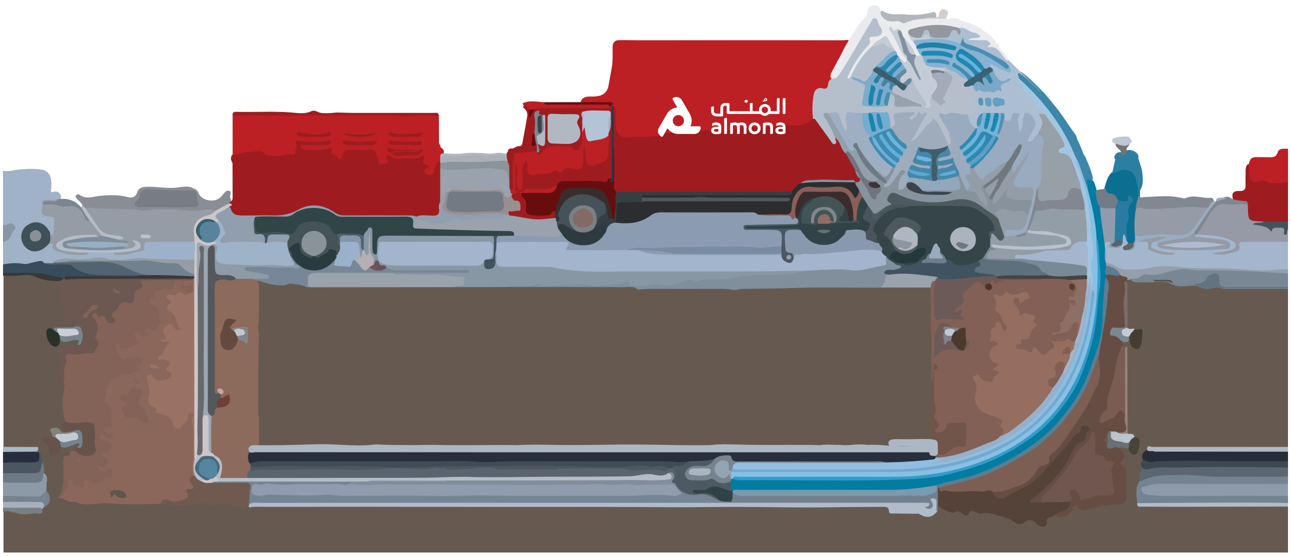
The design of the head and mole depends on the existing pipe material. Relatively brittle materials can be burst using moles that have simple cutting heads, whilst more demanding materials may require heads that have an air hammer to provide shock effect. Flexible materials such as plastic and steel are generally split open by a head that makes use of cutting blades or rotating discs. The most demanding materials might require the use of heads with hydraulically expanding segments. These can crack and open out existing pipes and even deal with items such as repair collars or concrete surrounds.



5.2.3 Close-fit insertion systems

Close-fit systems offer two major advantages. They never require grouting and in most cases, even though there is a slight reduction in pipe diameter, the smooth inner surface and hence improved flow performance of the almona liner enables flow capacity to be increased.

If the existing pipeline is structurally unsound, fully structural close-fit PE liners that are designed to take the full operating pressure can be used. For pipelines that are strong but leaking, PE down to SDR33 can be considered. With a 50-year minimum life and exceptional gap-bridging performance, thin-walled PE linings provide a cost-effective sealing membrane that is totally reliable.



The two principal options are the use of concentrically reduced liners and folded liners. In the first case, a PE liner having an outside diameter slightly larger than the inner diameter of the host pipe is drawn through a diameter reduction die or set of hydraulically powered rollers to temporarily reduce its diameter by approximately 10%. The reduced diameter liner is then pulled through the host pipe, whilst being kept under tension. Once installed the winch cable and pulling head are removed and with the release of the tension, the memory effect of the PE material causes the liner to try and slowly return to its original diameter, providing a tight fitting liner to the host pipe.

In the second case a folded PE liner, having the same outer diameter as the inner diameter of the host pipe is pulled through the host pipe and then expanded to create a tight fitting liner. Fully structural thick walled liners generally have to be folded at the manufacturer's factory, as part of the extrusion process. These are then transported to site on large drums ready for installation. Thinner non-structural liners can be folded on site as less force is required and the liner experiences lower stress levels during the folding process.

After installation a close-fit lining can be joined to other PE pipes through the use of electrofusion joints, providing that the pipe outside diameter and liner wall thickness are suitable. In many cases however mechanical joints such specialized 'liner grip' flange adaptors or couplings are used as installation conditions can make high quality fusion jointing difficult.

5.3 Above Ground Installation

5.3.1 Above ground supported installation

Design of exposed above ground almona PE pipework must take full account of the effect that temperature variations have on PE pipe systems, especially thermal movement, as described in section 3.4 of this catalogue. This shall involve support systems that either resist or accommodate thermal stresses movement over the temperature range to which the pipe system will be subjected. It should be emphasized that the surface temperature of black PE pipe systems exposed to sunlight can be considerably higher than the ambient temperatures in the surrounding air. It is the surface temperature, together with the temperature of the liquid being carried by the pipeline that should be taken in to account when calculating thermal movement and stresses.

Where practical the arrangement of the PE pipeline and its supports should be arranged to allow the free movement of pipeline. As with above ground steel pipelines this usually involves the building in expansion loops and bends or flexible arms at regular intervals and lining the interface between the PE pipes and concrete supports with a smooth plastic liner than is built in to the concrete support. Such a design reduces the friction between the pipe and support together with eliminating any rubbing that can lead to abrasion of the outer pipe surface

Where thermal movement of almona PE pipes cannot be accommodated support and anchors must be designed to take account of the full annual variation in surface temperatures. In desert conditions away from a coastline a temperature range of at least 60°C is commonly used with some designers adopting a conservative value of 80°C.

5.3.2 Support of above ground pipework

Above ground pipework is usually supported on concrete or steel pipe supports when supported from below or by a variety of metallic or even plastic (for small diameter) pipe brackets and hangers when supported from above or off a vertical structure.

The width of such supports varies greatly but in the case of concrete saddles it is typically around half the pipe outer diameter, except for very small diameters where the width will be closer to the pipe diameter. Where pipe clips are used to ensure that pipes remain on concrete supports they should have flat, non-abrasive contact faces or be lined with plastic or rubber sheeting and should not be over-tightened, so as to allow for thermal movement.

In the case of steel pipe brackets and hangers, designers should refer to section 5.7 of DVS Technical Code 2210-1.

The spacing of pipe supports depends on several factors including the pipe dimeter, wall thickness, material stiffness at different operating temperatures and acceptable level of pipe deflection at the mid-point.

Outside Diameter DN	Spans (L_A) in mm at Pipe Wall Temperature (T_R)				
	20°C	30°C	40°C	50°C	60°C
16	500	450	450	400	350
20	575	550	500	450	400
25	650	600	550	550	500
32	750	750	650	650	550
40	900	850	750	750	650
50	1050	1000	900	850	750
63	1200	1150	1050	1000	900
75	1350	1300	1200	1100	1000
90	1500	1450	1350	1250	1150
110	1650	1600	1500	1450	1300
125	1750	1700	1600	1550	1400
140	1900	1850	1750	1650	1500
160	2050	1950	1850	1750	1600

Outside Diameter DN	Spans (L_A) in mm at Pipe Wall Temperature (T_R)				
	20°C	30°C	40°C	50°C	60°C
180	2150	2050	1950	1850	1750
200	2300	2200	2100	2000	1900
225	2450	2350	2250	2150	2050
250	2600	2500	2400	2300	2100
280	2750	2650	2550	2400	2200
315	2900	2800	2700	2550	2350
355	3100	3000	2900	2750	2550
400	3300	3150	3050	2900	2700

The above table is based on Table 13 of DVS Technical Code 2210-1 and gives guidance on the spacing of supports to SDR17 PE100 pipes of different diameters at a range of temperatures, where the deflection is not to exceed 0.2% of the pipe span. Should the design make us of SDR11 pipes the span lengths may be increased by 7%.

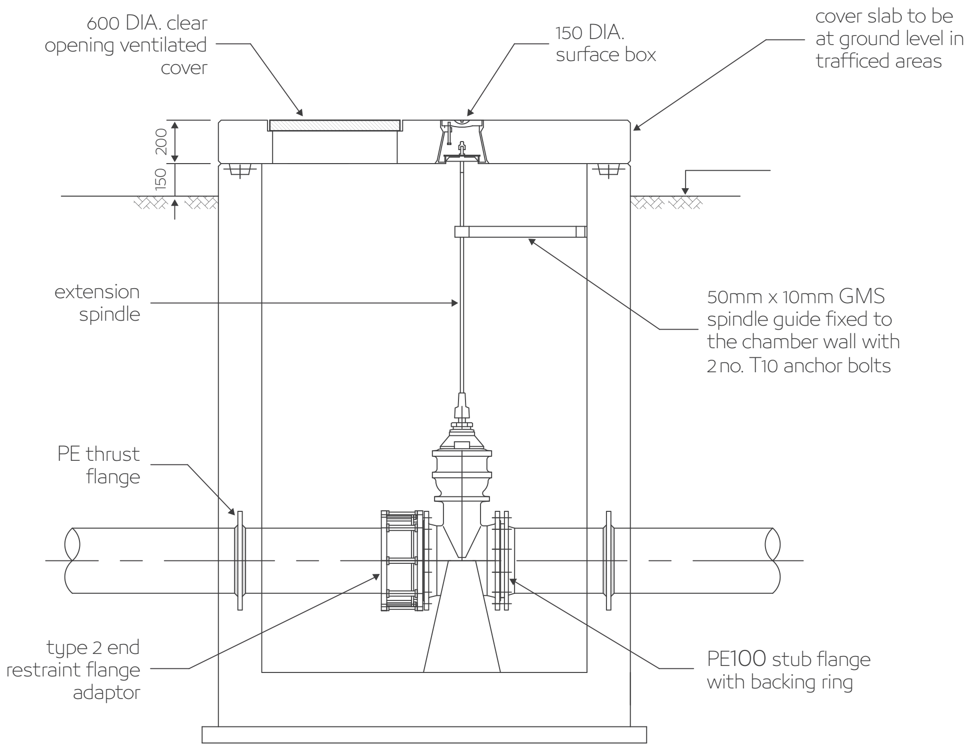
5.4 Entry to structures

5.4.1 Anchoring of pipes at the entry to structures

When almona PE pipelines comprise continuously jointed pipes and fittings the pipeline can take all the operational stresses at their rated pressure. There is therefore no need to provide anchoring of the PE pipeline at the entry and exit from structures, from a structural design requirement. If, however there is a break in the restrained continuity of the pipeline, perhaps through the use of an unrestrained joint inside a chamber, then the pipeline should be anchored at the point where it enters and exits from the structure.

Structural anchoring of pipes where they pass through a chamber wall, for example, requires the use of a fully rated thrust flange. Such fully rated fittings should be homogeneous and either machined from an extruded PE100 solid bar or produced as an injection moulded fitting.

An example of a flange arrangement is shown in the following diagram. Please note that the chamber walls must be designed to withstand the punching shear that will be generated by the thrust flange.



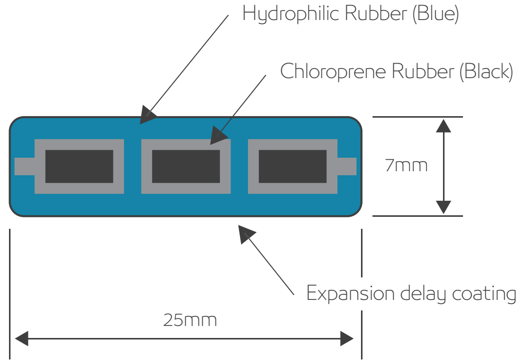
5.4.2 Waterproofing the points where pipes enter structures

The smooth surface of PE pipes and fittings mean that they do not readily bond to concrete and often provide an entry point for ground water in to structures. almona recommend three steps that can be taken to improve the waterproof properties of such entry points:

a. The surface of the pipe and fittings that will be in contact with the structure wall should have their surface roughened with a stiff wire brush prior to being installed, with the aim of improving the bond between the smooth plastic surface and surrounding concrete.

b. Providing a thrust flange in the centre of the wall, even if this is not required for structural reasons, can be used to extend the length of the path that any water will travel along to enter the chamber and hence reduce the risk of leakage.

c. The wrapping of hydrophilic strips around the pipe or fitting, next to the exterior face of the thrust flange has proven to be an effective measure in preventing leakage of ground water in to structures. Such strips can typically expand between 2 and 3 times their original thickness when in contact with water, providing a tight seal around the pipe. A typical example of such a system, Hydrotite, is shown below. The latest easy to apply development in such materials are sealant gun applied versions, such as Hydrotite Leakmaster



Before expansion

After expansion

5.5 Embankment Installation

Where pipes are to be installed above the existing ground level in an embankment, the construction shall be of a suitable granular material that shall be compacted in layers of no more than 150mm thickness and to a minimum modified Proctor (AASHTO) density of 90%. The embankment shall first be constructed to its full height and then a trench excavated in the top of the embankment and the pipe laid in the conventional manner. The embankment shall not be built up around the pipe as the high degree of compaction required to construct a stable embankment carries a high risk of damaging the pipe.

5.6 Towing Loads

Long PE pipe strings are often created when installing pipes and liners using trenchless technology applications or when installing underwater pipelines such as intakes, outfalls and channel crossings. When the pipe is placed on rollers the degree of friction can be kept to a minimum and it is possible to pull PE100 pipe strings of over 1 km in length under the right conditions. Nowadays, PE80 pipes are not used for such spplications.

The following table, which is extracted from "Trenchless Technology for Installation of Cables and Pipelines" by Dr Dietrich Stein gives guidance on the maximum tensile load which should be applied SDR17 and SDR11 PE100 pipes at temperatures of 20°C and 40°C. This should be the maximum surface temperature of the PE100 pipe during the installation process. Almona can provide guidance on maximum allowable loads at higher temperatures.

PE100 Pipe Outside Diameter (mm)	SDR17 Max tensile force at 20°C (kN)	SDR17 Max tensile force at 40°C (kN)	SDR11 Max tensile force at 20°C (kN)	SDR11 Max tensile force at 40°C (kN)
25	1.1	0.7	1.6	1.1
32	1.7	1.2	2.7	1.9
50	4.2	2.9	6.5	4.5
63	6.7	4.7	10	7.2
90	14	9.5	21	15
110	20	14	31	22
125	26	18	41	28
160	43	30	66	47
180	55	38	84	59
200	67	47	104	73
225	85	60	131	92
250	105	74	162	114
280	132	92	204	142
315	167	117	258	180
355	212	149	327	229
400	269	189	415	291
450	341	239	526	368
500	421	295	649	454
560	529	370	814	570
630	668	468	1030	721
710	849	594	1309	916

"ONE OF THE MAIN ADVANTAGES OF ALMONA SYSTEMS IN INSTALLATION IS THEIR LIGHTNESS AND FLEXIBILITY, COUPLED WITH HIGH DURABILITY AND TOTALLY SECURE JOINTING METHODS"

Section VI

6. Jointing

Almona PE pipe systems are relatively simple to joint and install. The most common jointing methods are fusion (butt-fusion and electrofusion) and mechanical (compression, stub flanged and restrained transition) joints.

Both butt-fusion and electrofusion require the use of specialist equipment and certified operators to carry out field jointing. Fusion equipment can either be purchased or hired from manufacturers and detailed product literature is available together with familiarization courses to ensure correct use of the machinery. Operators should have successfully passed a dedicated training course, which can be organized via almona either at its customer training facility or at the customer's premises. For more information, please contact almona.

Modern butt and electrofusion machines are largely automatic, reducing the risk of operator error and providing a detailed record for Quality Assurance of site welding. The type of joint that is preferable in each case depends on many factors, but the following is presented as a guide.

- PE pipes and fittings of 90mm OD and above shall joined by butt fusion whenever practical.
- PE Pipes and fittings of less than 90mm OD shall be joined together using electro-fusion couplings and fittings whenever practical.
- Electro-fusion fittings may also be used to undertake repairs and install off-takes or connections on existing pipelines. They may also be used for the joining together of pipe strings where it is not practical to use a butt fusion welding machine.
- To join PE pipes to metal pipes and fittings such as valves, restrained mechanical transition fittings and stub flanges shall be used.
- Compression joints and fittings may also be used to join together small diameter service connection pipework
- In remote areas, where it may not be practical to undertake fusion jointing, compression joints and fittings may be used for PE pipe sizes of up to 110mm outside diameter (OD).

6.1 Fusion welding equipment requirements

All fusion welding machines and equipment should comply with the requirements of DVS 2208-1, Welding of thermoplastics: Machines and devises for the heated tool welding of pipes, pipe parts and panels and the relevant part of ISO 12176, Plastics pipes and fittings — Equipment for fusion jointing polyethylene systems.

As a minimum, all machines should undergo a yearly service, calibration and function test, carried out by a service centre authorized by the machine manufacturer.

All butt fusion welding machines should be of a fully or semi-automatic design where the welding machine determines, measures and controls the welding parameters such as force, time and temperature, based on the pipe and fitting details entered by the operator. They should include a data logging function that measures and records data listed in DVS 2208-1.

For the purposes of this document, a semi-automatic butt fusion machine shall be defined as one which operates the movement of the clamping device on the machine carriage automatically. A fully-automatic butt fusion machine shall be defined as one which, in addition to the above, also operates the movement of the heating element automatically.

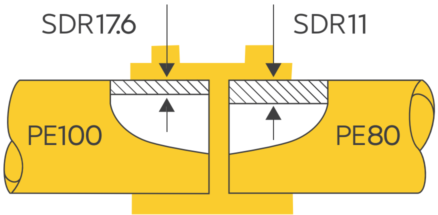
All electrofusion welding machines shall incorporate data input using a bar code reader pen or scanner and a data retrieval facility to allow historical fusion data to be exported to an external computer or memory stick.

6.2 Fusion welding equipment requirements

Butt-fusion jointing involves the fusing together of two pipe or fitting ends in a specialist machine which prepares the pipe ends, heats and then brings them together under pressure to form a homogeneous fusion joint. The joint is fully end-load resistant and is at least as strong as the parent pipe. Butt-fusion has the advantage that it does not require the use of specialist fittings.

With butt-fusion only pipes of the same OD and SDR, i.e. the same wall thickness can be jointed, whereas electrofusion fittings can be used to join pipes of the same OD but different SDRs.

When welding almona PE100 and PE80 pipes this is only possible when the pipe material melt flow characteristics are similar.



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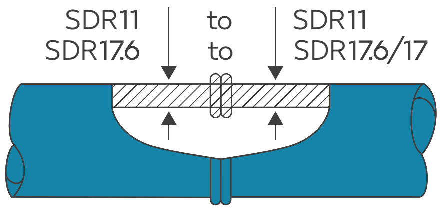

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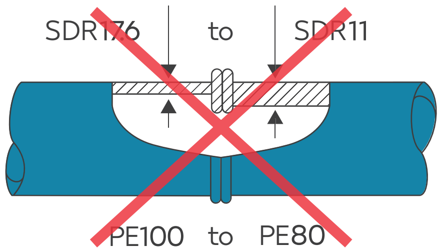

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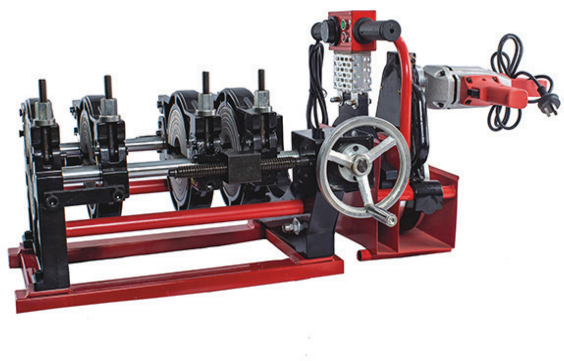
6.2.1 Butt-fusion equipment description

The main body of the equipment is a clamping unit or carriage, with adjustable gripping collars, consisting of a static and moving parts. The pipe ends are gripped in the clamping collars and moved towards or away from each other. The interconnected hydraulic pump provides the motive force for the axial movement. A rotating plane device and a heating element complete the basic parts of the butt-fusion equipment. The pump, plane and heating element are all normally powered by electricity and so a supply, generally from a site generator, is required.

The rotating plane is used for the preparation of the pipe ends with the aim of removing any oxidised, dirty or contaminated material from both pipe ends, together with making sure that the ends are smooth and parallel ready for the fusion process.

The heater plate or fusion mirror is the equipment responsible for transferring the energy to the pipe that is required to melt the pipe ends and so allow fusion to take place. After removal of the heater plate it is the carriage that brings the ends together and so allows fusion to take place. The heater plate temperature should be 220°C ± 10°C.



6.2.2 Step by step overview of the butt-fusion jointing process

In addition to the steps described below, the butt-fusion process should comply with the requirements of the following standards:

- DVS 2207-1, Welding of thermoplastics Heated tool welding of pipes, pipeline components and sheets made of PE-HD.
- ISO 21307, Plastics pipes and fittings — Butt fusion jointing procedures for polyethylene (PE) pipes and fittings used in the construction of gas and water distribution systems.

1. Check all the equipment (including the generator) is in working condition and that welding equipment is shaded from the sum and protected from the wind by means of a tent or similar shelter.
2. Clean the pipe around the joint surface, check the heater plate for any residue or dirt and clean both sides. Cleaning should be undertaken using lint free cloths and a solvent, normally 99% ethanol and 1% MEK, that will 100% evaporate almost immediately.
3. Place the pipes in the butt fusion machine clamps and align them using external support rollers and by adjusting the carriage clamps.
4. Place the planer between the pipe ends. Start the planer and bring the pipe ends on to the face of the tool until continuous shavings (swarf) are cut from each pipe end.
5. Release the pressure slowly with the planer still running to prevent a step forming in the pipe end. Then turn off and remove the planer.
6. Remove the swarf without touching the pipe ends and again bring the pipes together to check alignment and that the pipe ends are parallel.
7. When using a manual butt fusion machine measure the drag force and add this to the required welding pressures given in tables. With automatic machines this compensation will take place automatically.
8. Read the heater plate temperature on the machine display and check using a hand held device. If within tolerance place it between the pipe ends.
9. Bring the pipe ends up to the heater plate and increase the pressure until the welding pressure plus the drag pressure is reached.
10. Once the bead up time has elapsed and a continuous weld bead has formed on both pipe ends release the pressure down to the heat soak pressure, which is between 0 and the drag pressure.
11. Allow the heat to soak into the pipe ends for the full heating time appropriate for the wall thickness of the pipe.

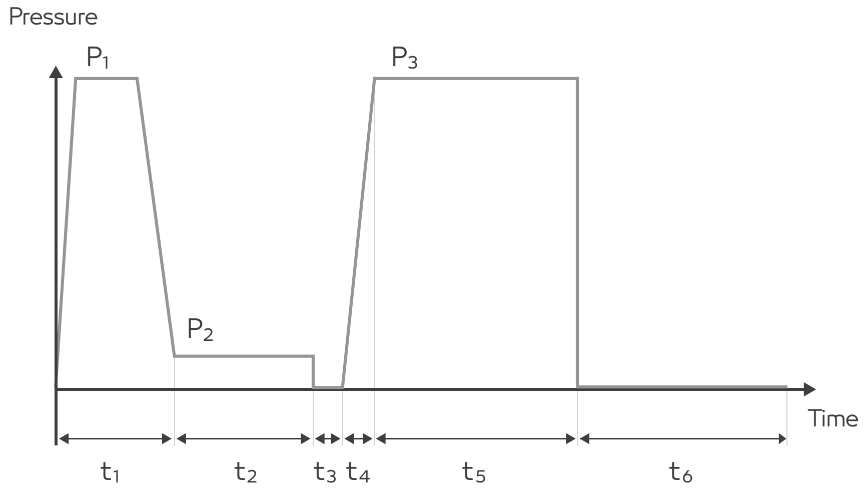
12. When the heat soak time is complete move the pipe ends apart from either side of the heater plate, remove the heater plate and then immediately bring the pipe ends together, increasing the pressure until the jointing pressure is achieved.

13. Maintain the jointing pressure for the prescribed cooling period and then the assembly can be carefully removed from the clamps. The joint should not be handled excessively until the total cooling time is reached.

6.2.3 Butt-fusion welding parameters

The heater plate temperature should be 220°C ± 10°C.

The fusion operation is carried out in clearly defined steps as listed above, whilst the time and pressure parameters comply with the following profile and table, unless otherwise advised by the welding machine manufacturer. All the parameters must be recorded.



P_1: fusion (jointing) pressure (generally 0.15 N/mm^2 + drag pressure)
P_2: maximum heat soak pressure (generally ~0.01 N/mm^2 + drag pressure)
t_1: bead up or alignment time (seconds)
t_2: heat soak time (seconds)
t_3: plate removal / changeover (maximum) time (seconds)
t_4: jointing pressure build-up (ramp) time, in seconds (nominal)
P_3: cooling pressure (generally 0.15 N/mm^2 + drag pressure)
t_5: cooling time in the machine (minutes)
t_6: cooling time out of the machine (minutes)

Fusion pressure is applied until the weld bead has reached the height as given in the fusion tables (usually 2-3 mm) is formed, whilst the heat soak pressure is much lower, to ensure that the heat is being absorbed in to the pipe ends, without creating an excessively large weld bead.

The time (t3) taken to remove the heater plate and then bring the pipe ends together should be as short as practical, as should the time (t6) taken to increase the pressure up to P3. This is to avoid the risk of getting a 'cold joint' that will be weak and could fail in a brittle manner.

The cooling figures given in the following table are based on an ambient temperature of between 15 and 25°C. If the ambient temperature is above 25°C the cooling periods should be extended. ISO 21307 recommends that the extension should be 1% per °C above 25°C.

Cooling time requirements out of the machine (t6) vary between end users, but in absence of any official requirement they can be taken as equal to t5.

In the event that butt-fusion machine manufacturer does not provide details of the welding parameters to be used with their machine, almona recommends that the following parameters, which are taken from DVS 2007-1, are followed.

Nominal wall thickness **(mm)**	**Bead height** **(mm)**	**Heat soak time** t_2 (= 10 x wall thick in mm) **(seconds)**	**Change time** t_3 **(seconds)**	**Ramp time** t_4 **(seconds)**	**Cooling time** t_5 **(seconds)**
≤ 4.5	0.5	45	5.0	5.0	5.0
4.5 … 7	1.0	45 … 70	5 … 6	5 … 6	6 … 10
7 … 12	1.5	70 … 120	6 … 8	6 … 8	5.0 … 7.5
12 … 19	2.0	120 … 190	8 … 10	8 … 11	12 … 18
19 … 26	2.5	190 … 260	10 … 12	11 … 14	18 … 24
26 … 37	3.0	260 … 370	12 … 16	14 … 19	24 … 34
37 … 50	3.5	370 … 500	16 … 20	19 … 25	34 … 46
50 … 70	4.0	500 … 700	20 … 25	25 … 35	46 … 64

6.2.4 Finishing off

After removal from the butt-fusion machine the joint number, date and welder identification code should be permanently marked on the pipe beside the joint. This is normally undertaken using a permanent white paint type marker pen.

A regular symmetrical double bead should be present all the way around the pipe circumference. The bead shape gives a first indication as to the uniformity of the fusion joint. Different bead shapes may be caused by the different flow properties of the materials being joined.

A useful quality control measure is to remove the exterior bead using the proper specialist tool and to then twist the bead at several points along its length. The bead should also be bent back and the portion that was in contact with the pipe be examined for any signs of contamination. If the bead splits whilst being twisted or if any contamination is detected the joint should be cut out and re-made.

If deemed necessary, the internal bead may be removed with the aim of minimizing any disturbance to the flow in the pipeline. However, the effect is minimal and so this step tends to be undertaken only when the pipeline is going to carry a slurry, where turbulence can cause greater erosion of the pipe surface.

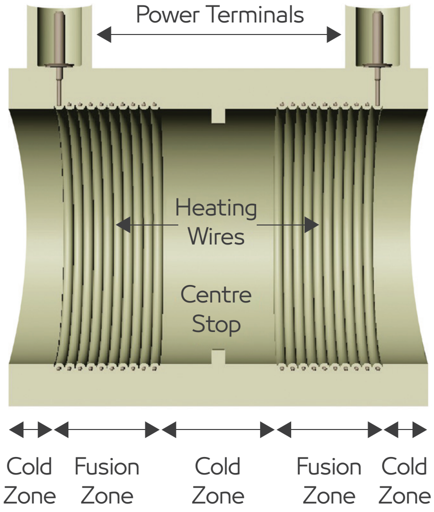
6.3 Electrofusion equipment description

This method of jointing makes use of special electrofusion fittings that incorporate electrical resistance wires which heat when an electrical current is passed through them. The fittings can couplers, bends, reducers, tees, and tapping saddles which are generally manufactured using an injection moulding based process.

When energised, the heat from the wires melts the polymer on the inside surface of the fitting and outside surface of the pipe that lies within the fusion zone. When the PE initially melts, it expands and fills the gap between the pipe and the fitting. As the fusion process continues the pressure rises within the fusion zone and this causes the PE to flow sideways until it reaches the cold zones where it cools and solidifies. This effectively seals the fusion zone which causes the full melt pressure to be generated and fusion to take place. It is the melt pressure that also pushes up the fitting fusion indicators.

The fusion process is powered and controlled by an electrofusion welding machine, which itself is powered by either an onsite electrical generator or mains power supply. Modern welding machines are robust self-contained units that use bar code scanners and pens for data input and take in to account ambient temperatures when calculating fusion parameters. Some also measure and record the GPS coordinates of each fusion joint.

It should be emphasized that excessive pipe ovality can frequently cause the failure of electrofusion joints as it can lead to gap between the pipe and fitting being too wide for the melted polymer to fill effectively. Ovality should not exceed 1.5% of the pipe outside diameter and any excessive ovality should be corrected using rerounding clamps.



6.3.1 Step by step overview of the electrofusion jointing process

In addition to the steps described below, the electrofusion process should comply with the requirements of the following standards:

DVS 2207-1, Welding of thermoplastics Heated tool welding of pipes, pipeline components and sheets made of PE-HD.

1. Check all the equipment (including the generator) is in working condition and that welding equipment is shaded from the sum and protected from the wind by means of a tent or similar shelter.
2. Connect the welding equipment to the mains or the AC generator and check proper function.
3. Deburr and smooth of the inner and outer edges of the pipe ends and make sure that they are at right angles to the pipe length.
4. Ensure the roundness of the pipes using rounding clamps, if required. Maximum ovality should not exceed 1.5% of the pipe outside diameter, to a maximum of 3mm.
5. Check that any conical reduction in diameter at the ends of the pipe (toe in) does not extend to the area that will be in contact with the electrofusion fitting fusion zone. If so, cut the pipe a little shorter.

6. Mark the depth of the pipe ends that will be inserted in to the electrofusion joint as this is the area that will be cleaned and have an outer layer removed.

7. Clean the joint surface in the weld area and beyond using a cleaning solvent and lint free cloth. The solvent should be normally 99% ethanol and 1% MEK, that will 100% evaporate almost immediately.

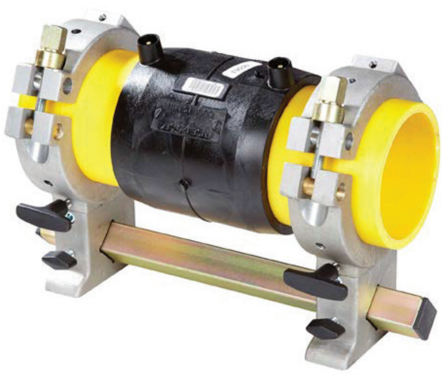
8. Use a rotational peeling machine to remove a continuous swarf of pipe wall material across the area marked in step 6. The depth of material to be removed should be approximately 0.2 mm thick and it should be removed without touching the pipe surface. A scraping tool should not be used as this will remove a variable amount of pipe wall material, depending on how many times and with what force the scraper is used on each section of the pipe wall.

9. Again, clean the peeled pipe surface, as described in step 7, if there is any sign that it might have been touched during the peeling process.

10. Remove the electrofusion fitting from its sealed bag and check that it is clean and undamaged. If required clean the fitting as described in step 7.

11. Insert the pipes in the fitting and check the insertion depth by means of the marking or a suitable tool. Check the alignment and then hold the pipe ends in place using a electrofusion clamping tool, similar to the one shown in the adjacent image. A clamping tool should be used whenever practical, to ensure that the joint does not move during the fusion process.

12. In the case of tapping saddles, fasten the saddle to the clean pipe surface and make sure that the fastening is sufficient to prevent movement during the fusion process.



13. Connect the cables from the electrofusion welding machine to the fitting power terminals.

14. Input the welding data into the electrofusion machine. Whenever possible this should be undertaken using the barcode reader that comes with the machine in order to minimise the risk faulty data input. Check the display on the device and then start the fusion process.

15. Check the correct welding sequence on the welding machine by monitoring the display and checking that the weld indicators on the electrofusion fitting have risen. Note any error messages or failure of the indicators to rise.

16. At the end of the fusion process the cables can be carefully detached and the welding machine moved to the next work site, taking great care not to disturb the cooling fitting.

17. At the end of the cooling period the clamping tool can be removed, again taking care to not to disturb the fitting

6.3.2 Finishing off

After removal from the electrofusion machine and welding clamps the joint number, date and welder identification code should be permanently marked on the pipe beside the joint. This is normally undertaken using a permanent white paint type marker pen.

6.4 Compression joints

Compression fittings are a type of mechanical joint designed to be used with smaller diameter PE pipes of between 16 and 110 mm OD. Their use is generally limited to water supply applications where fusion jointing is not practical and to jointing of cable ducting. Some water utilities do however allow them to be used on small diameter service connections, particularly when used for undertaking repairs.

Compression couplers comprise a threaded body or spigot and two threaded sockets, which as they are wound on to the spigot, gradually increase their grip on the PE pipe, whilst at the same type compressing a ring gasket, which gives a water tight seal.

As shown in the below image, there are a wide variety of different compression fittings available and on small diameter networks in remote areas they frequently comprise all of the fittings on the network.

In each case the threaded body and sockets are made of injection moulded polypropylene and fittings used for potable water supply applications should be certified as complying with ISO 17885 – 2015, Plastics piping systems - Mechanical fittings for pressure piping systems – Specifications. It should be noted that there are large quantities on poor quality compression fittings, that do not comply with the standard produced for use in irrigation applications.

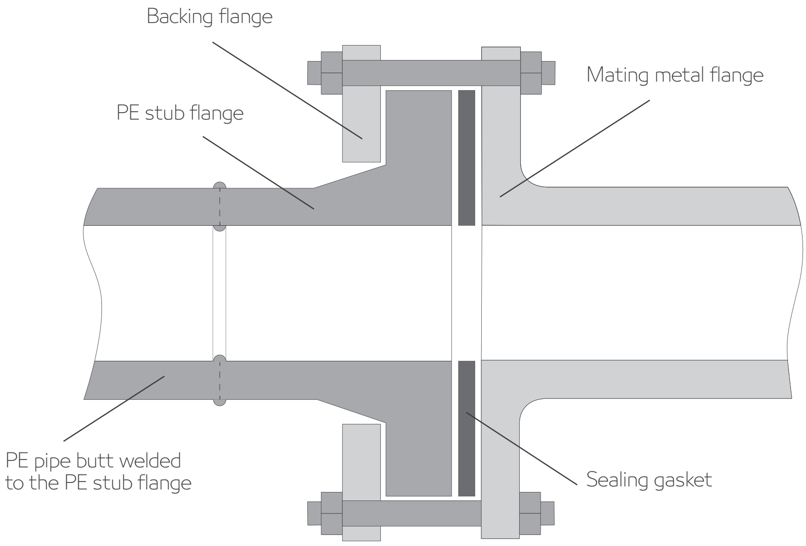
6.5 Flange connections

Flange connections are bolted mechanical joints that are generally used to connect PE pipes to flanged fittings and machines such as valves, hydrants and pumps. They are also used to connect to pipes made of other materials and in some cases blank ends or even other PE pipes in situations, such underwater pipelines, where fusion jointing cannot be used.

The large majority of flanged joints that will found on any PE pipeline or pipework will comprise stub flanges which comprise a PE stub end and a metallic backing flange, as shown in the following images. Smaller diameter stub ends are frequently manufactured using the injection moulding process, whilst larger diameters are first produced as very thick walled pipe or even solid bars of PE which are then machined down on a lathe to give the shape shown below.

The backing flange, through which the bolts will pass are slid on to the pipe and the stub end is then butt fusion welded on to the pipe end. In the case of small diameter pipes electrofusion couplings can be used, provided long stub ends are used. The flange joint is then made by placing a gasket between the stub end and metal flange faces, bring the faces together and then inserting bolts through the holes in both flanges. After all bolts have been tightened by hand, a torque wrench should be used to progressively and evenly tightened up the bolts until the required torque is reached.

A common technique is to tighten diagonally opposite pairs of bolts until all bots are tightened to 5% of the final torque force and then repeat the exercise to achieve, 25%, 50%, 75% and finally 100% of the final torque force. This is to ensure that the gasket is evenly compressed around its full circumference and so minimise the risk of failure.



6.6 Flange adaptors and couplings

Specially designed flange adaptors are an alternative method for connecting PE pipes to flanged valves, hydrants and machines, whilst couplings are used for connecting pipes of different materials and to a limited extent, different outside diameters.

The flange adaptors and couplings used with PE pipes employ a range of grippers and teeth to grip on to the pipe and ensure that they are fully restrained (full end-load resistant) fittings that will not allow the pipe to be pulled out of the fittings. Such fittings, which are essential to ensure the continuity of the pipe system and its ability to absorb all internal forces, must comply with ISO 17885 – 2015 Plastics piping systems - Mechanical fittings for pressure piping systems – Specifications.

Section VII

7. Hydrostatic Testing and Disinfection of Completed Pipe Systems

7.1 Hydrostatic Testing

7.1.1 General

Many utilities and other end user organisations have their own requirements for the hydrostatic (pressure) testing of completed pipelines and networks. The following test method, which follows the Finnish Standard SFS 3115:E, is provided in case the end user organisation does not have a test method suited to the visco-elastic nature of almona PE pipe systems.

7.1.2 Alternative Test Methods

There are several other an alternative hydrostatic test methods that take account of the visco-elastic nature of PE materials. Possible alternatives are German Technical Code DVS2210-1 Supplement 2 and the methods described in Appendix M of ASNZS 2566-2.

7.1.3 Outline Test Procedure

Firstly, seal the pipeline, fix blank flanges on all outlets, remove air valves and other online equipment that may be damaged by high test pressures. Note that testing should only be undertaken against blank flanges and never against closed valves.

Cover the pipe with sufficient backfill to protect it from direct sunlight, leaving joints exposed where practical. If backfilling is not practicable, schedule the tests for early morning or in the late afternoon so that the pipeline will not be exposed to direct strong sunlight.

Fill the pipeline from the lowest point. Bleed the air from all high points and flange points where it is possible and tighten once water begins to spill. Once the line is full, close off the filling valve and check all flanges and the small diameter test pipework for leaks.

Phase 1
Commence raising the pressure at the filling point to the operating pressure or a pressure of 5 bar, whichever is higher. Hold this pressure for a period of 2 hours and add water whenever the pressure drops by 0.2 bar in order to maintain a steady pressure, whilst visually inspect the pipe length for leakage.

Phase 2
After a period of two hours raise the pressure to 1.3 times the nominal pressure as quickly as is practical. Again maintain this pressure for two hours by adding water whenever the pressure drops by 0.2 bar. Visually inspect the pipe length for leakage.

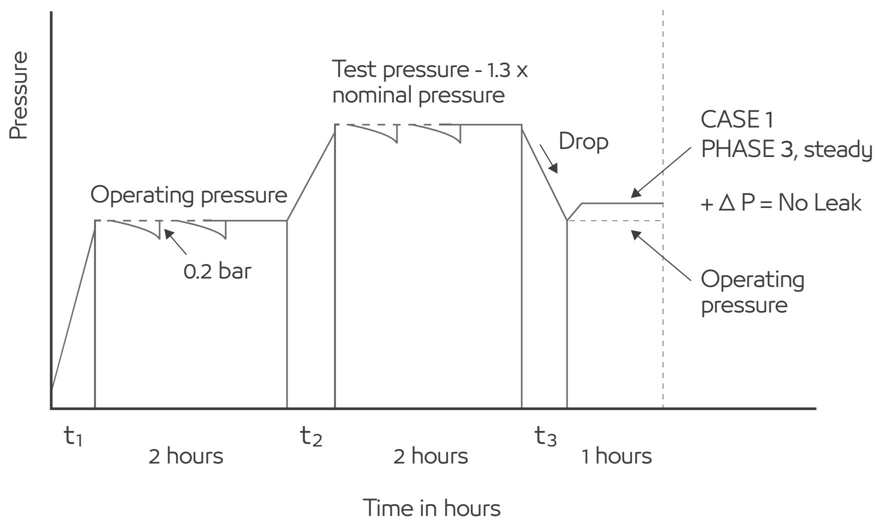
Phase 3
At the end of the second two hour phase release the pressure back down to the phase I level i.e. the operating pressure or 5 bar, within a period of no more than 30 minutes and as quickly as is practical, in a controlled manner.

Phase 3 – Case 1
If after one hour the pressure in the pipelines remains at or above the operational pressure, the test is considered to be completed with the pipeline passing the hydrostatic test.

Phase 3 – Case 2
If after one hour the pressure in the pipeline has fallen below the operational pressure, water shall be added to raise the pressure back to the operating pressure level, having first noted the low pressure before adding any water.

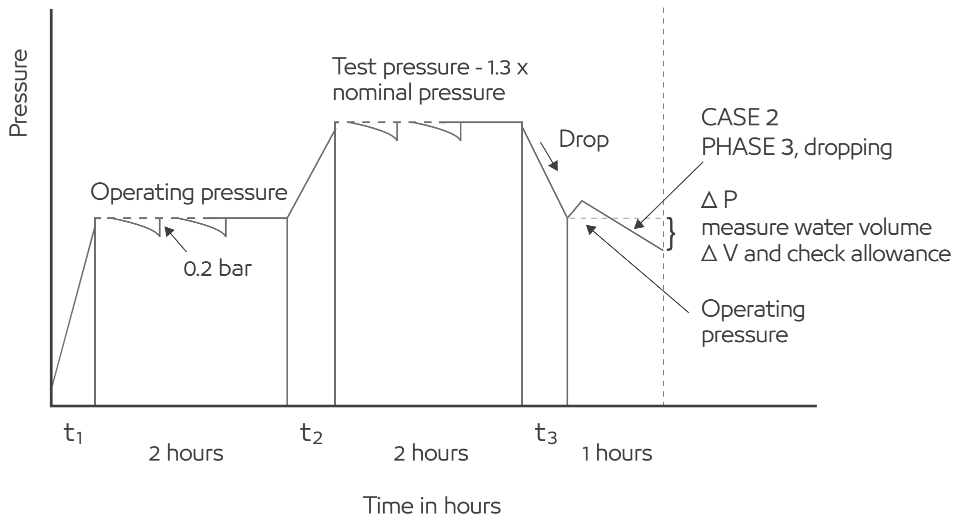
Phase 3 – Case 2
Measure the added water by draining it off into a measuring cylinder. (i.e. reduce pressure to the previously recorded low value and save the water bled off). The measured quantity is then compared against the allowable quantity to determine if the pipeline passes the hydrostatic pressure test.

Figure 7.1
Graphical Representation of the Hydrostatic Test Process
Case 1 – Pipeline passes test without adding any make up water



t_1 - as quickly as possible
t_2 - as quickly as possible
t_3 - 10-30 minutes depending on diameter & length

Figure 7.2
Graphical Representation of the Hydrostatic Test Process
Case 2 – Water to be added to determine if the pipeline passes or fails



t_1 - as quickly as possible
t_2 - as quickly as possible
t_3 - 10-30 minutes depending on diameter & length

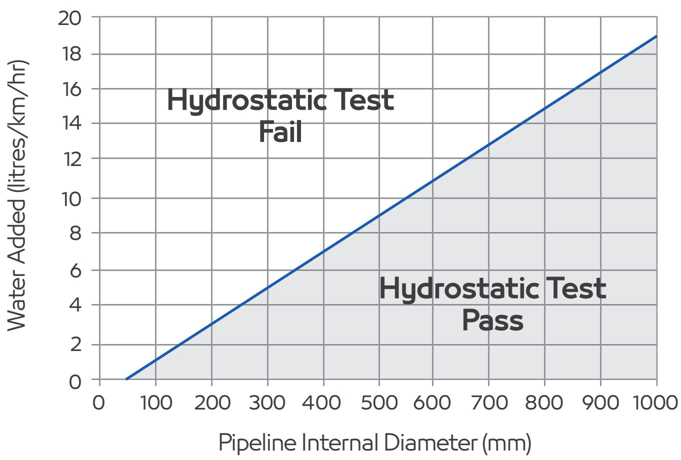
7.1.4 Test Result

If during Phase 3 the pressure within the pipeline remains at or above the operational pressure of the pipeline for a period of at least one hour, the pipeline is considered to have passed the hydrostatic test.

If water needs to be added the pipeline is considered to have passed the hydrostatic test if the quantity of water added in terms of litres of water per km of pipeline length per hour of the phase 3 period is less than that given in the following expression and in Figure 7.3.

$Q \leq Di/50 - 1$ (litres / km/ hour)
Q = added water in litres.
Di = internal diameter for the pipeline in mm.

Figure 7.3 Hydrostatic Test – Allowable Quantities of 'Make Up' Water



7.1.5 Notes on Test Equipment

The master pressure gauge shall be calibrated, certified and to accurate to 0.1 bar. It shall be connected to the feed pipework. If possible, a digital pressure test recorder incorporating a pressure transducer, digital data logger and display screen shall be used to measure and record the variations in pressure. Regular measurements of the air and water temperature shall be taken and recorded, preferably by means of the digital recorder.

The small diameter test pipework shall include a bleed valve at upper end of the pipeline and at all high points together with feed pipework and valve at the lower end of the pipeline. The feed pipework shall include a means of draining off the water into a measuring cylinder that shall have a capacity of at least 2 litres capacity, graduated to 100 millilitres.

7.1.6 Differences in elevation

Care should be taken not to over pressure the lower end of the system during testing. Gauges should always be placed at the lower end of the length under test. As far as possible the difference between the lower and upper end should be kept to one bar. It is recognized that this may not always be possible when longer lengths are being tested or where the slope of the pipeline makes it impractical.

7.1.7 Test pressures at elevated temperature

Where the phase II pressure is within the pressure rating of the pipe and test temperatures are less than 25°C no adjustment of test pressure is necessary.

When the pipe is exposed and the temperature of the pipe surface is 25°C or higher, the test pressures may exceed the pressure rating of the pipe. In this case it is necessary to modify the test pressure according to the table below or as agreed with almona. If the pipe is backfilled then any derating shall be based on the temperature of the water being used for the testing.

Table 7.1
Test Pressure Derating Factors at Elevated Temperatures

Test Temp. (°C)	Multiplier
25	0.94
30	0.87
35	0.81
40	0.74
45	0.68
50	0.61
55	0.56
60	0.48

7.1.8 Additional Notes

Care should be taken that any mechanical elements on the system are protected from elevated pressure or completely removed from the pipeline.

Do not subject the line to prolonged over-pressure. Always aim to complete the procedure within one working day.

During hot weather make sure that the pipe is not subject to direct sunlight during testing. This is normally achieved by backfilling the pipe or undertaking the test during the early morning or late afternoon, so that any pipe laid in a trench is shaded by the trench walls.

The test equipment must be capable of pressurizing the test length within a reasonable time. If the procedure becomes protracted (beyond one working day) the test length may be modified or reviewed. Extremely long test lengths may be subject to special procedures.

7.2 Disinfection and Flushing of Water Pipeline

7.2.1 General

Most water utilities and other end user organisations will have their own requirements for the disinfection of the completed pipeline or network. In case this is not available, the following disinfection procedure, which follows the guidance given in the American Water Works Association (AWWA) Standard C651, Disinfecting Water Mains, is provided.

7.2.2 Method Statement

Prior to commencing work a detailed method statement for the disinfection procedure shall be prepared by the responsible organisation. It shall, step by step, describe in detail how the responsible organisation proposes to perform the disinfection to ensure compliance with the requirements of this document and applicable standards, together with the requirements of the relevant authorities. The method statement shall also calculate the amount of water needed for the disinfection and flushing of the pipeline or network so that this volume can be provided by the end user.

7.2.3 Disinfection and Flushing

The chlorine dose shall be obtained from a sodium hypochlorite solution or other suitable solution to be approved by the end user. Chlorine Dioxide shall not be used. Samples taken from the pipeline during disinfection at locations directed by the end user shall be checked by a suitable comparator in order to ensure that the sterilising liquid is present throughout the system and at sufficient concentration.

Sodium Hypochlorite shall not be added directly to the pipe, but prepared as a concentrated solution that shall be injected to the water used to fill the pipeline or network. The free chlorine concentration shall not exceed 25mg/l.

At the end of an initial 24 hour period during which the pipeline shall have remained under pressure, the chlorine concentration shall be checked. If there is less than 1mg/l of free available chlorine in the water, more sodium hypochlorite solution shall be introduced, flushed through the system and left for a further 24 hour period, after which it shall again be checked.

This procedure shall be repeated until the available free chlorine taken after 24 hours exceeds 1mg/l for all samples taken from the length of the pipeline or network being disinfected. If the concentration of free available chlorine exceeds 5mg/l at any point the after 48 hours the pipeline shall be flushed out until the concentration falls below this level.

After all testing and disinfection has been completed and the pipeline is ready for handing over it shall be flushed out with potable water. Flushing entry and exit points shall be designed to allow a minimum of 1.0m/s water velocity in the main pipeline to remove any sand or other debris. The quantity of flushing water shall typically be calculated as the equivalent to 3 times the volume of the pipeline or network to be flushed out. Prior to flushing testing should be undertaken to ensure that the potable flushing water has a minimum of 0.4mg/l of free available chlorine when tested with a site comparator.

Once flushed, the water in the new pipelines shall be allowed to stand for a further 24 hours. 100ml water quality samples shall then be taken at locations identified by the end user and immediately submitted for chemical and bacteriological testing at approved laboratories.

Please note that flushing water shall be discharged via temporary discharge lines to adjacent drain, water courses or surrounding open areas, as approved by the appropriate local authorities. The flushing water is likely to contain high levels of free chlorine and so should be discharged through a baffle tank or similar arrangement, into with sodium thiosulphite or a similar de-chlorinating agent shall be added.

7.2.4 Acceptance Criteria for Disinfection

The pipeline or network shall only be considered as acceptably disinfected when, in the case of each 100 ml sample:

- No faecal coliforms are detectable
- The bacterial count is within the limits approved by the end user.
- The recorded total chlorine content is a minimum of 0.2mg/l
- The pH is within acceptable limits, typically between 7.0 and 9.0.

If the tests show that a satisfactory drinking water standard has not been achieved, the disinfection and flushing process shall be repeated until the requirements are met.

Section VIII

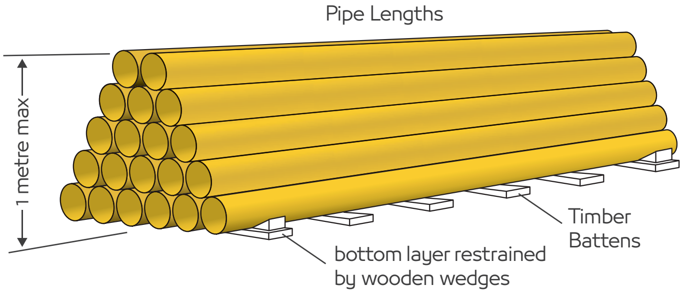
8. Storage, Transportation and Handling of pipes and fittings

8.1 Storage

During storage, almona PE100 and PE80 pipe systems shall be protected from extended exposure to direct sunlight to avoid heat build-up which can lead to pipe deformation, principally ovalisation, particularly when pipes are stacked on top of each other.

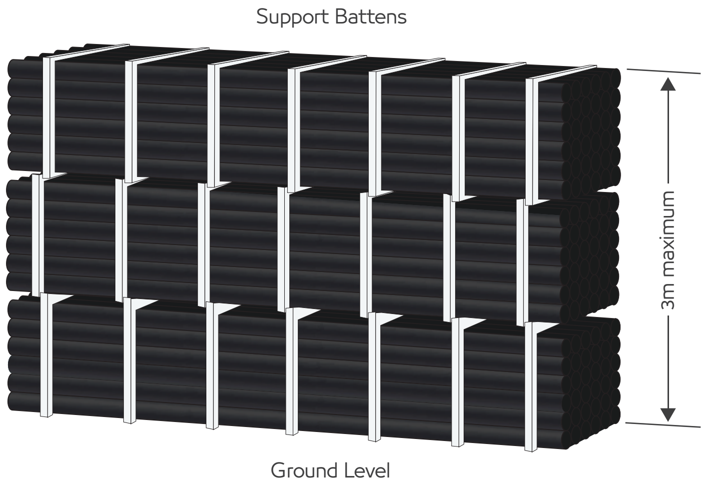
8.1.1 Storage of individual pipes

Individual pipes shall be stacked in a pyramid not more than one meter high, with the bottom layer fully restrained by wedges. Where possible, the bottom layer of pipes should be laid on timber battens as shown in below figure. On site, pipes may be laid out individually in strings. Where appropriate, protective barriers should be placed with adequate warning signs and lamps.



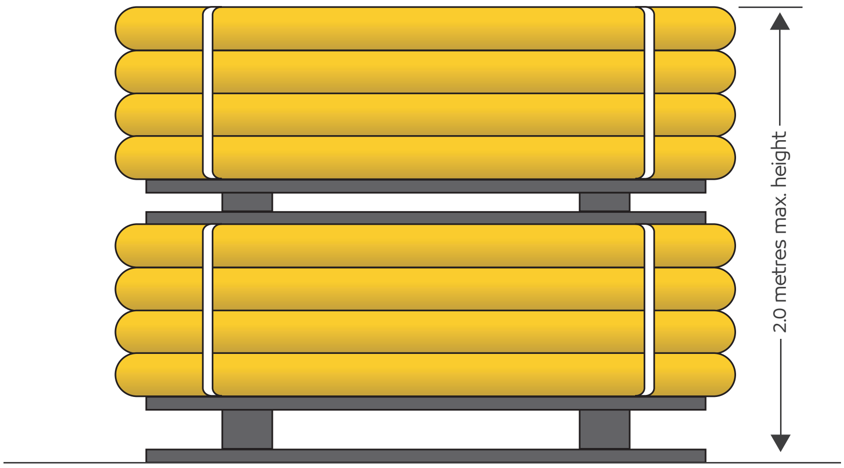
8.1.2 Storage of pipe bundles

Packing pipes in bundles with fully restraining timber battens allows them to stacked up to a height of 3m and almost eliminates pipe deformation. Bundled packs of pipe should be stored on clear, level ground, with the battens supported from the outside by timbers or concrete blocks as shown in below figure.



8.1.3 Storage of large coils

Coiled pipe should be stored horizontally to prevent deformation of the pipe and coil, especially during periods of hot weather. They should be placed on firm level ground which has suitable protection for the bottom coil (see below figure). Where space is limited and coils are to be stacked, the height of stacked coils should be such that the stack is stable, and the uppermost coil can be safely handled. Under no circumstances should the stack exceed 2.0 metres in height. .



Batches of small diameter pipe coils are sometimes packed on pallets to facilitate storage and transportation. Coils delivered on pallets should remain main secured to the pallet and only be taken off when being prepared for use.

Tightly coiled pipes is under tension and is strapped accordingly. Coils may be hazardous if released in the incorrect manner, particularly if the end of the pipe is not kept restrained at all times.

8.1.4 Storage of fittings

almona fittings shall be stored under cover in shaded and sheltered dry conditions, preferably on racking. They should be kept in their boxes/packaging until ready for use. Fabricated fittings may be stored outdoors, as long as they are protected against damage and prolonged direct sunlight.

8.1.5 Considerations for outside storage

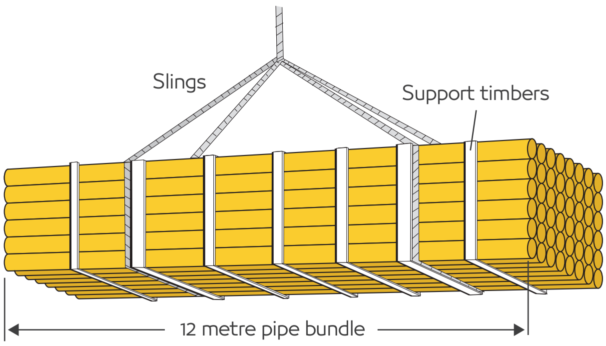
The presence of between 2 and 2.5% carbon black, by mass, in accordance with the international standards, enables almona black PE80 and PE100 pipes to resist degradation by ultraviolet (UV) rays for very long periods of time.

Almona yellow PE80 pipes and orange PE100 pipes are also stabilized in accordance with international standards, but using materials that are consumed as they protect against UV rays. Whilst such stabilization is sufficient for at least one year under central European conditions, under Arabian weather conditions pipes and fittings can receive the same level of UV radiation in only 4 months during the summer season. Therefore when yellow and orange pipes are to be stored in the sun for periods of longer than 1 month it is recommended that they should be protected with an opaque UV resistant covering and that they are not laid down beside the trench for extended periods of time, prior to being jointed and installed.

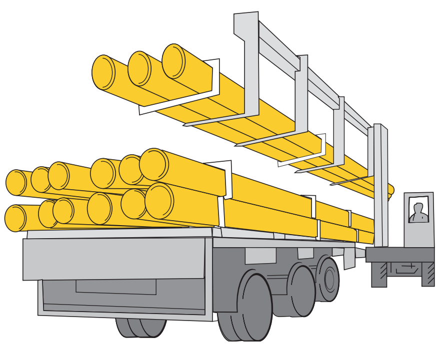
8.2 Transportation and Handling

8.2.1 Transportation of individual pipes and bundles

A flat-bed vehicle, free from sharp objects and projections should be used for transportation of almona pipes. When lifting pipes and pipe bundles by crane (see below figure), wideband slings of polypropylene, nylon or similar material are recommended. Chains, steel wire rope slings, hooks and hawsers, which can easily damage the PE pipes, should not be used.



Some deflection or slight bending of pipes and pipe bundles is acceptable when loading or unloading. Standard 6m long bundles may be handled by forklift, provided that the forks themselves are covered in a protective wrapping to minimise the risk of damaging the pipes. Longer lengths should be loaded and unloaded using either a crane with a spreader bar and slings that support the pipes at four points or a specialised a side-loader with a minimum of four supporting forks.



It is the responsibility of the site management to ensure that the site is safe to accept pipe deliveries. The area where the delivery vehicle is to stop shall be safe and the location for storage shall be on firm level ground which is free from sharp and protruding objects and also from any hydrocarbon (typically gasoline and diesel) contamination, which may be absorbed by the pipe wall.

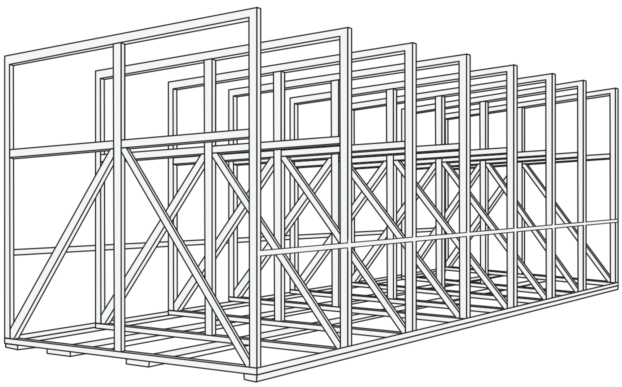
8.2.2 Transportation of fittings

Boxed fittings shall be stacked on pallets for transport which should be adequately secured. They should be stacked, secured and transported such that no loads are imparted to the fittings.

8.2.3 Transportation of coils

Coils should be transported whilst laid flat against the bed of the truck in order to minimise the risk of deformation of the movement of the coil. Whilst shorter small diameter coils may be loaded and off loaded by hand, larger coils will require lifting by a fork-lift or crane. Guidance concerning the handling of pipes and pipe bundles also applies to coils.

Small coils of pipe strapped to pallets may be stacked during transportation provided that it is safe to do so. They should be loaded and unloaded using forklifts. Coils delivered in shrink-wrapped packs should be handled with care to avoid damage of the wrapping.



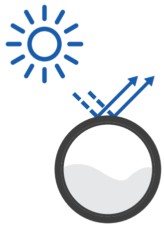
Where large diameter coils are to be transported or stored vertically, they must be secured in purpose-built racking, similar to that shown in the above figure, with protective matting positioned beneath the coil. When transported in such frames the coils must be secured to prevent movement.

Section IX

9. Advantages of almona PE100, PE80 and PE63 pipe systems

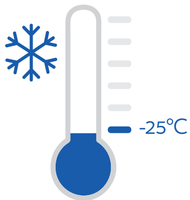
High strength and long lifetime suitable for high pressure water networks

Superior performance and long lifetime suitable for gas distribution networks



UV resistance due to presence of well dispersed carbon black or UV stabilizer

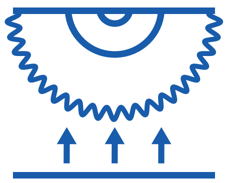
Fast and easy installation due to advanced welding technologies



Resistance to low temperatures (above -25°C) operation and installation

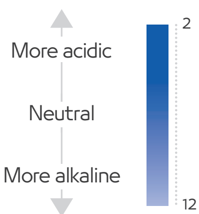
Leak free due to advanced welding technologies

Resistant earthquakes due to high pipe and welded joint flexibility



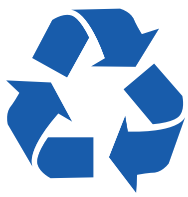
Abrasion resistance suitable for slurry lines

50 years free maintenance lifetime



Chemical resistance ranging from pH2 to pH12

Corrosion free system



100% recyclable and sustainable systems

Section X

10. Appendix

10.1 Chemical resistance list PE80 and PE100

The data in this list is intended only as a guide. Considerable deviations can occur depending on type of exposure and contamination of the chemical medium. almona cannot be held liable for any damages. No warranty can be derived concerning the data given below.

Chemical or Product	Concentration	PE80		PE100	
		21°C	60°C	21°C	60°C
Acetaldehyde	100%	L	NS	-	-
Acetic Acid (Glacial)	Conc.	L	NS	-	-
Acetic Anhydride		NS	NS	-	-
Acetic Acid	1-10%	S	S	-	-
Acetic Acid	10-60%	S	L	-	-
Acetic Acid	80-100%	L	NS	-	-
Acetone		S	S	S	S
Acetone	100%	NS	NS	-	-
Acrylic Emulsions		S	S	S	S
Allyl Alcohol		NS	NS	-	-
Allyl Chloride		NS	NS	-	-
Aluminum Chloride	Dilute	S	S	S	S
Aluminum Chloride	Conc.	S	S	S	S
Aluminum Fluoride	Conc.	S	S	S	S
Aluminum Hydroxide	Conc.	S	S	-	-
Aluminum Sulfate	Conc.	S	S	S	S
Alums (all types)	Conc.	S	S	S	S
Ammonia	100% Dry Gas	S	S	S	S
Ammonium Carbonate		S	S	S	S
Ammonium Chloride	Sat'd	S	S	S	S
Ammonium Carbonate	Conc.	S	S	-	-
Ammonium Chloride	Sat'd	S	S	-	-
Ammonium Fluoride	20%	S	S	S	S
Ammonium Hydroxide		S	S	S	S
Ammonium Hydroxide	35%	S	S	-	-
Ammonium Metaphosphate	Sat'd	S	S	S	S
Ammonium Nitrate	Sat'd	S	S	S	S
Ammonium Persullitt	Sat'd	S	S	S	S
Ammonium Persulfate	Sat'd	S	S	-	-
Ammonium Sulfate	Sat'd	S	S	S	S
Ammonium Sulfide	Sat'd	S	S	S	S
Ammonium Thiocyanate	Sat'd	S	S	-	-
Ammonium Thiocyanst	Sat'd	S	S	S	S
Amyl Acetate	100%	NS	NS	L	NS
Amyl Alcohol	100%	S	S	S	S

Legend
S = Satisfactory (no attack) , **L** = Limited, **NS** = Not Satisfactory, **-** = No Applicable

Chemical or Product	Concentration	PE80		PE100	
		21°C	60°C	21°C	60°C
Aniline	100%	S	NS	S	-
Aniline Hydrochloride	Sat'd	-	NS	-	-
Antimony Chloride		NS	NS	-	NS
Aqua Acid		NS	NS	-	-
Aqua Regis		L	NS	L	NS
Arsenic Acid	100%	S	S	-	-
Barium Carbonate	Sat'd	S	S	S	S
Barium Chloride	Sat'd	S	S	S	S
Barium Hydroxide	Sat'd	S	S	-	-
Barium Sulfide	Sat'd	S	S	S	S
Beer		S	S	S	-
Benzene		NS	NS	L	NS
Benzene Sulfonic Acid		S	S	S	S
Benzoic Acid	Sat'd	L	L	-	-
Benzoic Acid	All Conc.	S	S	-	-
Benzene Sulfonic Acid		S	S	-	-
Bismuth Carbonate	Sat'd	S	S	S	S
Black Liquor		S	S	S	S
Bleach Lye	10%	S	S	S	S
Borax	Sat'd	S	S	-	-
Borax	Cold Sat'd	S	S	-	-
Boric Acid	Conc.	S	S	S	S
Boric Acid	Dilute	S	S	S	S
Bromic Acid	10%	S	S	-	-
Bromic Acid	100%	NS	NS	-	-
Borax Cold	Sat'd	S	S	S	S
Bromic Acid	10%	S	S	S	S
Bromine Liquid	100%	NS	NS	L	NS
Bromine Water		NS	NS	-	-
Butanediol	100%	S	S	-	-
Butanediol	60%	S	S	-	-
Butanediol	10%	S	S	-	-
Butyl Alcohol	100%	S	S	-	-
Butyric Acid	Conc.	NS	NS	-	-
Calcium Bisulfide		S	S	S	S
Calcium Carbonate	Sat'd	S	S	S	S
Calcium Chlorate	Sat'd	S	S	S	S
Calcium Chloride	Sat'd	S	S	S	S
Calcium Hydroxide	Sat'd	S	S	-	-
Calcium Hydroxide		S	S	S	S
Calcium Hypochlorite	Bleach Sol'n	S	S	S	S
Calcium Nitrate	Sat'd	S	S	-	-
Calcium Nitrate	50%	S	S	S	S
Calcium Sulfate		S	S	S	S
Camphor Oil		NS	NS	-	-
Carbon Dioxide	100% Dry	S	S	S	S
Carbon Dioxide	100% Wet	S	S	S	S

Legend
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Chemical or Product	Concentration	PE80		PE100	
		21°C	60°C	21°C	60°C
Carbon Dioxide	Cold Sat'd	S	S	S	S
Carbon Disulfide		NS	NS	-	-
Carbon Disulphide		NS	NS	-	NS
Carbon Monoxide		S	S	S	S
Carbon Tetrachloride		NS	NS	NS	NS
Carbonic Acid		S	S	S	S
Caster Oil	Conc.	S	S	-	-
Chloracetic Acid	100%	NS	NS	-	-
Chlorine Moist Gas		L	NS	-	-
Chlorine Liquid		NS	NS	L	NS
Chlorine Water	2% Sat'd Sol	NS	NS	-	-
Chlorobenzene		NS	NS	L	NS
Chloroform	100%	NS	NS	NS	NS
Chlorosulfonic Acid		NS	NS	NS	NS
Chrome Alum	Sat'd	S	S	S	S
Chromic Acid	10-20%	S	L	S	L
Chromic Acid	20%	S	S	-	-
Chromic Acid & Sulfuric Acid		S	L	-	-
Chromic Acid	50%	S	L	S	L
Cider		S	S	S	S
Citric Acid	Sat'd	S	S	S	S
Coconut Oil Alcohols		S	S	S	S
Cola Concentrates		S	S	-	-
Copper Chloride	Sat'd	S	S	S	S
Copper Cyanide	Sat'd	S	S	-	-
Copper Fluoride	2%	S	S	S	S
Copper Nitrate	Sat'd	S	S	S	S
Copper Sulfate	Dilute	S	S	S	S
Copper Sulfate	Sat'd	S	S	S	S
Cottonseed Oil	100%	S	S	-	-
Cottonseed Oil		S	S	S	S
Cresol	100%	NS	NS	-	-
Cresylic Acid	50%	S	S	-	-
Cuprous Chloride	Sat'd	S	S	S	S
Cyclohexane	100%	NS	NS	-	-
Cyclohexanone		NS	NS	NS	NS
Cyclohexanol	100%	S	S	-	-
Detergents, Synthetic		S	S	S	S
Developers Photographic		S	S	S	S
Dextrin	Sat'd	S	S	S	S
Dextrose	Sat'd	S	S	S	S
Diazo Salts		S	S	-	-
Dibutylphthalate		L	L	-	-
Diethylene Glycol	100%	L	NS	-	-
Diethylene Glycol		S	S	S	S
Diglycolic Acid		S	S	-	-
Dimethylamine		NS	NS	-	-

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Chemical or Product	Concentration	PE80		PE100	
		21°C	60°C	21°C	60°C
Dioctyl Phthalate		L	NS	-	-
Disodium Phosphate	Sat'd	S	S	-	-
Emulsions, Photographic		S	S	-	-
Ethyl Acetate	100%	L	L	L	L
Ethyl Alcohol	35%	S	S	S	S
Ethyl Alcohol	100%	S	S	S	S
Ethyl Butyrate	100%	L	NS	-	-
Ethyl Chloride		NS	NS	L	NS
Ethyl Ether	100%	NS	NS	-	-
Ethylene Chloride		NS	NS	-	-
Ethylene Chlorohydrin		NS	NS	-	-
Ethylene Dichloride		NS	NS	-	-
Ethylene Glycol		S	S	S	S
Ferric Chloride	Sat'd	S	S	S	S
Ferric Nitrate	Sat'd	S	S	S	S
Ferric Sulfate	Sat'd	S	S	-	-
Ferrous Chloride	Sat'd	S	S	S	S
Ferrous Sulfate		S	S	S	S
Fish Solubles		S	S	-	-
Fluoboric Acid		S	S	-	-
Fluorine		S	NS	-	-
Fluosilicic Acid	32%	S	S	-	-
Fluosilicic Acid	Conc.	S	L	-	-
Fluoboric Acid		S	S	S	S
Fluorine		S	NS	-	-
Fluosilicic Acid	32%	S	S	-	-
Fluosilicic Acid	Conc.	S	L	-	-
Fluoboric Acid		S	S	S	S
Fluorine		S	NS	S	NS
Fluosilicic Acid	32%	S	S	S	S
Fluosilicic Acid	Conc.	S	L	S	S
Formaldehyde	40%	S	S	S	S
Formic Acid	20%	S	S	S	S
Formic Acid	50%	S	S	S	S
Formic Acid	100%	S	S	S	S
Fructose	Sat'd	S	S	S	S
Fruit Pulp		S	S	-	-
Fuel Oil		L	NS	S	NS
Furfural	100%	NS	NS	L	NS
Furfuryl Alcohol		NS	NS	-	-
Gallic Acid	Sat'd	S	S	S	S
Gasoline		NS	NS	NS	NS
Gin		NS	NS	-	-
Glucose		S	S	S	S
Glycerine		S	S	S	S
Glycol		S	S	S	S
Glycolic Acid	30%	S	S	S	S

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Chemical or Product	Concentration	PE80		PE100	
		21°C	60°C	21°C	60°C
Grape Sugar	Sat'd Aq.	S	S	-	-
Heptane	100%	NS	NS	-	-
Hydrobromic Acid	50%	S	S	S	S
Hydrocyanic Acid	Sa'd	S	S	S	S
Hydrochloric Acid	10%	S	S	S	S
Hydrochloric Acid	30%	S	S	S	S
Hydrochloric Acid	35%	S	S	S	S
Hydrochloric Acid	Conc.	S	S	S	S
Hydrofluoric Acid	40%	S	S	S	S
Hydrofluoric Acid	60%	S	S	S	S
Hydrofluoric Acid	75%	S	L	S	S
Hydroflurosllicic	31.1%	S	S		
Hydrogen	100%	S	S	S	S
Hydrogen Bromide	10%	S	S	S	S
Hydrogen Chloride Gas	Dry	S	S	S	S
Hydrogen Peroxide	30%	S	L	S	S
Hydrogen Peroxide	90%	S	NS	S	L
Hydrogen Phosphide	100%	S	S	-	-
Hydrogen Sulfide		S	S	S	S
Hydroquinone		S	S	S	S
Hypochlotous Acid	Conc.	S	S	S	S
Inks		S	S	S	S
Iodine (in KI Sol'n)		L	NS	-	-
Lactic Acid	10%	S	S	S	S
Lactic Acid	90%	S	S	S	S
Lead Acetate	Sat'd	S	S	S	S
Latex	100%	S	S	-	-
Lead Acetate	Sat'd	S	S	-	-
Lead Tetra-Ethyle	100%	S		-	-
Linseed Oil		L	NS	-	-
Lube Oil		L	NS	-	-
Magnesium Carbonate	Sat'd	S	S	S	S
Magnesium Chloride	Sat'd	S	S	S	S
Magnesium Hydroxide	Sat'd	S	S	S	S
Magnesium Nitrate	Sat'd	S	S	S	S
Magnesium Sulfate	Sat'd	S	S	S	S
Maleic Acid	Sat'd	S	S	-	-
Mercuric Chloride	Sat'd	S	S	-	-
Mercuric Cyanide	Sat'd	S	S	S	S
Mercurous Nitrate	Sat'd	S	S	-	-
Mercury		S	S	S	S
Methyl Alcohol	100%	S	S	S	S
Methyl Bromide		L	NS	L	
Methyl Chloride		L	NS	-	-
Methyl Ethyl Ketone	100%	NS	NS	NS	NS
Methylene Chloride	100%	NS	NS	NS	NS
Methylsufuric Acid		S	S	S	-

Legend
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Chemical or Product	Concentration	PE80		PE100	
		21°C	60°C	21°C	60°C
Milk		S	S	-	-
Mineral Oils		L	NS	S	NS
Molasses	Comm.	S	S	-	-
Naphtha	100%	S	NS	-	-
Naphtha	100%	S	NS	-	-
Naphthalene		NS	NS	-	-
Nickel Chloride	Sat'd	S	S	S	S
Nickel Nitrate	Con.	S	S	S	S
Nickel Nitrate	Conc.	S	S	-	-
Nickel Sulfate	Sat'd	S	S	S	S
Nicotinic Acid	100%	S	S	-	-
Nitric Acid	0-30%	S	S	S	S
Nitric Acid	30-50%	S	S	S	S
Nitric Acid	70%	S	L	S	L
Nitric Acid	95-98%	NS	NS	NS	NS
Nitrobenzene	100%	NS	NS	NS	NS
Octyl Cresol		L	NS	-	-
Oils and Fats		L	NS	-	-
Oleic Acid	Conc.	L	NS	-	-
Oleum	Conc.	NS	NS	NS	NS
Orange Extract	Dilute	S	S	-	-
Oxalic Acid	Dilute	S	S	S	S
Oxalic Acid	Sat'd	S	S	S	S
Oxygen	100%	S		-	-
Ozone	100%	L	NS	-	-
Perchloric Acid	10%	S	S	-	-
Petroleum Ether		NS	NS	NS	NS
Phenol	90%	NS	NS	-	-
Phosphoric Acid	0-30%	S	S	S	S
Phosphoric Acid	Over 30%	S	S	S	S
Phosphoric Acid	90%	S	NS	S	S
Phosphorus (Yellow)	100%	S		-	-
Phosphorus Pentoxide	100%	S	S	-	-
Phosphorus Trichloride		S		-	-
Photographic Solutions		S	S	S	S
Pickling Baths				-	-
Hydrochloric Acid		S	S		
Sulfuric Acid		S	S		
Sulfuric-Nitaric		S			
Pickling Baths, Sulfuric					
Acid Hydrochloric					
Acid Sulfuric-Nitric					
Picric Acid	1%	S	L	-	-
Plating Solutions					
Brass Cadmium		S	S	S	S
Chromium		S	S	S	S
Copper		S	S	S	S

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S = Satisfactory (no attack) , **L** = Limited, **NS** = Not Satisfactory, **-** = No Applicable

Chemical or Product	Concentration	PE80		PE100	
		21°C	60°C	21°C	60°C
Gold					
Indium					
Lead					
Nickel					
Rhodium					
Silver Tin					
Zinc					
Potassium Bicarbonate	Sat'd	S	S	S	S
Potassium Borate	1%	S	S	S	S
Potassium Bromate	10%	S	S	S	S
Potassium Bromide	Sat'd	S	S	S	S
Potassium Carbonate		S	S	S	S
Potassium Chlorate	Sat'd	S	S	S	S
Potassium Chloride	Sat'd	S	S	S	S
Potassium Chromate	40%	S	S	S	S
Potassium Cyanide	Sat'd	S	S	S	S
Potassium Dichromate	40%	S	S	S	S
Potassium Ferricyanide	Sat'd	S	S	-	-
Potassium Ferri/Ferro Cyanide		S	S	S	S
Potassium Fluoride		S	S	S	S
Potassium Hydroxide	20% Conc.	S	S	S	S
Potassium Nitrate	Sat'd	S	S	S	S
Potassium Petborate	Sat'd	S	S	S	S
Potassium Perchlorate	Sat'd	S	S	-	-
Potassium Perchlorate	10%	S	S	S	S
Potassium Permanganate	20%	L	NS	-	-
Potassium Persulfate	Sat'd	S	S	-	-
Potassium Sulfate	Conc.	S	S	S	S
Potassium Sulfide	Conc.	S	S	S	S
Potassium Sulfite	Conc.	S	S	S	S
Potassium Persullate	Sat'd	S	S	S	S
Propargyl Alcohol		S	S	S	S
Propyl Alcohol		S	S	S	S
Propylene Dichloride	100%	NS	NS	-	-
Propylene Glycol		S	S	S	S
Rayon Coagulating Bath		S	S	S	S
Sea Water		S	S	S	S
Selenic Acid		S	S	-	-
Shortening		S	S	S	S
Silicic Acid		S	S	S	S
Silver Nitrate Sol'n		S	S	S	S
Soap Solution	Conc.	S	S	S	S
Sodium Acetate	Sat'd	S	S	S	S
Sodium Benzoate	35%	S	S	S	S
Sodium Bicarbonate	Sat'd	S	S	S	S
Sodium Bisulfate	Sat'd	S	S	S	S
Sodium Bisulfite	Sat'd	S	S	S	S

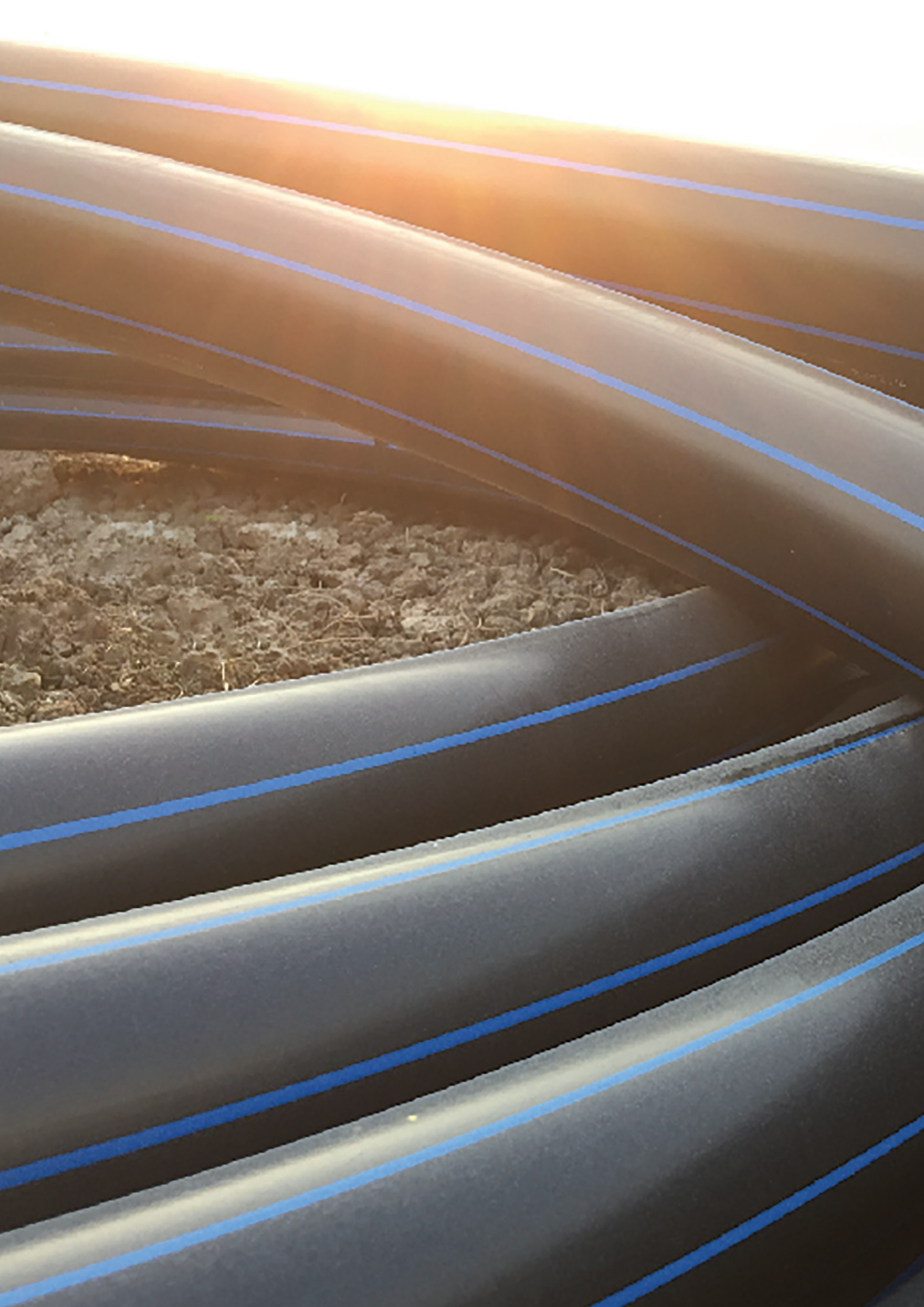
Legend
S = Satisfactory (no attack) , **L** = Limited, **NS** = Not Satisfactory, **-** = No Applicable

Chemical or Product	Concentration	PE80		PE100	
		21°C	60°C	21°C	60°C
Sodium Borate		S	S	S	S
Sodium Bromide Oil Sol'n		S	S	S	S
Sodium Carbonate	Conc.	S	S	S	S
Sodium Chlorate	Sat'd	S	S	S	S
Sodium Chloride	Sat'd	S	S	S	S
Sodium Cyanide		S	S	-	-
Sodium Cyanide		S	S	S	S
Sodium Dichromate	Sat'd	S	S	S	S
Sodium Ferricyanide	Sat'd	S	S	S	S
Sodium Fluoride	Sat'd	S	S	S	S
Sodium Hydroxide	Conc.	S	S	S	S
Sodium Hypochlorite		S	S	S	S
Sodium Nitrate		S	S	S	S
Sodium Sulfate		S	S	S	S
Sodium Sulfide	25%	S	S	-	-
Sodium Sulfide	Sat'd Sol'n	S	S	-	-
Sodium Sulfide	25% to Sat'd	S	S	S	S
Sodium Sulfite	Sat'd	S	S	S	S
Stannic Chloride	Sat'd	S	S	S	S
Stannous Chloride	Sat'd	S	S	S	S
Starch Solution	Sat'd	S	S	S	-
Stearic Acid	100%.	S	S	S	-
Sulfur	Colloidal	S		-	-
Sulfur Dioxide	Dry, 100%	S	S	-	-
Sulfur Dioxide	Wet, 100%	S		-	-
Sulfur Trioxide		S	S	-	-
Sulfuric Acid	0-50%	S	S	S	S
Sulfuric Acid	70%	S	L	S	L
Sulfuric Acid	80%	S	NS	S	NS
Sulfuric Acid	96%	L	NS	L	NS
Sulfuric Acid	98% Conc.	L	NS	L	NS
Sulfuric Acid Fuming		NS	NS	NS	NS
Sulfurous Acid		S	S	S	S
Tallow	.	S	L	-	-
Tannic Acid	10%	S	S	S	S
Tanning Extracts	Comm.	S	S	-	-
Tartaric Acid	10%	S	S	-	-
Tartaric Acid	Sat'd	NS	NS	-	-
Tetralin		NS	NS	-	-
Tetrahydrofuran	100%	NS	NS	-	-
Toluene		NS	NS	NS	NS
Tetrachloroethylene	100%	NS	NS	-	-
Tetrahydrofurane		L	L	L	L
Transformer Oil		L	NS	S	L
Trichloroacetic Acid	10%			-	-
Trichloroethylene		NS	NS	NS	NS
Triethanolamine	100%	S	NS	-	-

Legend
S = Satisfactory (no attack) , **L** = Limited, **NS** = Not Satisfactory, **-** = No Applicable

Chemical or Product	Concentration	PE80		PE100	
		21°C	60°C	21°C	60°C
Trisodium Phosphate	Sat'd	S	S	-	S
Turpentine		S	NS	-	-
Urea	Up to 30%	S	S	-	-
Urea		S	S	S	
Urine		S	S	S	S
Vinegar	Comm.	S	S	S	S
Vanilla Extract		S	S	-	-
Wetting Agents		S	S	S	S
Whiskey		S	S	S	-
Wines		S	S	S	S
Xylene		NS	NS	NS	NS
Yeast		S	S	S	S
Zinc Chloride	Sat'd	S	S	S	S
Zinc Sulfate	Sat'd	S	S	S	S

Legend
S = Satisfactory (no attack) , **L** = Limited, **NS** = Not Satisfactory, **-** = No Applicable



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