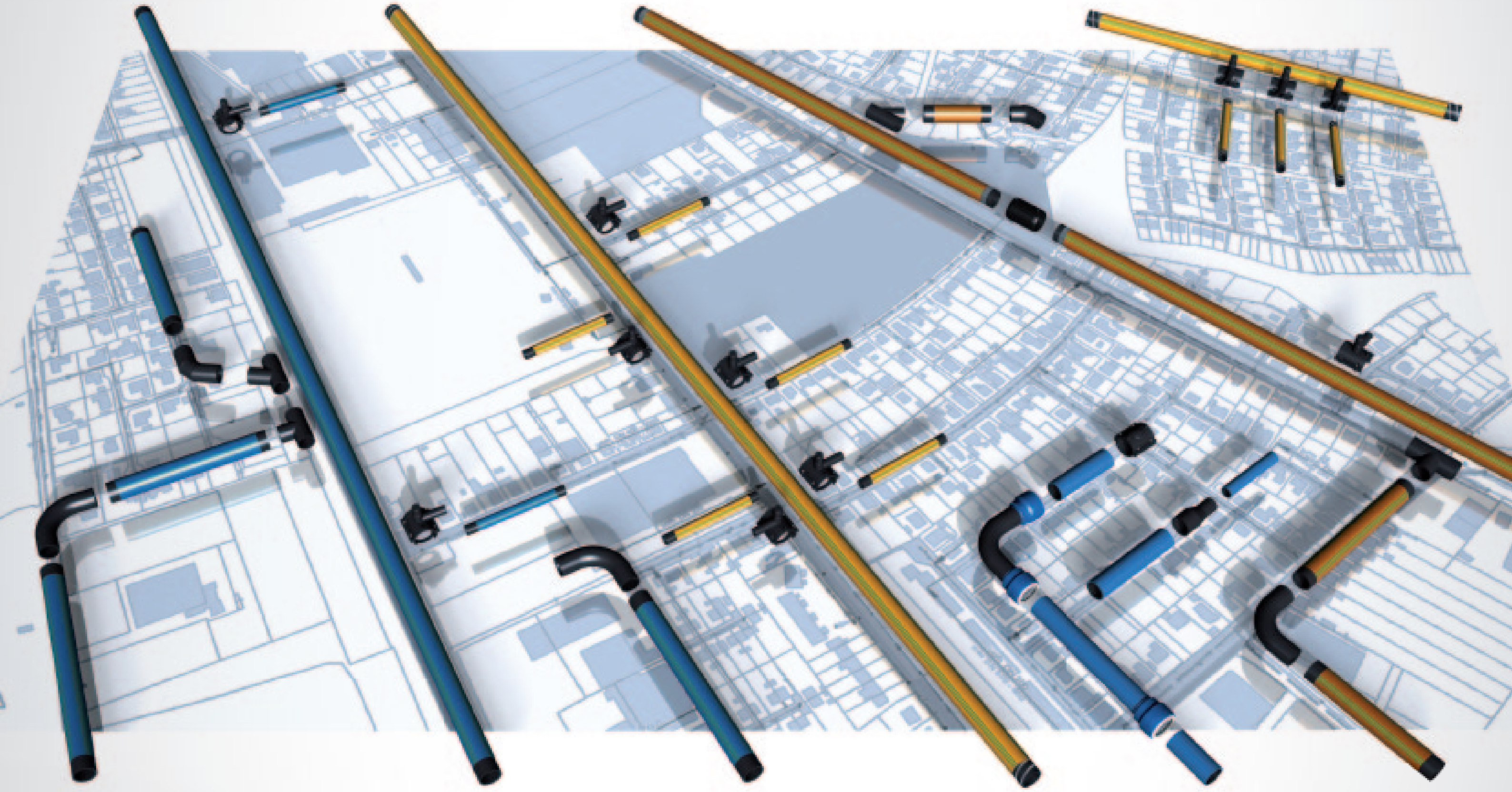
Pressure piping systems made from polyethylene

Planning



egeplast

egeplast – Future-proofed Pipe Systems

egeplast is an extremely innovative manufacturer of plastic pipe systems, and has been setting benchmarks for decades. Customers in over 30 countries rely on egeplast consultancy solutions and quality products for transporting water, gas and data. The customers of the owner-run enterprise include some of the largest and most demanding utility companies and network operators in the world.

Our head office and production location are in Greven/Germany.

Our range of products offer a solution to meet almost any of our customers' challenges. Our focus is on intelligent pipe systems for the modern, trenchless pipe installation and rehabilitation processes. The products offer our customers maximum security of investment – egeplast pipe systems are future-proof.

There is a long tradition of research and development at egeplast. The company is well known as a forge of innovation for multi-layered pipes. We are technology leaders with more than 60 patents for products and manufacturing processes. Worldwide leading machinery manufacturers for plastics, like Krauss Maffei Berstorff and Battenfeld Cincinnati rank among the licence holders of egeplast.

Established in 1908 by Engelbert Gröter, today egeplast is still family-owned and operated by the fourth generation. The initials of the founder are reflected in the name of the company. Highly qualified and motivated employees strive daily to satisfy our customers.

Our head office and production location are in Greven/Westphalia. Here egeplast operates the most state-of-the-art factory for polymer pipe systems in Europe. We also develop tailor-made solutions with our customers in a separate technology centre.

We would like to invite you to get to know our Company and we look forward to having discussions with you in this regard.

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1 General

The use of plastic piping systems in the most varied applications is continuously increasing. The reason is their incredible versatility and high innovative potential. Thanks to their high resistance against a range of chemicals from acids and lyes, their good flexibility, low weight, and especially their long service life, plastic piping systems guarantee efficient, economically beneficial and safe long-term solutions.

1.1 Advantages of PE piping systems in supply networks

Pressure pipes made of polyethylene (PE) have a number of material-specific advantages as compared to pipes made of other materials. Metallic pipes are prone to corrosion and have to be protected from corrosion when in service. Ceramic materials are very brittle, posing special challenges in handling and bedding. That is not necessary with pipes made of polyethylene. That's why they are successfully in use since 1956 and have gained a significant market share in the most diverse application fields due to their advantageous characteristics.

- Low specific weight
  Pipes from polyethylene are very lightweight, helping to reduce transport costs and avoid additional heavy lifting equipment on-site.
- No corrosion
  The material polyethylene is very resistant and does not require corrosion protection.
- Flexibility
  The good flexibility of pipes made of polyethylene makes handling them easier and enables delivery of long lenghts as coiled bundles.
- Weldability
  Polyethylene pipes can be welded to each other in a simple and safe fashion. The most used methods are state-of-the-art and are described in the DVS Guidelines.
- Longevity
  Pipes from polyethylene have been in service for more than 50 years. Today, a service life of at least 100 years is normatively assured.
- Low pressure losses
  Thanks to their smooth inner surface, incrustations cannot form and the pressure losses are low.
- Ductility
  Polyethylene is a very ductile material. Even in sub-zero temperatures in winter it does not get brittle.
- Compensation of pressure surges
  The high flexibility and ductility of polyethylene make PE pipes resistant to surges in pressure.
- Environmentally friendly
  Their low weight and their ressource-efficient production make pipes of polyethylene a very environmentally sound product.
- Complete piping systems
  The high availability of the most diverse connectors and moulded parts make polyethylene piping systems very flexible in application.

1.2 Polyethylene (PE) as a Pipe Material

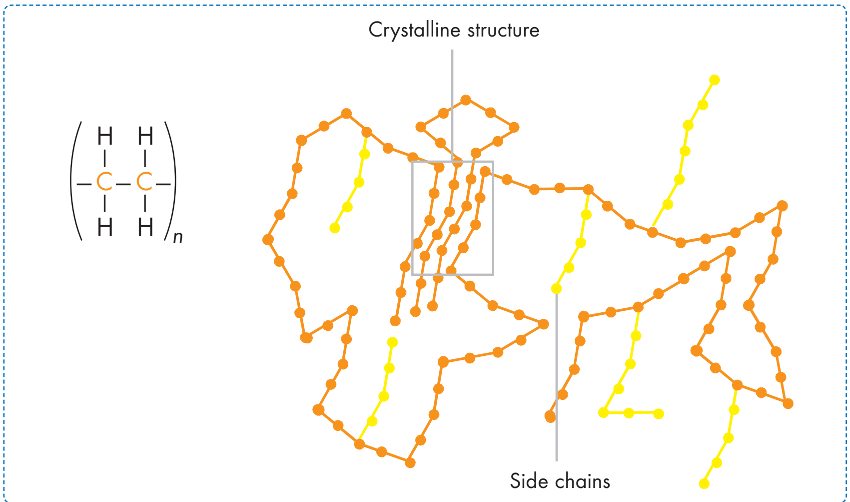


Fig 1-1: Molecular structure of polyethylene: long, fine thread molecules with few side chains

The material polyethylene consists of long chain molecules which are made up of the base molecule ethylene C_2H_4. These molecule chains are not exclusively straight-line; the degree of branching significantly affects the properties of the material.

The straight-line sections of the molecule chains form crystalline regions, called crystallites. These are the parts of the structural make-up responsible for the strength of the material. The crystallites are bonded with one another through amorphous, i.e. unordered, structures. Material properties such as tensile strength and resistance to stress cracking are dependent on the amorphous structures. Modern PE materials are optimised for use as pressure pipe materials. The various polyethylene piping materials are classified according to the strength of the material:

PE 100	(= MRS 10.0 N/mm²)
PE 100-RC	(= MRS 10.0 N/mm²)

The designation PE 100 or PE 100-RC e.g. stands for a material with MRS 10 (Minimum Required Strength), that is, with a minimum strength of 10.0 $\frac{N}{mm^2}$. This means that for this material, after a 50 year operating life at a temperature of 20 °C with water as a test medium, the timeto-rupture curve is crossed by a comparative stress of at least 10.0 $\frac{N}{mm^2}$.

The designation "RC" (Resistance to Crack) stands for selected PE 100 materials with exceptional resistance to stress cracking, which is required for extreme loads such as those that arise during installation without a sand bed or during trenchless installation.

Internal pressure creep strength graphs in accordance with DIN 8075 for PE 100 can be found in Section 1.2.3.

1.2.1 Distinguishing Features of Different PE Pipe Materials

Property	Dimension	PE 100 PE-HD 003	PE 100-RC PE-HD 003
MRS	N/mm²	10	10
Density	g/cm³	>0.955	>0.955
Elastic Modulus	N/mm²	>1000	>1000
Yield Stress	N/mm²	23	23
Elongation at Break	%	>500	>500
FNCT	h	>300	≥8760
Melt Index MFR 190 °C/5kg	g/10 min	0.3	0.3
Welding Group		003	003
Main Fields of Application		Gas, water, effluent, and industrial pipes	Gas and water supply, pressurised effluent disposal with modern installation methods
Joining Techniques		All commonly used welding methods	All commonly used welding methods

Tab 1-1: Comparison of PE pipe materials. The values given are averages. Deviations are material dependent.

1.2.2 Physical Material Characteristics of Polyethylene

Properties	Test Standard	Test Method Test Specimen	Dimension	PE-HD
Mechanical properties				
Density	DIN 53479	Method C	g/cm^3	0.96
Melt index group	DIN 16776	MFR 190/5	Group	003
Tensile test	DIN EN ISO 527	Test speed 50 mm/min.		
– Yield stress			N/mm^2	22
– Elongation at yield stress			%	18
– Elongation at break			%	300
Flexural test	DIN 53457	Test specimen		
– Flexural elastic modulus		120 x 10 x 4 [mm]	N/mm^2	1000
Impact flexural test	DIN EN ISO 179	Charpy		
– Impact resistance		Standard small rod	kJ/m^2	No break
– Notch impact strength		Ditto with U-notch	kJ/m^2	12
Surface hardness				
– Ball indentation hardness	DIN 53456	H 132/30	N/mm^2	46
– Shore hardness	DIN 53505	D	-	63
Thermal properties				
Crystal melting range		Polarisation microscope	°C	125–135
Mean linear thermal expansion coefficient	DIN 53752		K^{-1}(°C^{-1})	$2 \cdot 10^{-4}$
Thermal conductivity	DIN 52612	Two plate method	W/m · K	0,43
Electrical properties				
Dielectric strength	DIN 53481	K 20/P 50	kV/mm	47
Specific volume resistance	DIN 53482	Ring electrode	Ohm · cm	10^{16}
Surface resistance	DIN 53482	Electrode A	Ohm	10^{14}
Creepage current resistance	DIN 53480	Method KC	V	600
Other properties				
Flammability	DIN 4102	Class	B 2	B 2
Water absorption	DIN 53495	Method C	%/24h	<0.01
Physiological harmlessness	Recommendation	BGA/KTW		Yes
Chemical resistance	DIN 8075 supplement			Satisfied

Tab 1-2: The data given are guideline values and can vary depending on processing procedures.
The suitability of our products for any particular purpose should be verified by the user.

1.2.3 Internal Pressure Creep Strength Graphs in Accordance with DIN 8075

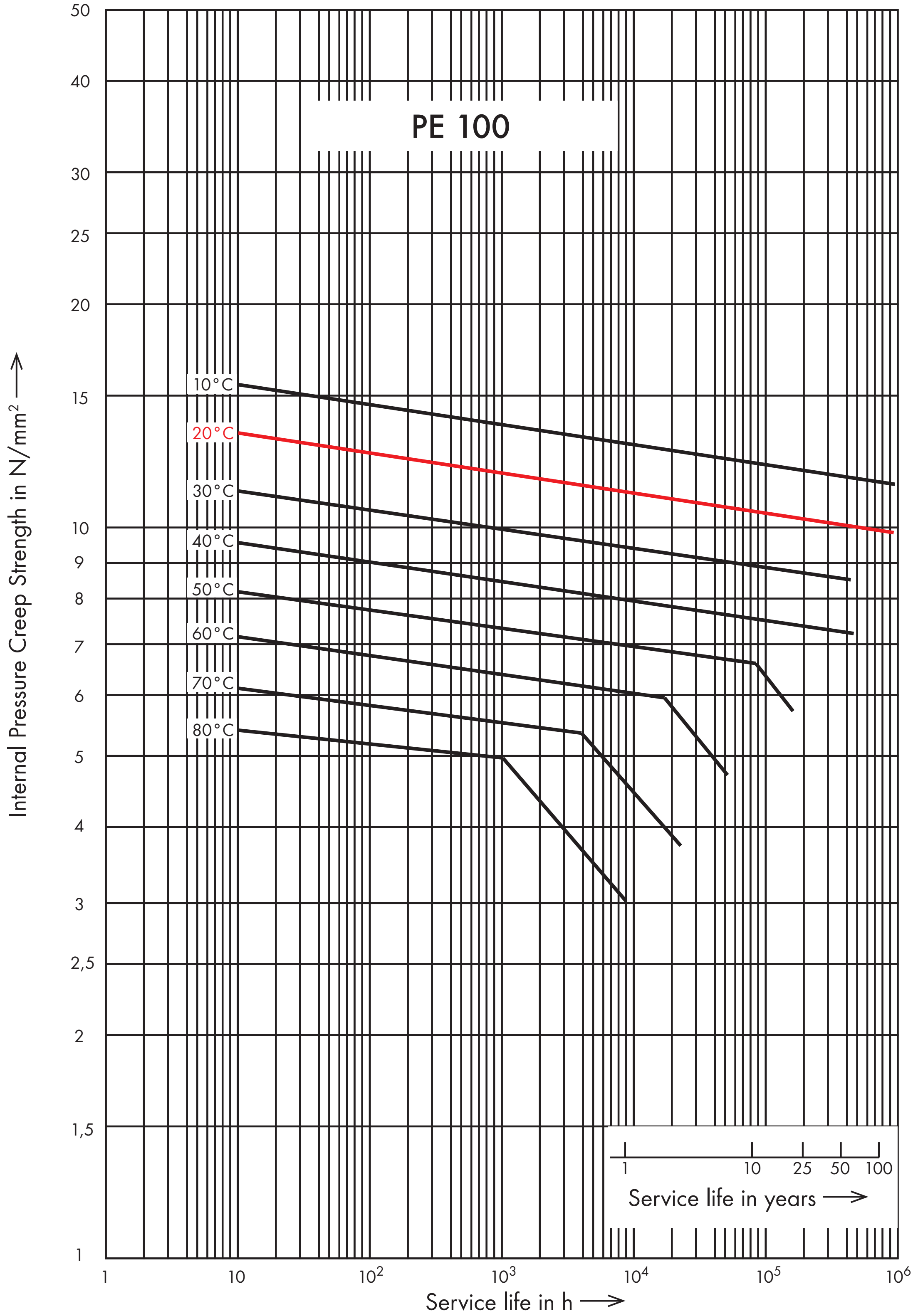


Fig 1-3: Reference internal pressure creep strength characteristics (minimum curves) for pipes made of PE 100, in accordance with DIN 8075 (12.2011)

1.2.4 Controlled Quality and Standards Monitoring

Checks on the quality of the piping utilised afford the security that constructors and operators of pipeline networks need. Extensive agreements on the quality of the plastic pipes used in gas and water distribution have evolved over the course of the years; today, these are fixed at a European standard minimum level specified by the European standards EN 1555 and EN 12201. In Germany, these are additionally described in DVGW (Deutscher Verein des Gas- und Wasserfaches) Worksheet GW 335 Part A2. The materials permitted for pressure piping are recorded in positive lists and furthermore are regularly monitored with respect to their quality according to Table 1-3. The relevant tests for the respective pipes can be found in Table 1-4 on the following page.

Testing of the Materials			
Property	**Requirement**	**Test Procedure**	**Frequency**
Melt index	As per specifications	EN ISO 1133:1999 Condition T 5 kg, 190 °C, 10 minutes	Min. 1 x per week as well as on every change of material and on every dimension check
Loss on drying	≤ 0.1%	Infrared method	Per charge
Homogeneity	≤ Grad 3	ISO 18553	Per charge
Density	≥ 930 kg/m³	DIN EN ISO 1183-2, DIN EN ISO 1872-1	Per charge
Colour	As per DVGW GW 335 Part A2	–	Regularly
Resistance to weathering	As per DVGW GW 335 Part A2 DIN EN 12201-1 DIN EN 1555-1	Black as per ISO 6964, blue and yellow as per DIN EN 921 and DIN EN 1056	Regularly
Thermal stability	> 20 minutes at 200 °C	DIN EN 728	Per charge
Microbiology	As per KTW recommendation as well as DVGW GW 335 Part A2	DVGW W 270	Approval testing
Fast crack growth	As per DVGW GW 335 Part A2 DIN EN 12201-1 DIN EN 1555-1	ISO 13477	1 x annually
Gas resistance	As per DVGW GW 335 Part A2 DIN EN 1555-1	DVGW GW 335 Part A2	Approval testing
Hygiene	As per KTW recommendation as well as DVGW GW 335 Part A2	–	Approval testing
Odour and flavour	As per KTW recommendation as well as DVGW GW 335 Part A2	–	Per charge
Slow crack growth	As per DVGW GW 335 Part A2 DIN EN 12201-1 DIN EN 1555-1	Notch Test DIN EN ISO 13479	Annually
Slow crack growth	–	FNCT ISO 16770 80 °C, 4 N/mm², 2% Arkopal	No testing required by the regulatory codes

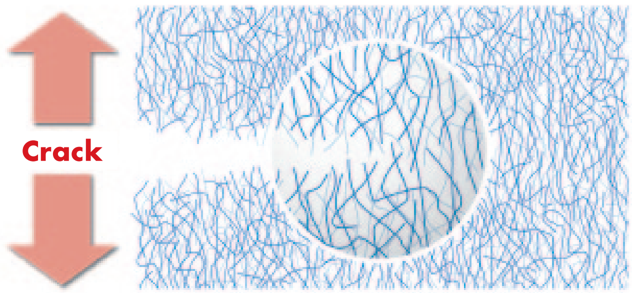
Tab 1-3: Quality and standards monitoring of the materials

Additional Testing of the Finished Piping			
Property	Requirement	Test Procedure	Frequency
Labelling	As per DVGW GW 335 Part A2 DIN EN 12201-2 DIN EN 1555-2	Visual inspection	Regularly every 2 hours
Texture	As per DVGW GW 335 Part A2	Visual inspection	Regularly every 2 hours
Colour	As per DVGW GW 335 Part A2	Visual inspection	Regularly every 2 hours
Warm storage	As per DVGW GW 335 Part A2		1 x per week
Homogeneity	As per DVGW GW 335 Part A2	Visual inspection	1 x per week
Thermal stability	> 20 minutes at 200°C	DIN EN 728	1 x per week
Internal pressure creep test	As per DVGW GW 335 Part A2 DIN EN 12201-2 DIN EN 1555-2	80°C, 165 h; PE 100 σ = 5,5 N/mm^2	On every start at least 1 x per week
Melt index	Max. 20% variation from the raw material	EN ISO 1133:1999 Condition T 5 kg, 190°C 10 minutes	On every change and on every dimension check at least 1 x per week
Hygiene	As per KTW recommendation as well as DVGW GW 335 Part A2	DVGW W 270 / KTW	1 x annually
Slow crack growth	-	FNCT ISO 16770 80°C, N/mm^2, 2% Arkopal	-
Point loading test	-	HESSEL PA PLP 2.2-2 2004-05 80°C, 4 N/mm^2, 2% Arkopal	-

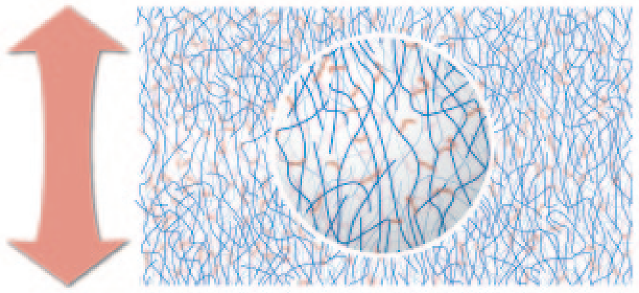
Tab 1-4: Additional tests on the finished piping

1.2.5 The Material PE 100-RC

An open installation with sandbedding has precisely defined bedding and backfilling materials. Compared to this method, open installations without sandbeds, installations with reduced trenching, such as with ploughing and milling, and completely trenchless techniques put elevated requirements on the materials and pipes used. They are subject to additional stresses from stones, shards of old pipes, and other objects contained in the soil. These forces with a direct impact on the pipe can cause a stress additional to that of the internal pressure of the pipe and lead to stress cracks (slow crack growth). An advancement of the well-proven PE 100 materials enables pipes to fulfill the elevated requirements of modern installation methods. These so-called PE 100-RC materials feature a significantly higher resistance to stress cracks. Owing to the high quality requirements, damages resulting from stress cracks can be clearly ruled out.



Low resistance to stress cracking



High resistance to stress cracking

The previous standard requirements cannot fully or partially cope with the elevated requirements that both the pipe and its material are subject to in alternative installation methods. PAS (publicly available specification) 1075 "Polyethylene pipes for alternative installation methods" serves as a supplement for existing standards and guidelines, and it defines characteristics, requirements and testing methods significantly beyond those laid out in the DIN EN and DVGW standards and guidelines. PAS 1075 distinguishes between two classes of testing; one for general approval and one for production monitoring of pipes and materials. The relevant requirements and tests have been summarized in the following tables.

Material requirements and tests

– Additional tests according to PAS 1075 –

Tests	Requirement	Test Method
Slow crack growth	> 8760 h	FNCT, ISO 16770, 80 °C, 4 N/mm², 2% Arkopal or correlating Test Procedures
Point loading test	8760 h	HESSEL, PA PLP 2.2-2 2004-05 80 °C, 4 N/mm², 2% Arkopal
Notch test	8760 h	Notch Test DIN EN ISO 13479

Material requirements and tests

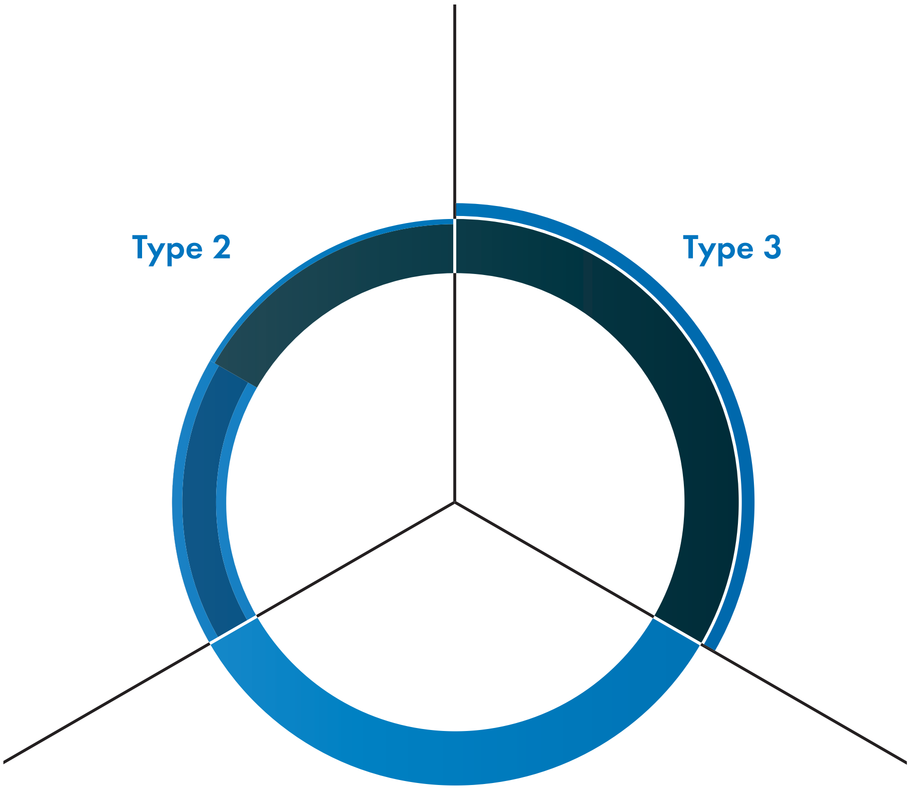
– Additional tests according to PAS 1075 –

Tests	Requirement	Test Method
Slow crack growth	> 3300 h	FNCT, ISO 16770, 80 °C, 4 N/mm², 2% Arkopal or correlating Test Procedures
Point loading test	8760 h	HESSEL, PA PLP 2.2-2 2004-05 80 °C, 4 N/mm², 2% Arkopal
Notch test	8760 h	Notch Test DIN EN ISO 13479

Tab 1-5

Classification of pipe constructions according to PAS 1075

PAS 1075 classifies pipe systems from PE 100-RC into three types, enabling the users to differentiate between pipe constructions.



Type 1: Solid wall pipes made from PE 100-RC

Solid wall pipes made from PE 100-RC according to DIN 8074

Type 2: Pipes with dimensionally integrated layers made of PE 100-RC

Two- and three-layer pipes with dimensionally integrated protective layers made of PE 100-RC. The single layers are inseparably joined by co-extrusion.

Type 3: Pipes with dimensions in accordance with DIN 8074/ISO 4065 made of PE 100-RC with additional external protective layer

Pipes with dimensions in acc. with DIN 8074 with a protective outer layer consist of a core pipe from PE 100-RC and an additional protective layer.

1.2.6 Assessment in the Context of Food Legislation

Defined as "consumer goods" are all objects which are intended to be used in the production, processing, distribution or consumption of foodstuffs and, in doing so, are meant to come into contact with the foodstuffs and act on them (cf. German Foodstuffs and Consumer Goods Act Art. 5 Clause 1). The German Federal Health Office (BGA) regulates the usage of polyethylene in the sense of Art. 5 Clause 1 No. 1 of the German Foodstuffs and Consumer Goods Act (LMBG) in its Recommendation III "Polyethylene".

Applying to public drinking watersystems are the "Recommendationsfor the health assessment of plastics and other non-metallic materials for use with drinking water", the so called KTW (plastic – drinking waterrecommendations) by the Federal Health Office in Berlin.

The regulatory codes stipulate the use of materials for drinking water supply which are commensurate with the best available technology. In DIN 2000, the use of DVGW certified materials, which have proved their functional capability and harmlessness with respect to hygiene, is expressly required in so far as they are available [DIN 2000, 6.6.3].

All of the pipes offered by egeplast for drinking water supply fulfil the conditions of these KTW recommendations with their material composition, as indicated by their marking with the authorisation of the German Technical and Scientific Association for Gas and Water (DVGW).

The health assessment of plastics in foodstuff legislation outside the Federal Republic of Germany differs according to country, even though similar principles apply.

1.2.7 Performance with Regard to Microorganisms

The microbiological and hygienic requirements are specified in DIN 2000, 6.6.1, to the effect that for system components coming into contact with the water, building and working materials, paints, seals, etc. are to be used which do not have any detrimental influence on the water's quality. Both the KTW recommendations and DVGW Worksheet W 270 are to be taken into consideration. Provided that materials, products, and system components are available which have a certification of functional capability and harmlessness with respect to hygiene, e.g. expressed by DVGW approval, then these must be used [DIN 2000, 6.6.3].

According to studies at the botanical institute of the University of Karlsruhe, HDPE offers no source of nutrition for bacteria, fungi, spores, etc. HDPE is therefore resistant to microbial corrosion of any kind.

Please note, in this context, that sulphate-reducing bacteria in the ground have no effect on HDPE pipes since the resistance of the pipes to sulphurous acids and sulphates can be taken for granted.

1.2.8 Performance with Regard to Rodents

Damage to PE pipes by rodents is not known. Rodent teeth do not find sufficient purchase on the smooth pipe surface to be able to cause damage.

1.2.9 Resistance to Light and Weathering

When stored for longer periods outdoors, polyethylene, like most natural and artificial materials, can be damaged by the action of weathering effects, especially by shortwave UV components of sunlight with the involvement of atmospheric oxygen. egeplast PE pipes are protected against these influences by the addition of UV stabilisers. In addition, stabilisers which counteract any thermal ageing that might occur are added to the material. The instructions and guidelines from the DVGW regarding storage of pipes and pipeline parts made of temperature-sensitive and light-sensitive materials are to be observed.

1.2.10 Resistance to Radiation

Pipes made of HDPE can certainly be used in regions of energetic radiation. Indeed, PE pipes have been proving their worth for 40 years for draining radioactive effluent from laboratories, and as cooling water pipelines in the field of nuclear engineering.

1.2.11 Behaviour on Exposure to Flames

Polyethylene is normally inflammable (building material class B2 according to DIN 4102). It ignites on exposure to flames, continues to burn with a weakly luminous flame even outside the source of ignition, and drips burning material. In the process, the usual combustion products for hydrocarbons – CO, C02 and water – are given off, but no corrosive or environmentally damaging residues are produced. According to ASTM-D 1929, the autoignition temperature is 348 °C; the piloted ignition temperature is 340 °C.

1.2.12 Chemical Resistance (in accordance with DIN 8075)

Transported Medium	Fraction[1]	Behaviour at		
		20 °C	40 °C	60 °C
A				
Acetaldehyde	TR	●	◎	◎
Acetic acid (glacial ethanoic acid), aqueous	min. 96%	●	●	◎
Acetic acid methyl ester (methyl acetate)[2]	TR	●	●	-
Acetic acid, aqueous	10%	●	●	●
Acetic anhydride (ethanoic anhydride)	TR	●	●	◎
Acetic anhydride (ethanoic anhydride)	TR	●	●	◎
Acetone	TR	●	●	◎
Acetophenone[2]	TR	●	-	-
Acrylonitrile[2]	TR	●	●	●
Adipic acid	GL	●	●	●
Aeth-, see Eth-				
Air[2]	TR	●	●	●
Allyl alcohol (2-propen-1-ol)	TR	●	●	●
Alum (metal (I) metal (III) sulphates)	L	●	●	●
Aluminium chloride	GL	●	●	●
Aluminium fluoride	GL	●	●	●
Aluminium potassium sulphate (potash alum)	L	●	●	●
Aluminium sulphate	GL	●	●	●
Ammonia solution, aqueous (ammonium hydroxide)	33%	●	●	●
Ammonia, gaseous	TR	●	●	●
Ammonia, liquid	TR	●	●	●
Ammonium aluminium sulphate (Ammonium alum)	L	●	●	●
Ammonium carbonate[2] and hydrogen carbonate	GL	●	●	●
Ammonium chloride	GL	●	●	●
Ammonium fluoride	L	●	●	●
Ammonium iron (III) sulphate (iron alum)	L	●	●	●
Ammonium nitrate	GL	●	●	●
Ammonium phosphate[2]	GL	●	●	●
Ammonium sulphate	GL	●	●	●
Ammonium sulphide	L	●	●	●
Amyl acetate (isopentyl acetate)	TR	●	●	◎
Amyl alcohols (C_5 alkanols)	TR	●	●	◎
Aniline	TR	●	●	◎
Anilinium chloride[2] (aniline hydrochloride)	GL	●	●	●

Tab 1-6

[1] and [2] see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20 °C	40 °C	60 °C
Anisole[2]	TR	◎	◎	
Anone[2] (Cyclohexanone)	TR	●	◎	◎
Antifreeze (motor vehicle)[2]	H	●	●	●
Antimony (III) chloride, aqueous	90%	●	●	●
Apple juice[2]	H	●	●	●
Aqua regia (HCl/HNO_3)	TR	○	○	○
Arsenic acid (arsenic (V) oxide)	GL	●	●	●
B				
Barium carbonate	GL	●	●	●
Barium chloride	GL	●	●	●
Barium hydroxide	GL	●	●	●
Barium sulphate	GL	●	●	●
Beer	H	●	●	●
Beer caramel[2]	VL	●	●	●
Beeswax[2]	H	●	●	◎
Benzaldehyde	TR	●	●	◎
Benzene	TR	◎	◎	◎
Benzoic acid	GL	●	●	●
Benzoyl chloride[2]	TR	◎	◎	◎
Benzyl alcohol[2]	TR	●	●	◎
Bleaching liquor[2] (sodium hypochlorite solution)	20%	◎	◎	○
Borax (disodium tetraborate)	GL	●	●	●
Boric acid	GL	●	●	●
Bromine (bromine water)[2]	GL	●	-	-
Bromine, gaseous, dry	TR	○	○	○
Bromine, liquid	TR	○	○	○
Bromomethane (methyl bromide)[2]	TR	○	○	○
1,3-Butadiene, gaseous[2]	TR	◎	○	○
Butane, gaseous	TR	●	●	●
1,2,4-Butanetriol	TR	●	●	●
Butanols (1-butanol, 2-butanol, tertiary butanol)	TR	●	●	●
2-Butene-1,4-diol[2]	TR	●	●	-
2-Butine-1,4-diol[2]	TR	●	●	-
Butyl acetates (ethanoic acid butyl esters)[2]	TR	◎	○	○
Butyl glycol[2]	TR	●	-	-

Tab 1-6

[1)] and [2)] see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20 °C	40 °C	60 °C
Butyl phenols[2]	GL	●	●	●
Butyl phthalate (Dibutyl phthalate)[2]	TR	●	◎	◎
Butylene glycol (1,4-butanediol)[2]	TR	●	●	●
Butylphenone[2]	TR	○	-	-
Butyric acid and isobutyric acid	TR	●	●	◎
C				
Calcium carbonate	GL	●	●	●
Calcium chlorate	GL	●	●	●
Calcium chloride	GL	●	●	●
Calcium hydroxide	GL	●	●	●
Calcium hypochlorite (chloride of lime), aqueous	slurry	●	●	●
Calcium nitrate	GL	●	●	●
Calcium sulphate	GL	●	●	●
Calcium sulphide	VL	◎	◎	◎
Camphor oil[2]	TR	○	○	○
Carbon dioxide, gaseous	TR	●	●	●
Carbon monoxide, gaseous	TR	●	●	●
Castor oil[2]	TR	●	●	●
Caustic potash (potassium hydroxide solution)	L	●	●	●
Caustic soda (sodium hydroxide solution), aqueous[2]	up to 60%	●	●	●
Caustic soda (sodium hydroxide)	up to 60%	●	●	●
Chloral (trichloroacetaldehyde)[2]	TR	●	●	●
Chloral hydrate[2]	TR	●	●	●
Chloramine[2]	●	●	-	-
Chloric acid, aqueous[2]	1%	●	●	●
Chloric acid, aqueous[2]	10%	●	●	●
Chloride of lime, aqueous	slurry	●	●	●
Chlorine water (chlorine)	GL	●	-	○
Chlorine, aqueous solution (chlorine water)	GL	◎	○	○
Chlorine, gaseous, dry	TR	◎	○	○
Chlorine, gaseous, moist[2]	0.5%	◎	-	○
Chlorine, gaseous, moist[2]	1%	○	○	○
Chlorine, liquid[2]	TR	○	○	○
Chloroacetic acid, aqueous[2]	85%	●	●	●
Chloroacetic acid[2]	L	●	●	●

Tab 1-6

1) and 2) see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20 °C	40 °C	60 °C
Chlorobenzene[2]	TR	◎	-	○
Chloroethane (ethyl chloride)[2]	TR	◎	-	-
2-Chloroethanol (ethylene chlorohydrin)[2]	TR	●	●	●
Chloroform	TR	◎	◎	○
Chloromethane (methyl chloride), gaseous	TR	◎	○	-
Chlorosulphuric acid (chlorosulphonic acid)	TR	○	○	○
Chrome alum (alums)[2]		●	●	●
Chromic acid (chromium (VI) oxide), aqueous	20%	●	●	◎
Chromic acid (chromium (VI) oxide), aqueous	50%	●	◎	◎
Chromic acid / sulphuric acid / water[2] (chromosulphuric acid)	15/35/50%	○	○	○
Chromium potassium (III) sulphate (chrome alum)	L	●	●	●
Cider[2]	H	●	●	●
Citric acid	GL	●	●	●
Citric acid	GL	●	●	●
Coal gas[2]	H	●	-	-
Common salt (sodium chloride)	GL	●	●	●
Copper (II) chloride	GL	●	●	●
Copper (II) nitrate	GL	●	●	●
Copper (II) sulphate	GL	●	●	●
Corn syrup[2]	any	●	●	●
Creosote[2]	H	●	-	-
Cresols[2] , aqueous	90%	●	●	●
Cresols[2] , aqueous	over 90%	●	●	◎
Crotonaldehyde[2] ((E)-2-butenal)	TR	●	-	◎
Cyclohexanol	TR	●	●	●
Cyclohexanone	TR	●	●	●
D				
Decalin (decahydronaphthalene)	TR	●	◎	◎
Detergent[2]	VL	●	●	●
Dextrin	L	●	●	●
Dextrin[2]	L	●	●	●
1,2-Diaminoethane (ethylene diamine)[2]	TR	●	●	●
Dibutyl phthalate[2] (phthalic acid dibutyl ester)	TR	●	◎	◎
Dichloroacetic acid methyl ester[2]	TR	●	●	●
Dichloroacetic acid, aqueous[2]	50%	●	●	●

Tab 1-6

1) and 2) see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20 °C	40 °C	60 °C
Dichloroacetic acid[2]	TR	◎	◎	◎
Dichloroethenes[2] (vinylidene chloride and vinylidene dichloride)	TR	○	-	-
Diesel fuel[2]	H	●	◎	◎
Diethanolamine[2]	TR	●	-	-
Diethyl ether (ethyl ether)	TR	◎	◎	-
Diglycolic acid (oxydiacetic acid)	GL	●	●	●
Diisobutyl ketone[2] (2,6-dimethyl-4-heptanone)	TR	●	-	-
Diisooctyl phthalate[2]	TR	●	●	◎
Diisopropyl ether[2]	TR	●	◎	
Dimethylamine, gaseous	100%	●	●	◎
N,N-Dimethylformamide	TR	●	●	◎
Di-n-butyl ether[2]	TR	◎	○	○
Dinonyl phthalate[2] (DNP)	TR	●	●	◎
Dioctyl phthalate	TR	●	●	◎
1,4-Dioxane	TR	●	●	●
Dithiocarbonic anhydride (carbon disulphide)	TR	◎		
Drinking water, chlorinated[2]	TR	●	●	●
E				
Engine lubricating oils[2]	TR	●	◎	○
Ethanol (ethyl alcohol), aqueous	40%	●	●	◎
Ethanol (ethyl alcohol)[2]	TR	●	●	●
Ethanol, denatured with 20% toluene[2]	96% (Vol.)	●	-	-
Ethyl acetate (acetic acid ethyl ester)	TR	●	◎	○
Ethyl chloride, gaseous (chloroethane)[2]	TR	◎	-	-
Ethylbenzene[2]	TR	◎	-	-
Ethylene chlorohydrin (chloroethanol)[2]	TR	●	●	●
Ethylene glycol (1,2-ethandiol)	TR	●	●	●
Ethylene oxide, gaseous (oxirane)	TR	●	-	-
Exhaust gases[2] and air-gas mixtures				
- carbon dioxide containing	any	●	●	●
- carbon monoxide containing	any	●	●	●
- hydrochloric acid containing	any	●	●	●
- hydrogen fluoride containing	traces	●	●	●
- nitrous (nitrogen oxide) containing	traces	●	●	●
- sulphur dioxide containing	any	●	●	●

Tab 1-6

1) and 2) see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20 °C	40 °C	60 °C
- sulphur trioxide (oleum) containing	traces	○	○	○
- sulphuric acid containing (moist)	any	●	●	●
F				
Fatty acids (from C_4)[2]	TR	●	●	◎
Fermentation mash[2]	H	●	●	●
Fluorine, gaseous	TR	○	○	○
Fluorosilicic acid, aqueous	40%	●	●	●
Formaldehyde, aqueous	40%	●	●	●
Formic acid	TR	●	●	●
Fructose[2]	L	●	●	●
Fruit drinks and fruit juices[2]	H	●	●	●
Furfuryl alcohol	TR	●	●	◎
G				
Gelatine[2]	L	●	●	●
Glucose (grape sugar)	GL	●	●	●
Glycerine (glycerol)	TR	●	●	●
Glycolic acid	L	●	●	●
Grape sugar (glucose)	GL	●	●	●
H				
Heating oil[2]	H	●	◎	◎
n-Heptane	TR	●	◎	○
Hexafluorosilicic acid, aqueous	40%	●	●	●
Hexanes[2]	TR	●	◎	◎
1,2,6-Hexanetriol[2]	TR	●	●	●
Hydrazine hydrate[2]	TR	●	●	●
Hydrobromic acid (hydrogen bromide solution), aqueous	50%	●	●	●
Hydrochloric acid, aqueous	37%	●	●	●
Hydrofluoric acid (hydrogen fluoride solution), aqueous	4%	●	●	●
Hydrofluoric acid (hydrogen fluoride solution), aqueous	60%	●	●	◎
Hydrogen bromide, gaseous	TR	●	●	●
Hydrogen chloride (hydrochloric acid), moist gas[2]	TR	●	●	●
Hydrogen peroxide, aqueous	30%	●	●	●
Hydrogen peroxide, aqueous	90%	●	◎	○
Hydrogen, gaseous	TR	●	●	●
Hydroquinone	GL	●	◎	○

Tab 1-6

[1] and [2] see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20°C	40°C	60°C
I K				
Iodine tincture[2]	H	●	●	◎
Iron (II) chloride	GL	●	●	●
Iron (III) nitrate	L	●	●	●
Iron (III) sulphate	GL	●	●	●
Iron (III) chloride	GL	●	●	●
Iron (II) sulphate	GL	●	●	●
Isoamyl alcohol	TR	●	●	◎
Isobutanol	TR	●	●	●
Isooctane[2]	TR	●	◎	◎
Isopropyl alcohol (2-propanol)[2]	TR	●	●	●
L				
Lactic acid	TR	●	●	●
Lanolin (wool grease)[2]	H	●	◎	◎
Lead (II) acetate	GL	●	●	●
Lead tetraethyl[2] (tetraethyl lead)	TR	●	-	-
Linseed oil[2]	H	●	●	●
M				
Machine oil[2]	TR	●	◎	○
Magnesium carbonate	GL	●	●	●
Magnesium chloride	GL	●	●	●
Magnesium hydroxide	GL	●	●	●
Magnesium nitrate	GL	●	●	●
Maleic acid	GL	●	●	●
Malic acid[2]	L	●	●	●
Menthol[2]	TR	●	●	◎
Mercury	TR	●	●	●
Mercury (I) nitrate	L	●	●	●
Mercury (II) chloride	GL	●	●	●
Mercury (II) cyanide	GL	●	●	●
Methanol	TR	●	●	●
Methoxybutanol[2]	TR	●	●	◎
2-Methyl-2-butanol (tertiary amyl alcohol)	TR	●	●	◎
Methyl acetate (acetic acid methyl ester)[2]	TR	●	●	-
Methyl bromide (bromomethane)[2]	TR	◎	-	○

Tab 1-6

[1)] and [2)] see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20 °C	40 °C	60 °C
Methyl chloride (chloromethane), gaseous	TR	◎	○	○
Methyl ethyl ketone[2]	TR	●	●	◎
Methylamine, aqueous[2]	32%	●	-	-
Methylbenzoic acids (toluic acids)	GL	◎	◎	-
Methylene chloride (dichloromethane)[2]	TR	◎	◎	○
Milk	H	●	●	●
Mineral fertilisers[2]	GL	●	●	●
Mineral oils	H	●	●	◎
Mineral water[2]	H	●	●	●
Molasses	H	●	●	●
N				
Naphtha[2]	H	●	○	○
Natural gas[2]	TR	●	-	-
Nickel (II) chloride	GL	●	●	●
Nickel (II) nitrate	GL	●	●	●
Nickel (II) sulphate	GL	●	●	●
Nicotinic acid	VL	●	●	-
Nitric acid, aqueous	25%	●	●	●
Nitric acid, aqueous	50%	◎	◎	○
Nitric acid, aqueous	75%	○	○	○
Nitrobenzene[2]	TR	●	◎	◎
2-Nitrotoluene[2]	TR	●	◎	○
O				
Oils and fats, edible	H	●	◎	◎
Oleic acid	TR	●	●	●
Oleum ($H_2SO_4 + SO_3$)[2]	TR	○	○	○
Olive oil[2]	TR	●	●	◎
Oxalic acid	GL	●	●	●
Oxygen	TR	●	●	◎
Ozone, gaseous	TR	◎	○	○
P Q R				
Paraffin emulsions[2]	H	●	●	◎
Paraffin oil[2]	TR	●	◎	◎
Peanut oil[2]	TR	●	●	-
1-Pentanol (n-amyl alcohol)	TR	●	●	◎

Tab 1-6

1) and 2) see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20 °C	40 °C	60 °C
2-Pentanol (secondary n-amyl alcohol)	TR	●	●	◎
Peppermint oil[2]	TR	●	-	-
Perchloric acid, aqueous	20%	●	●	●
Perchloroethylene (tetrachloroethene)[2]	TR	◎	◎	○
Petrol (petroleum ether and regular petrol, aliphatic carbon hydrides)	H	●	●	◎
Petroleum ether[2]	TR	●	◎	◎
Petroleum spirit[2]	TR	●	◎	○
Petroleum[2]	TR	●	◎	◎
Phenol	L	●	●	●
Phosgene, gaseous[2] (carbonyl chloride)	TR	◎	◎	◎
Phosphates, inorganic[2]	GL	●	●	●
Phosphoric acid	50%	●	●	●
Phosphoric acid	95%	●	●	◎
Phosphorus (III) chloride[2]	TR	●	●	◎
Phosphorus oxychloride[2]	TR	●	●	◎
Phosphorus trichloride	TR	●	●	◎
Photo developer	H	●	●	●
Photo emulsions[2]	H	●	●	-
Photo fixers	H	●	●	-
Phthalic acid	GL	●	●	●
Picric acid	GL	●	●	-
Pine oil[2]	H	●	◎	◎
Potassium bromate	GL	●	●	●
Potassium bromide	GL	●	●	●
Potassium carbonate	GL	●	●	●
Potassium chlorate	GL	●	●	●
Potassium chloride	GL	●	●	●
Potassium chromate	GL	●	●	●
Potassium cyanide	L	●	●	●
Potassium cyanide	L	●	●	●
Potassium dichromate	GL	●	●	●
Potassium fluoride	GL	●	●	●
Potassium hexacyanoferrate (II) and (III)	GL	●	●	●
Potassium hydrogen carbonate (potassium bicarbonate)	GL	●	●	●
Potassium hydrogen sulphate (potassium bisulphate)	GL	●	●	●

Tab 1-6

1) and 2) see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20°C	40°C	60°C
Potassium hydrogen sulphite (potassium bisulphite)	L	●	●	●
Potassium hypochlorite	●	●	●	◎
Potassium iodide[2]	GL	●	●	●
Potassium nitrate	GL	●	●	●
Potassium perchlorate	GL	●	●	●
Potassium permanganate, aqueous	20%	●	●	●
Potassium peroxydisulphate (potassium persulphate)	GL	●	●	●
Potassium phosphate	GL	●	●	●
Potassium sulphate	GL	●	●	●
Potassium sulphide	L	●	●	●
Propane, gaseous[2]	TR	●	●	-
1-Propanol[2] (propyl alcohol)	TR	●	●	●
Propargyl alcohol, aqueous[2] (2-propyn-1-ol)	7%	●	●	●
Propionic acid	TR	●	◎	◎
Propionic acid, aqueous	50%	●	●	●
Propylene glycols[2] (propanediols)	TR	●	●	●
Prussic acid, aqueous	10%	●	●	●
Prussic acid[2]	TR	●	●	●
Pyridine	TR	●	◎	◎
S				
Salicylic acid	GL	●	●	●
Sea water[2]	H	●	●	●
Sea water[2]	H	●	●	●
Silicic acid, aqueous[2]	any	●	●	●
Silicone emulsion[2]	H	●	●	●
Silicone oil	TR	●	●	●
Silver acetate	GL	●	●	●
Silver cyanide	GL	●	●	●
Silver nitrate	GL	●	●	●
Soda (sodium carbonate)[2]	50%	●	●	●
Sodium acetate[2]	GL	●	●	●
Sodium benzoate	GL	●	●	●
Sodium benzoate, aqueous[2]	35%	●	●	●
Sodium borate - hydrogen peroxide[2] (sodium perborate)	GL	●	●	◎
Sodium bromide	GL	●	●	●

Tab 1-6

[1] and [2] see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20 °C	40 °C	60 °C
Sodium carbonate	GL	●	●	●
Sodium chlorate	GL	●	●	●
Sodium chloride (common salt)	GL	●	●	●
Sodium chlorite, aqueous[2]	2 to 20%	●	◎	○
Sodium cyanide	GL	●	●	●
Sodium dichromate[2]	GL	●	●	●
Sodium fluoride	GL	●	●	●
Sodium hexacyanoferrate (II) (sodium ferrocyanide)	GL	●	●	●
Sodium hexacyanoferrate (III) (sodium ferricyanide)	GL	●	●	●
Sodium hydrogen carbonate (sodium bicarbonate)	GL	●	●	●
Sodium hydrogen sulphite (sodium bisulphite)	L	●	●	●
Sodium hydroxide, aqueous (caustic soda)	40%	●	●	●
Sodium hypochlorite (15% available chlorine (bleaching liquor))	L	●	●	●
Sodium nitrate	GL	●	●	●
Sodium nitrite	GL	●	●	●
Sodium phosphate	GL	●	●	●
Sodium silicate (water glass)[2]	L	●	●	●
Sodium sulphate	GL	●	●	●
Sodium sulphide	GL	●	●	●
Sodium tetraborate (borax)	GL	●	●	●
Sodium thiosulphate[2]	GL	●	●	●
Soybean oil[2]	TR	●	◎	◎
Spindle oil[2]	TR	●	◎	◎
Spirits of ammonia (ammonia water)	GL	●	●	●
Spirits of every type[2]	H	●	●	●
Spirits of turpentine[2]	TR	◎	◎	◎
Starch[2]	any	●	●	●
Succinic acid[2]	GL	●	●	●
Sugar syrup[2]	H	●	●	●
Sulfuryl chloride[2] (sulfonyl chloride)	TR	○	○	○
Sulphur dioxide, gaseous	TR	●	●	●
Sulphur hydride, gaseous (hydrogen sulphide)	TR	●	●	●
Sulphur trioxide	TR	○	○	○
Sulphuric acid	98%	◎[3]	◎	○
Sulphuric acid, aqueous	80%	●	●	●
Sulphuric acid, fuming	H	○	○	○

Tab 1-6

1) and 2) see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20°C	40°C	60°C
Sulphurous acid, aqueous	30%	●	●	●
T				
Tannic acid (tannin)	L	●	●	●
Tannin (tannic acid)	L	●	●	●
Tartaric acid	L	●	●	●
Tetrachloroethane[2]	TR	◎	◎	○
Tetrachloroethene (perchloroethylene)[2]	TR	◎	◎	-
Tetrachloromethane (Carbon tetrachloride)	TR	◎	○	○
Tetrahydrofuran[2]	TR	◎	◎	○
Tetrahydronaphthalene (tetralin)[2]	TR	◎	◎	○
Thionyl chloride (sulphinyl chloride)	TR	○	○	○
Thiophene[2]	TR	◎	◎	○
Tin (II) chloride	GL	●	●	●
Tin (IV) chloride	GL	●	●	●
Toluene	TR	◎	○	○
Transformer oil (insulating oil)[2]	TR	●	◎	◎
Trichloroacetic acid, aqueous	50%	●	●	●
Trichloroethylene (trichloroethene)	TR	○	○	○
Tricresyl phosphate (phosphoric acid tritolyl ester)[2]	TR	●	●	●
Triethanolamine (2,2´,2´´-nitrilotriethanol)	●	●	●	◎
Trioctyl phosphate[2]	TR	●	●	◎
U V W				
Urea	L	●	●	●
Urine		●	●	●
Vaseline oil[2]	TR	●	◎	◎
Vinegar (wine vinegar)[2]	H	●	●	●
Vinyl acetate[2]	TR	●	●	◎
Vinylidene chloride (1,1-dichloroethylene)[2]	TR	○	-	-
Water	TR	●	●	●
Wine vinegar (edible vinegar)	H	●	●	●
Wines and spirits	H	●	●	●
X Y Z				
Xylene	TR	◎	○	○
Yeast	L	●	●	●
Zinc carbonate	GL	●	●	●

Tab 1-6

1) and 2) see Page 28

Transported Medium	Fraction[1]	Behaviour at		
		20 °C	40 °C	60 °C
Zinc chloride	GL	●	●	●
Zinc oxide	GL	●	●	●
Zinc sulphate	GL	●	●	●
Sugar syrup[2]	H	●	●	●

Tab 1-6

[1]) The following abbreviations are used for the composition of the transported materials:

- If there is no "(vol.)" annotation after the fraction specification, then the value refers to the mass fraction in % (previously wgt %).
  - VL: aqueous solution, whose mass fraction is <10%.
  - L: aqueous solution, whose mass fraction is >10%.
  - GL: saturated (at 20 °C), aqueous solution.
  - TR: transported material is at least commercially pure.
  - H: commercially usual composition.
- Volume fraction in % (previously vol. %); this is specially marked with "(vol.)".

The chemical resistance of pipes and pipeline components is generally not reduced for mass or volume fractions and temperatures lower than those given in the table.

[2]) This information on chemical resistance is not contained in ISO/TR *7474*.

[3]) The chemical resistance is rated to be one group higher in ISO/TR *7474*.

The reaction of pipes and pipeline parts with the transported media should be classified in the following groups:

● Resistant
The pipe material is generally rated as suitable

◎ Partially resistant
The suitability of the pipe material for the particular application is to be verified; further tests should be carried out if necessary

○ Not resistant
The pipe material is generally rated as unsuitable

\- Information about the chemical resistance is not available

1.3 Grid creation

1.3.1 Fittings

Next to the pipe itself, construction of a pipeline requires molded parts for joints, directional changes, transitions to other materials, and branches.

In connection technology for plastics pipes, there is a general differentiation between separable joints (such as flanges) and inseparable joints (such as electrofusion welds). When choosing a particular connection technology, it is wise to consider if a longitudinally force-locked joint is required or not.

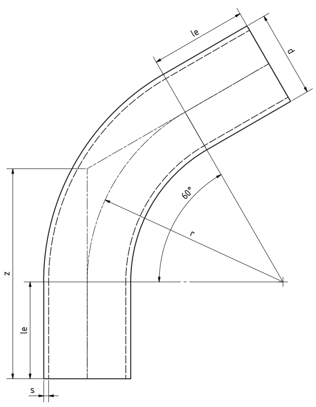
In general, fittings are available as short and long version. Short fittings need to be installed with short clamping jaws or collar brackets since they might not have sufficiently large cylindrical ends for clamping.

Long fittings can be processed with standard butt welding machines and equipment, as well as with electrofusion jointing.

1.3.1.1 Fittings compliant with pressure class

Pressure-class compatible fittings are parts that can withstand the entire inner pressure of the pipeline used. For example, this includes:

■ Seamless bends

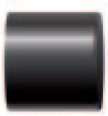


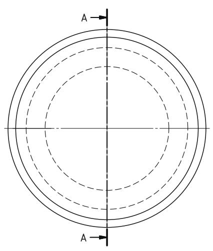
Seamless bends are produced with a tolerance of $\alpha = \pm 5°$, following DIN EN 12201. Please note, that the bends might expand in case of long storage times or exposure to heat due to the memory effect. For larger bends, it is recommended to also order pipe fixations to avoid this effect.

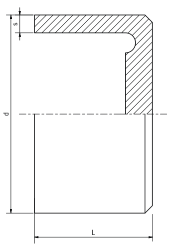
Generally available are dimension-related standard radii of r = 1,5 x d in standard angles of:
$\alpha = 11°, 22°, 30°, 45°, 60°, 90°$

The specification for degrees and radii can be custom-made for your project. Seamless bends are designed for electrofusion and butt welding by default.

■ End caps

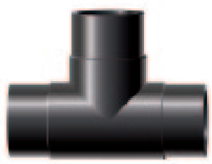


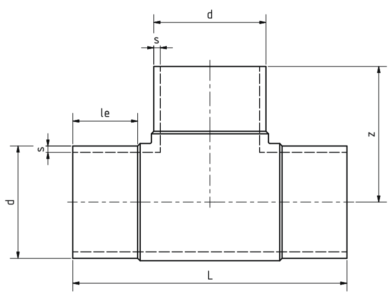




End caps made of PE 100 for a pressure-class compatible sealing of pipe ends.

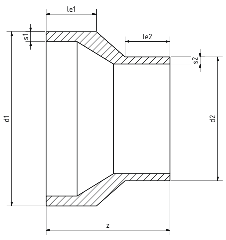
■ Tees / Branches

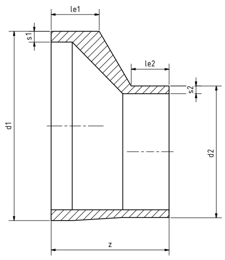




Pressure-class compatible tees and branches made of PE 100 for pressure applications where segmented fittings with pressure reduction factor are inadequate.

■ Reducers





Reducers differ by a centric (concentric) or excentric design.

1.3.1.2 Pressure-class incompatible fittings

Segmented fittings are made from pipe depending on their requirements. They are designed for electrofusion and butt welding by default. Inner beads up to a dimension of OD 630 mm are always removed (for larger dimensions upon request).

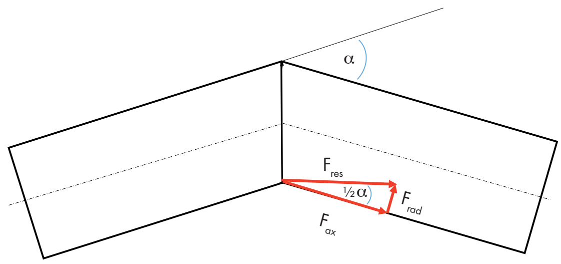
Fittings made from pipe segments are usually not pressure-class compatible due to the position of the weld seams and are to be calculated with a pressure reduction factor (reduction factor for operating pressure) when planning. However, these parts are used frequently if the admissible inner pressure resistance of the fitting is suffiently high for the designed operating pressure of the pipeline.

The reduction coefficient is:
Segmented bends: 0.8
Segmented tees: 0.6
Segmented tees, reduced: 0.5
Y-sections: 0.6

Example: A pipe-made segmented bend, SDR17 (PN10) would thus be designed for a maximum operating pressure of 8 bar.

The reduction coefficient accomodates the fact that a segmented bend has the tendency to 'straighten out' under inner pressure. Considering forces around the joining section on the inside of the bend and calculating the resultant, the impact of cutting angle $\alpha/2$ on the resultant becomes evident. The lower cutting angle $\alpha/2$, the lower its impact on the resultant. $\alpha/2 = 0°$ → standard butt weld.

One could just as well imagine a drawn, pressure-class compatible bend as a segmented bend made of an unlimited number of segments. This way pressure-class compatible segmented bend could be produced, provided there is a sufficiently high amount of single segments. This is a low-cost alternative to seamless bends, especially for larger dimensions.



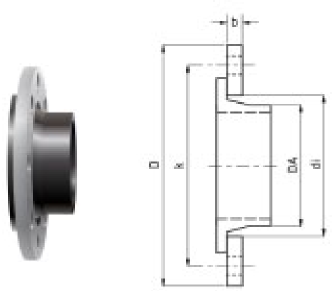
1.3.2 Joining Techniques

In general, a distinction is made between separable jointings that can be separated and re-connected using tools, and inseparable jointings.

1.3.2.1 Separable joints

All separable jointings have in common that they are made of a combination of different materials. The flange joint is probably the best known separable type of jointing.

There are fixed flanges (with fixed flange leaf) and loose type flanges (with freely rotating flange leaf).



Stub end with loose flange

D largest flange diameter
k drill hole circle
b flange thickness
DA outer diameter pipe
di inner diameter flange

A stub end with freely rotating loose flange is the most used, whereby the stub end is welded to the pipeline. Brackets need to be used to clamp the stub end in the welding machine. If these are not available, long stub ends have to be used.

Flanges always seal the connection either with a seal that is inserted in between the sealing surfaces or as an O-ring.

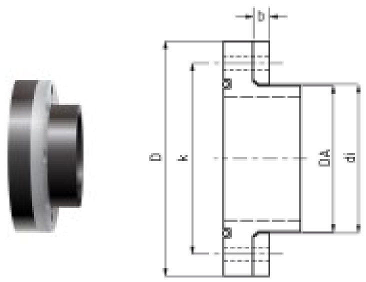
There is a multitude of sealing materials and forms. In terms of plastic flanges, a profile gasket with steel insert is state of the art. In order to achieve an appropriate tightness of the flange with the necessary surface pressure, the choice of screw quality in combination with the required torque are of importance.

Since their application is derived from metallic pipelines, flange dimensions are related to cast iron and steel pipes. The different dimensional base of the pipe systems (inner diameter for metallic pipelines, outer diameter for plastic pipelines) can cause "unharmonious" dimensions throughout the pipe grid.

Special flange joints for PE pipe systems have entered the market in order to avoid the described problem and to accomodate the many different requirements.

These are special bored collars (fixed flanges) with steel flanges (stainless steel, plastic-coated steel, or galvanized), whose nominal width DN is reduced by one step compared to loose flanges and are thus also fit to be used in nominal width-compatible connections between pipes and fittings.

Example using a pipe with diameter 355mm:



Special flange joints

Loose flange joint ➡ stub end d 355/loose flange DN 350 ➡ valve/fitting DN 350
Special flange joint ➡ special flange d 355 DN 300 ➡ valve/fitting DN 300

1.3.2.2 Inseparable joints

Welding PE pipes and fittings is considered as inseparable jointing. Welding PE 100/PE 100-RC pipes to each other, or to normed fittings, is possible in accordance with the parameters set out in DVS guideline 2207, part 1, issue of 08/2015 for PE-HD, using:

- Butt welding
- Electrofusion

Next to welded jointings, plug-in sleeve connections (in appropriate executions) are also regarded as inseparable jointing methods.

■ Electrofusion Welding Procedure

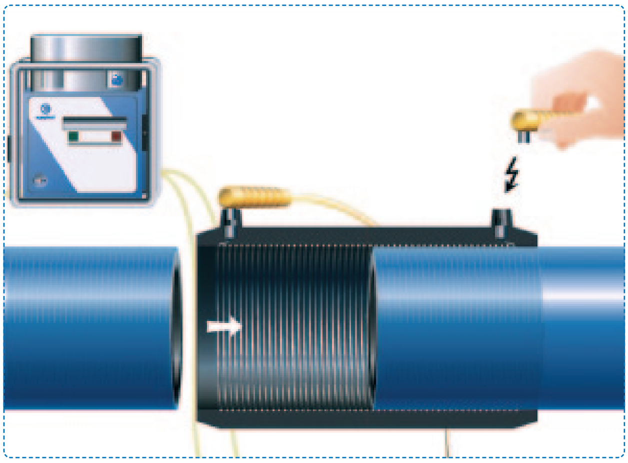


Fig 1-4

Fig 1-5

The requirements of DVS Guideline 2207 Part 1 apply for electrofusion welding. The circularity of the pipes is to be ensured using re-rounding clamps if necessary. Ovality up to a maximum of 1.5% of the outer diameter is permitted. In electrofusion, fittings equipped with resistance wires are used for joining. Pipe and fitting are welded together by applying a defined current for a defined time. The welding pressure is generated in the process through the design of the fitting. The manufacturers of the fittings specify the welding parameters. The nominal diameter of the pipe must be existent in the electrofusion area.

The welding area is cleaned with lint-free, non-colouring paper and PE cleaning agent. The insertion depth of the fitting is marked on the surface of the pipe, the pipe ends chamfered, and the surface of the pipe in the area of the welding zone machined. After the fitting has been cleaned, the insertion depth is transferred to the pipe for checking purposes, without touching the grease-free surface. The fitting is put on, connected to the contacts of the welding unit, and welded. Misunderstandings are avoided by labelling the weld with the date and the end of the cooling-off period.

Butt Fusion Welding Procedure

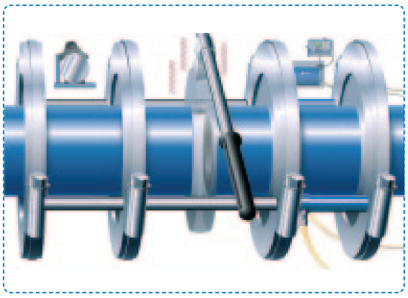


Fig 1-6

Checklists for butt fusion welding in accordance with DVS 2207 Part 1 are provided by the Institute for Plastic Processing in Trade and Industry at the RWTH Aachen e.V..
The maximum permissible misalignment of the piping to be welded together in accordance with DVS 2207 Part 1 amounts to less than 10% of the wall thickness. If necessary, the circularity of the pipes is to be ensured using re-rounding clamps. Ovality up to a maximum of 1.5% of the outer diameter is permitted. Specifications regarding the maximally permissible gap widths according to DVS 2207-1 can be found in Table 1-7.

Fig 1-7

OD ≤ 355 mm	gap widths ≤ 0.5 mm
400 mm ≤ OD < 630 mm	gap widths ≤ 1.0 mm
630 mm ≤ OD < 800 mm	gap widths ≤ 1.3 mm
800 mm ≤ OD ≤ 1000 mm	gap widths ≤ 1.5 mm
OD > 1000 mm	gap widths ≤ 2.0 mm

Tab 1-7: Maximally permissible gap widths in accordance with DVS 2207 Part 1

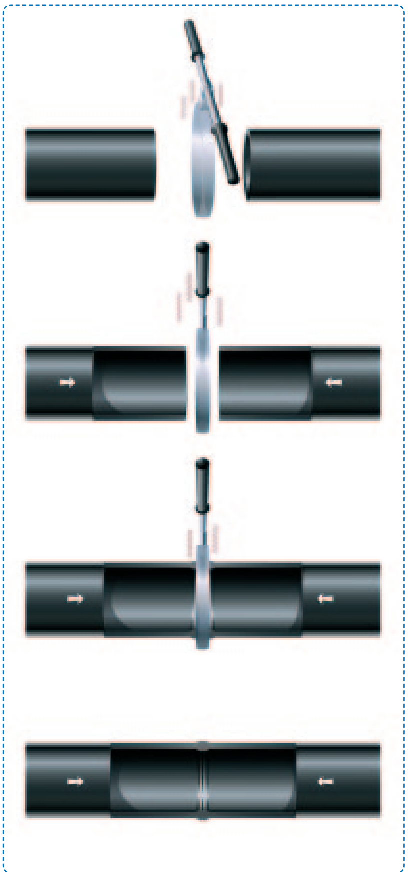


Fig 1-8: Principle of butt fusion welding

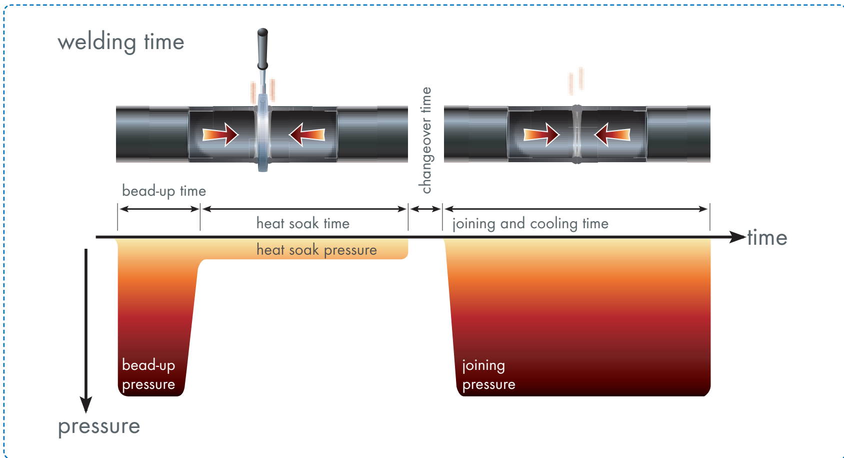


Fig 1-9: Time flow for butt fusion welding in accordance with DVS 2207 Part 1

The piping sections are brought to the heating element (recommended temperature 220 °C +/- 10 °C) and heated under pressure (0.15 $\frac{N}{mm^2}$), until a circumferential bead of a specific height has formed (see Tab 1-8). Heat soaking then takes place almost without pressure until the pipes can be welded. The heat soak time in seconds corresponds to 10 times the wall thickness of the pipes according to DVS 2207 Part 1. On completion of the heat soak time, the heating element is removed and the pipes are joined together under pressure (likewise 0.15 N $\frac{}{mm^2}$). The changeover time should be kept as short as possible.
The pipes must be allowed to cool off without stress under joining pressure. The cooling-off time is independent of the wall thickness of the piping.

Guideline values for butt welding of piping and pipeline parts made of HDPE at moderate air movement

Nominal wall thickness s	Bead-Up Bead Height at Heating Element at End of Bead-Up Time (Bead-Up under 0.15 N/mm² +/- 0.01)	Heat Soaking Heat Soak Time = 10 x Wall Thickness (Heat Soaking p ≤ 0.01 N/mm²)	Changeover Maximum Time	Joining	Cooling-Off Time under Joining Pressure p = 0.15 ± 0,01 N/mm²
	Minimum Values			Joining Pressure Build-Up Time s	Minimum Values
mm	mm	Seconds	Seconds	Seconds	Minutes
up to 4.5	0.5	up to 45	5	5	see table 1-9
4.5...7	1.0	45...70	5...6	5...6	
7...12	1.5	70...120	6...8	6...8	
12...19	2.0	120...190	8...10	8...11	
19...26	2.5	190...260	10...12	11...14	
26...37	3.0	260...370	12...16	14...19	
37...50	3.5	370...500	16...20	19...25	
50...70	4.0	500...700	20...25	25...35	
70...90	4.5	700...900	25...30	35	
90...110	5.0	900...1100	30...35	35	
110...130	5.5	1100...1300	max. 35	35	

Tab 1-8: Source: DVS 2207, Part 1

Cooling-off times of pipes and pipeline parts made of HDPE dependent upon the ambient temperature

Nominal wall thickness s [mm]	Cooling-off time (minimal values) under joining pressure p = 0.15 ± 0,01 N/mm² depending on the ambient temperature [min]		
	up to 15 °C	15 °C ... 25 °C	25 °C ... 40 °C
up to 4.5	4.0	5.0	6.5
4.5...7	4.0...6.0	5.0...7.5	6.5...9.5
7...12	6.0...9.5	7.5...12	9.5...15.5
12...19	9.5...14	12...18	15.5...24
19...26	14...19	18...24	24...32
26...37	19...27	24...34	32...45
37...50	27...36	34...46	45...61
50...70	36...50	46...64	61...85
70...90	50...64	64...82	85...109
90...110	64...78	82...100	109...133
110...130	78...92	100...118	133...157

Tab 1-9: Source: DVS 2207, Part 1

Interim values are to be interpolated according to:

$$coolingtime_{interpolated} = coolingtime_{small} + \left(\frac{s_{real} - s_{small}}{s_{large} - s_{small}}\right) \cdot (coolingtime_{large} - coolingtime_{small}) \text{ [in minutes]}$$

with:

s_{real} = wall thickness of the piping to be welded
s_{small} = smaller nominal wall thickness in Table 1-9
s_{large} = larger nominal wall thickness in Table 1-9
cooling $time_{small}$ = cooling time for the smaller wall thickness, according to Table 1-9
cooling $time_{large}$ = cooling time for the larger wall thickness, according to Table 1-9

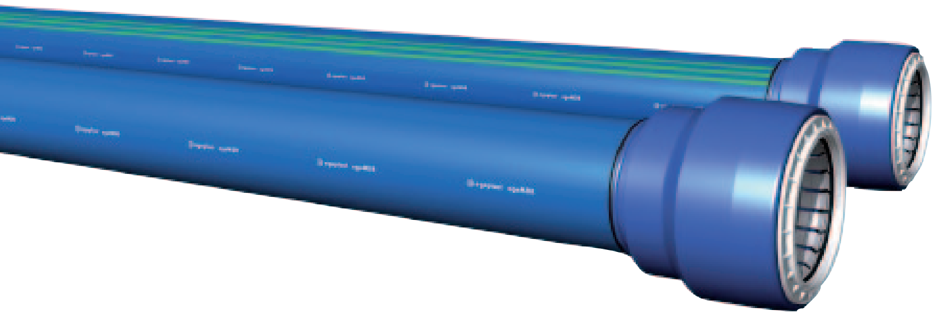
Example

PE 100 pipe, OD 160 mm, wall thickness s = 14.6 mm, ambient temperature 15 °C. Pursuant to table 1-9, the cooling-off time for 12 mm of wall thickness amounts to 12 minutes, for 19 mm 18 minutes respectively (minimum values).

$$coolingtime_{interpolated} = 12min + \left(\frac{14.6mm - 12mm}{19mm - 12mm}\right) \cdot (18min - 12min) \approx 15min$$

■ Plug-in sleeve connection

If applicable, plug-in sleeve jointing can also be regarded as inseparable jointing methods.



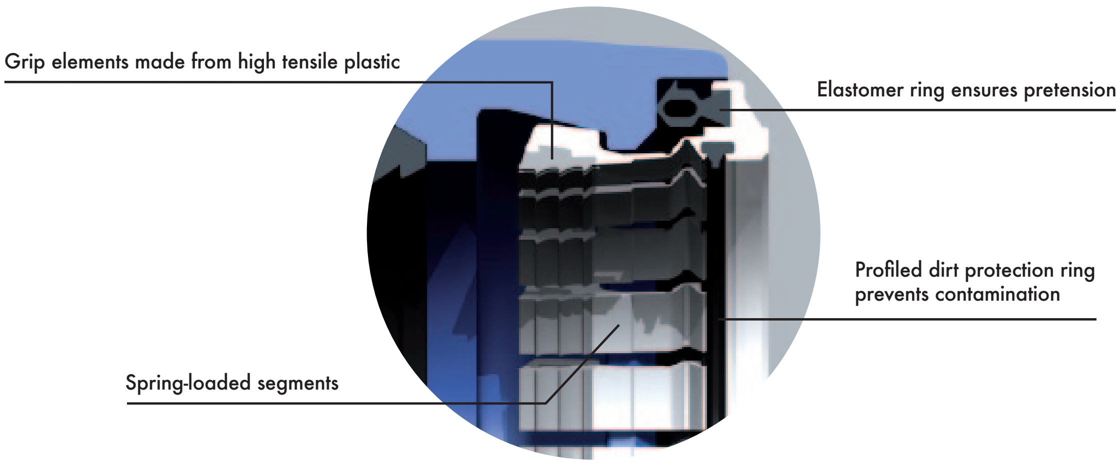
Spigot and socket systems are well established in water supply applications for decades because of its ease of assembly. It represents a practical alternative to welding and offers a number of benefits, especially for small sections of pipelines.

Short installation and processing times through simple and fast assembly and short preparation times, installation irrespective of weather, as well as processing without any specialty equipment – and all this while maintaining the familiar flexibility, permanent tightness and pressure resistance. Also an ideal solution for smaller installers that don´t have easy access to welding technicians.

Fig 1-10

Example of an inseparable and longitudinally force-locked jointing method using plug-in sleeves:

- Grip elements made from high tensile plastic integrated in the socket provide a guarantee against the spigot from being pulled out – the connection is axially force locked
- The socket's individually attached flexible segments avoid damage during assembly as the segments grip the outer pipe surface smoothly on the entire pipe circumference
- An elastomeric ring ensures sufficient pretension already during installation stage
- The socket's profiled dirt protection ring prevents contamination of connection surfaces



1.3.3 Material transitions

Transitions to other materials can be executed in a separable and an inseparable way.

1.3.3.1 Separable material transitions

One of the most used types is the separable flange connection, enabling a material transition owing to the standardized flange dimensions (DIN EN 1092-1). The relevant nominal widths and pressure classes need to be observed on both sides of the joint.

Another separable material transition is the group of plug-in sleeves, available both with and without longitudinal force-locking.

1.3.3.2 Inseparable material transitions

An example for inseparable material transitions are transition pieces that are factory-made from both materials (e.g. steel / PE-HD) and only need to be welded into the pipeline on site.

In terms of smaller dimensions, inseparable material transitions using compression fittings are becoming more and more common practice in pipe installation. This usually entails pressing a metallic material axially onto the pipe on a support bushing. The support bushing is equipped with a metallic pipe piece in standard dimension so it can be welded onto the metallic pipe. Threaded models are also available.

1.3.4 Repair options

Damaged pipelines can be repaired in different ways. According to DVGW standards, scores and notches with more than 10% of the pipe wall thickness constitute a damage. While it is economically reasonable to cut out and replace these damaged segments for smaller dimensions, weld-on repair saddles are an example of a better option for larger dimensions (OD 560 mm up to OD 1200 mm).

These and similar components are also available for smaller dimensions and even enable a repair while the medium is leaking out.

Fig 1-11

Mechanical fittings are a possibility just as well, especially since they offer a repair in outdoor conditions where welded jointings cannot be used all the time as these always require dry material surfaces.

If pipelines need to be repaired after a longer operating time, these fittings are a good choice as the pipeline might have a larger outer diameter. That stems from the expansion due to the inner pressure and does not affect operation negatively since this expansion was already provided for in the design of the pipe.

If a change of material is not required, plastic plug-in fittings as repair couplers can be used, both available with and without tensile strength.

2 Planning of PE piping systems

2.1 General

The relevant guidelines for planning and constructing water pipelines are prescribed in DVGW's regulation W 400 "Code of practice for water distribution systems - Part 1: Design; and Part 2: Construction and testing". These guidelines should also be applied for similar applications, such as for raw water, process water and sewage water pipelines if no other technical guidelines exist for them (in keeping with their respective specific requirements). DVGW worksheet G 472 applies for planning and constructing gas pipelines "Polyethylene gas pipelines with an operating pressure up to and including 10 bar - Construction". Among others, trench excavation is stipulated in standard DIN 4124: "Construction trenches and pits - slopes, planking and working space widths" as well as in DIN EN 805 "Water supply - Requirements for systems and components outside buildings; German version EN 805:2000". More information can be obtained in KRV guidelines A 135/99-15 and A 435/96-10. An assessment of the backfilling material requirements is laid out in DIN 18196 "Earthworks and foundations - Soil classification for civil engineering purposes" as well as DIN EN ISO 14688 "Identification and classification of soil". The mentioned standards do not warrant a claim for completeness.

All pipeline components need to be installed in a depth safe from frost. The minimal depth of coverage for gas pipes ranges from 0.6 to 1.0 m, while the cover for sections of up to approx. 2.0 m without a specific load (frontyards, sidewalks) may be reduced to 0.5 m. For pressurized water mains, installation depths are to be frost-free at 1.0 m to 1.8 m (depending on soil and climate conditions).

The trench bottom is to be constructed in such a way as to accomodate the pipeline in a level manner. Should there be rocks or stones at the trench bottom, the trench needs to be dug deeper and the soil has to be replaced with appropriate material. The grain size composition of that new material may also not cause damages to the pipes.

The drainage effect of pipe trenches on steeply sloping sections should be prevented with appropriate measures, since the pipe bed may otherwise be washed out, resulting in an undermination of the pipe. It also needs to be secured against slipping. Differing soils and different load capacities can for example be countered with larger sandbeds. The bedding is to be carried out so as to avoid an erosion of fine particles.

2.2 Route planning

Today's supply grids have been created nationwide, at least concerning Germany. This results in an increased focus on renewal and rehabilitation of pipes, especially using alternative trenchless installation methods, as compared to new constructions.

DVGW association is also recommending to consider the utility of trenchless techniques in its W 400-1 guideline: "When renewing pipelines, the utility of trenchless techniques for rehabilitation or new construction projects should be considered, as they could lead to a significant reduction of the surrounding circumstances of the construction project, to sizable cost reductions, and to environmentally relevant advantages [refer to DVGW GW 320 (A), DVGW GW 321 (A) and DVGW GW 323 (M)]."

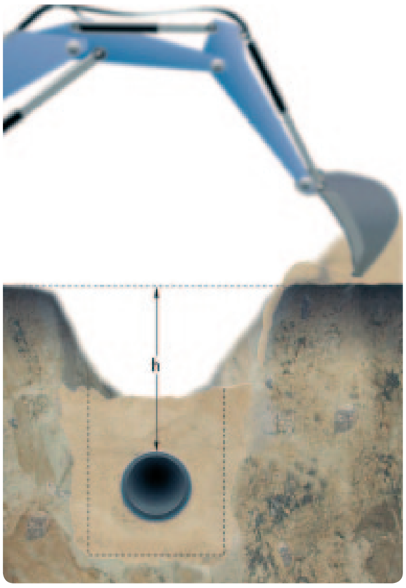
In trenchless installations it is impossible to execute a quality control, seeing the newly installed pipe is laid in a 'black box', increasing the risks for damages resulting from that installation. A trenchless installation also entails that the new pipe has no protecting sandbed, posing additional risks, such as point loads.

Trenchless constructions thus have higher requirements for the pipe systems used. That is why it has to be technically assured that the pipe reaches the same service life in trenchless installations or methods with reduced trenching as compared to pipelines installed in a sandbed.

Fig 2-1: Black box as a characteristic of trenchless installation methods

2.2.1 Installation methods

2.2.1.1 Open trench installation method



■ Open trench installation in a sand bed

When installation takes place using an open trench construction method with sand bed, the pipeline zone is precisely defined and the pipe is laid in a protective sand bed. The surface levels must then be restored.

DIN 4124 "Excavations and trenches" applies among other things with respect to execution of the pipe trench, and precisely stipulates how the working space width and shoring are to be achieved. The pipe must be free from scoring and scratches; the ground surrounding the pipe is then prepared so that the pressure-bearing medium pipe is protected from external influences. DIN EN 805 and the DVGW directive W 400-2 prescribe embedding the pipe in sand or fine gravel.

DVGW Code of Practice W 400-2 permits maximum particle sizes of 22 mm for rounded material and up to 11 mm for a mix of crushed sand and stone chippings. Their construction therefore excludes point loads and linear loads to the pipeline.

Fig 2-2: Standard pipes are installed in a sand bed.

Fig 2-3: When installation is not executed in a sandbed, pipes with integrated protective layers are recommended to be used.

■ Open trench installation without sand bed

When installation takes place using an open trench construction method without sand bed the pipe is directly laid in pipe trenches. The surface levels must then be restored.

Growing cost pressures force several utility companies to question whether the time-consuming embedding of the new pipeline in sand is necessary. If the excavated soil can be compressed it may be used as backfill material instead of sand. The prerequisite for these installation conditions is a pipe system that is capable of withstanding the increased strain arising here. Dispensing with the sand bed may result in stones causing point loads or linear loads to the pipe over a larger period of time, which is in addition to the operating strains such as internal pressure, soil or traffic strain.

If the protection of a sand bed is dispensed with, the selected pipe system must be able to withstand the typical surface damage caused by scratches and in particular point loads so that these do not lead to stress cracks.

One of the main advantages is the cost reduction because soil replacement in the area of the embedment is not necessary.

■ Ploughing method

With this method the new pipe is continually ploughed in and the channel cut for the pipe is then immediately closed again. The plough has a relatively small influence on the soil. It is not necessary to lower the groundwater level when this method of installation is used. For this reason this method is very environmentally friendly, also because of the very limited field damage it causes. The method can be deployed in undeveloped areas up to soil class 5. Installation depths of up to 2 metres are possible depending on the soil classification.

Fig 2-4: When using the ploughing installation method, the use of pipelines with integrated protective layers is recommended.

Installation using a ploughing method can achieve up to 5,000 metres of laid pipeline per workday, making it probably the most economically efficient method for installing new pipelines. The installation unit consists of the plough with the ploughshare and the installation box, together with a winch mounted on a truck or caterpillar vehicle. The installation unit is pulled towards this vehicle by the winch. Once the plough reaches the vehicle the winch is placed at the next point on the route and the procedure is repeated. The ploughshare is dropped to the desired installation depth at the starting pit. Several pipelines can be ploughed simultaneously depending on the pipe diameter, with installation possible up to OD 225 mm. The pipelines are guided into the ground from above in the installation box that follows behind. The pipe is installed in the ground, similar to open trench installation. The soil closes again behind the ploughshare due to its own weight, although the process can also be accelerated using machines.

The prerequisite for this type of installation is a pipe system that is capable of withstanding the increased strain that arises here. Depending on the soil conditions the surface of the newly installed pipeline might become scratched (max. 10 % of the wall thickness is permissible). Moreover, stones may cause point loads or linear loads to the pipe over a longer period of time in addition to the operating strains such as internal pressure, soil or traffic strain. Point loads triggered by stones in the soil, for example, may cause damage to the pipeline. Pipelines should be used that are made from a material that has been proven to have a high resistance to stress induced cracking in order to actually achieve the intended minimum service life.

The rocket-plough method is a variation of the ploughing method, and is in particular deployed for pipe materials whose permissible bending radii are too great for a standard plough. The procedure is identical exept for the fact that the pipeline is introduced length-ways. This means that the pipeline is drawn across the entire installation route together with the ploughshare. Pipelines have to demonstrate additional external pipe protection due to the considerably greater mechanical load. It must be ensured here that the permissible tensile forces of the pipeline and the joint are not exceeded. Tensile forces limit the length of the pipeline.

■ Milling method

Special machines cut a narrow pipe trench and at the same time introduce the flexible pipe. The excavated soil is used as backfill material. Depending on the soil conditions the surface of the newly installed pipeline might become scratched (max. 10 % of the wall thickness is permissible). Moreover, stones may cause point loads or linear loads to the pipe over a longer period of time, in addition to the operating strains such as internal pressure, soil or traffic strain.

A motor-operated milling machine opens up a narrow trench with a width of up to 60 cm and depth of up to 2.5 m. The pipe is introduced into this trench, with simultaneous backfilling of the pipe trench, generally using the excavated material. In contrast to the plough method, this method also enables work to take place on difficult soils up to Soil Category 7. The installation performance achieved will be largely influenced by the prevailing soil category, but is lower than the installation using the plough method.

Fig 2-5: Since excavated soil is used as backfill material in the milling method it is recommended that pipe systems with integrated protective layers be used.

Since the rules of technology generally do not specify laying the pipeline in a sand bed, pipelines should be used that are made from a material that has been proven to have a high resistance to stress induced cracking.

2.2.1.2 Trenchless Installation

The advantage of trenchless installations is the protection of resources, cost efficiency and the faster turnaround times of the construction projects as compared to open trench installation methods. A disadvantage is the higher stress exerted on the pipes used. The installation methods that are posing high demands on the pipe material are, among others, horizontal directional drilling, burst lining, and relining. With all of these methods, it is impossible to control the condition of the medium pipe during or after installation. There is a risk of stones, rockbeds or shards of old pipe damaging the pipe that is to be installed.

In order to avoid this risk, the use of pipes with an additional outer protective layer is recommendable.

The technical rules of DVGW concur: DVGW worksheet GW 321 "Horizontal directional drilling methods for gas and water conduits - Requirements, quality assurance and testing" concludes: "In practice, an outer protection of the pipe has proven to be efficient, for example a polyolefin layer, assuming the core pipe remains free from scratches after installation". Worksheet GW 323 "Trenchless renewal of gas and water supply conduits in burstlining; Requirements, quality assurance and testing" also recommends an additional protective layer for PE-HD pipes.

The protective layer absorbs all scratches and notches that can occur during transport as well as during installation. Subsequently joining house connections, valves and fittings, saddles, etc. can be welded onto the undamaged pipe wall after the protective layer has been removed. A weld on scratched pipe surfaces that is not in accordance with the guidelines is ruled out.

■ Soil displacement / impact moles

An impact mole is "fired" through a few metres of the soil when connecting general building services. The soil here may lead to unacceptable deep scratches in the new pipe. The maximum permissible depth of the scoring in the pipe wall is 10 %. Surrounding stones may also lead to point loads.

The soil displacement installation method using impact moles is generally used to connect building services. A pneumatic hammer creates a hollow space into which the new pipeline is embedded. In order for this to occur the soil must be sufficiently displaceable. Structural support for the impact mole is necessary where soil is loose and soft because insufficient friction is created with the soil to permit independent forward movement. The design of the jacking conduit is therefore more precise in stony ground due to lateral displacement of the stones. There is limited lateral deflection of the impact moles. The target is identified from the starting pit.

Pipelines with an outer diameter of up to OD 200 mm can be laid using this method.

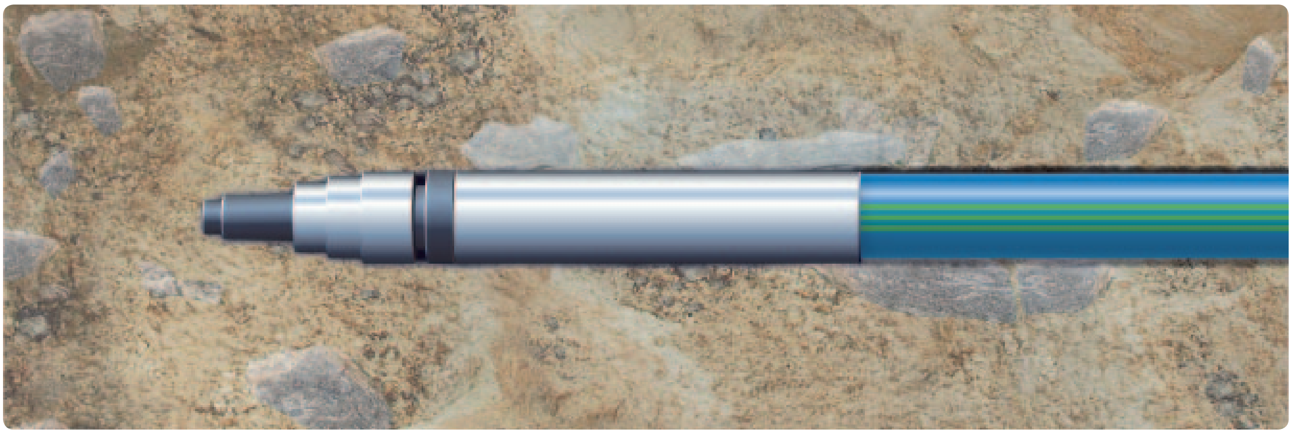


Fig 2-6: It is necessary to use pipelines with additional protective layers because installation using impact moles can damage the pipeline that has been injected.

Relining

Relining can be used to renovate defective pipelines. Scratches and notches can occur on the new pipe depending on the state of the old pipe. Steel pipes welded with a V-joint carry a particularly high risk.

Relining is numbered among the trenchless renovation methods.The functional capacity of the existing pipeline is restored using the existing section of pipeline.Industrially prefabricated and tested plastic pipes are deployed that are jacked or pushed into the old pipe with or without annular gap. In the case of pipeline relining the entire drive length outside the jacking pit is prepared in advance, while in the case of long pipe relining the sections of pipe are joined together when they are jacked in the jacking pit.

Depending on the state of the old pipe the new pipe must take on a structural support function in addition to its sealing function. Relining is accompanied by a reduction in cross-section which is also often desired for reasons of capacity adjustment, e.g. due to the moving away of industry, business and residents. For flow-related reasons the new plastic pipes have comparably low levels of frictional resistance. Despite their reduced cross-section, experience has shown that they often produce an increase in flow rate compared to the old pipes in need of renovation.

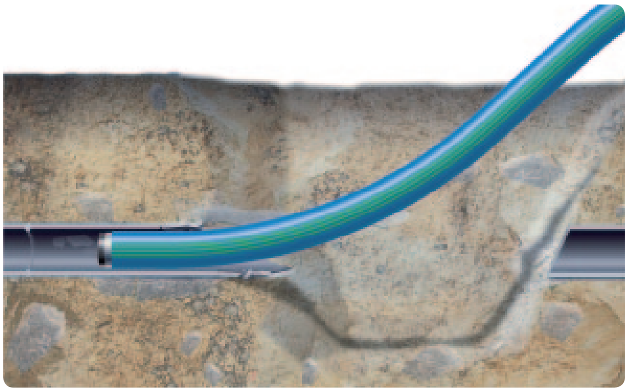


Fig 2-7: The use of pipelines with additional protective layers is necessary because the new pipeline may become damaged during the relining process.

Relining with annular gap

The annular gap between the old and the PE pipeline is grouted on completion of the construction work. Guides and spacers fix and secure the pipeline in the desired position. Ballasting with water acts as a support. The resistance to buckling pressure should be heeded when grouting in order to prevent cross-section deformation. Grouting prevents a drainage effect caused by groundwater. Old pipelines frequently contain fittings, residues of welding materials and rough welded surfaces that may lead to damage to the surface when jacking the new pipe.

Relining without annular gap

If an annular gap is undesirable or might obstruct the required hydraulic capacity, a relining installation without annular gap is a valid option. There are different methods available:

PE Reduction Method

The outer diameter of the PE pipe is chosen just a little too large to fit into the old pipeline. It is then pulled into the old pipe through a die, using the reversible and visco-elastic properties of PE. The new pipe is constantly under tension during this installation process. As soon as the pipe tension is relaxed once the pipe is in place, it will adhere "close fit" to the old pipe; the annular gap is closed.

Close-Fit-Lining

A close fit lining with PE pipes means renewing a pipeline efficiently, durably and environmentally friendly using a factory-made PE pipe. This pipe is deformed (folded) thermomechanically in the production process. The maximum length of the pipe to be coiled up is determined by the outer diameter of the pipe. Depending on the nominal width, several hundred meters of new pipe can be installed in one run thanks to its reduced cross-section. By passing steam and pressure through the new pipe, it expands to its original round form and fits tightly in the old pipe, being statically autonomous.

Before commencing the rehabilitation, the existing pipeline is cut off. Following a camera inspection, obstables and incrustations are removed from inside the old pipe. If necessary, a provisional pipeline is installed to ensure supply of the users during the construction process. After that, the liner is pulled into the existing pipe with a motor winch. The liner pipe is then heated with hot steam which activates the 'memory effect'. Passing steam and pressure through the close-fit-liner causes it to unfold and fit tightly to the inner wall of the old pipeline. After the joints are connected through electrofusion, the rehabilitated pressurized or non-pressurized pipeline is safely reconnected to the grid.

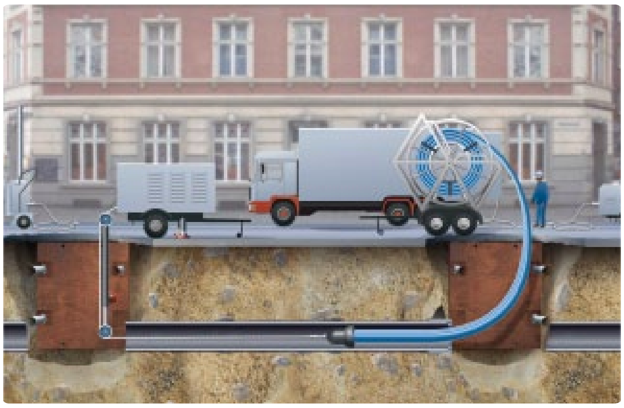


Fig 2-8: Close-Fit-Lining

Wherever there is little or no space available, rehabilitation methods such as close-fit-lining are suited. It enables a rehabilitation of old pipes with a low reduction of the cross-section and requires little space on-site due to small excavation pits. This allows traffic to flow unobstructed and has a very low impact on the environment. Close-fit-lining is economical, as the timeframe for the rehabilitation process is short and the costs related to excavation works are minimized.

HDD – Horizontal Directional Drilling

Horizontal directional drilling is a controllable drilling method. HDD enables controlling the drilling process so as to adjust the pipe route as designed. Depending on the soil conditions and drilling radius, scratches and notches as well as point loads due to stones pose a risk for the new pipe. Horizontal directional drilling is used for parallel installations, sub-terranean crossing of water bodies and buildings, for drainage and irrigation purposes, for cable connections in traffic control systems, as well as for protective measures for hillsides and dams, among others.

Drilling is controlled by rotating the angled pilot drill head in the hole.The drilling suspension flows out of the drill head at high pressure, loosens the soil and stones and drives the cuttings out of the hole. The drilling suspension is adapted to the respective soil conditions and in addition to bentonite, a clay mineral, may contain other additives that can have a further supporting effect on the drill channel.
Several drilling operations to produce expansion may be required after the pilot bore depending on the required

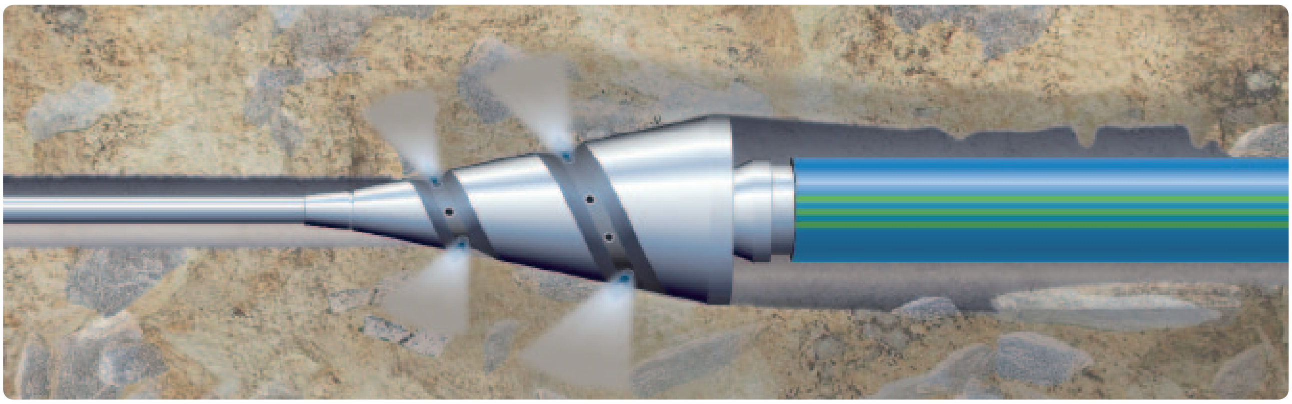


Fig 2-9: The use of pipelines with additional protective layers is necessary because the new pipeline may become damaged during installation using the HDD method

pipe diameter in order to prepare the bore channel for insertion of the pipeline that will conduct the media. A hammer mechanism may be deployed in stony ground up to Soil Category 5 and sometimes also for Soil Category 6 which not only makes jacking easier but also eases the control process. A downhole drilling motor with roller chisels is attached to the front when drilling in rock.

Pipes must not be subjected to strain that goes beyond the permissible tensile forces during the jacking procedure. According to DVGW Code of Practice GW 321 or at the request of the customer the tensile forces that have a direct impact on the media pipe must therefore be measured and recorded. Measurement is conducted using a tensile force measuring device that is mounted in front of the pipe to be jacked.

Pipelines for the renewal of drinking water systems must at least correspond to 10 bar pressure level in accordance with DVGW Code of Practice GW 321 "Controlled horizontal directional drilling procedure for gas and water pipelines - requirements, quality assurance and inspection". Only pipelines from the SDR 11 series should be deployed especially for small pipe diameters because of the mechanical strain that arises when using this method of installation. The service life of the newly installed pipeline will depend on how intact it is. Damage of up to 10 % of the pipe wall thickness is tolerated by the material, but scratches and scoring that go beyond this will reduce the service life of the supply line. For this reason DVGW Code of Practice GW 321 also recommends use of pipes with protective cladding.

Fig 2-10: Dynamic Pipe busting

Fig 2-11: Static Pipe bursting

■ Pipe bursting

In the case of pipe bursting a bursting and expanding implement is drawn through the old pipe, the broken pieces of pipe are pressed into the soil and at the same time an industrially prefabricated pipe with the same or larger diameter is jacked. The sourrounding soil must be displaceable, and there must be knowledge of the position and state of pipes that run parallel. These are dynamic and statically operating systems, which are able to break up almost all pipe material including reinforced concrete pipes. Scratches and notches may occur in the new pipe depending on the material and state of the old pipe. Shards and stones cause point loads during operation.

The power for pipe bursting is introduced in a pulsating manner using modified impact moles or pile drivers. The bursting and expanding implement is guided in the pipe using rope and winch as stabilising factor. Dynamic methods are particularly suitable for use in compressed or stony ground and for brittle old pipes made from cast iron, stoneware or concrete.

The hydraulically generated bursting force is transmitted via a rod assembly to the bursting and expansion implement.

Static pipe bursting is deployed for bursting old pipes made of brittle and ductile materials; the latter are cut in the bottom of the pipe using a special rotating cutter. Subsequent expansion displaces the old pipe and calibrates the burst duct for the jacking procedure.

The new pipe is subjected to considerable stress as a result of the pipe bursting and jacking process. Shards of old pipe lead to scratches and scoring, while stones cause point loads in the end position.

For this reason the DVGW Code of Practice GW 323 recommends the use of pipes with protective layers. Furthermore, the requirements with respect to the minimum thickness of damage or compliance with permissible tension stresses apply here too as they do with respect to other trenchless installation methods.

2.2.1.3 Economic perspectives

The selection of pipe materials and systems in civil engineering has extremely long-term and especially economic implications. Once they have been installed and designed for several generations, subsequent access to pipelines is scarcely possible.

- Valuable and sealed surface areas are created
- Enormous costs are incurred in the event of subsequent damage
- It is almost impossible to divert traffic or close off streets in the light of current traffic density

Economic efficiency means a favourable price-performance relationship taking into consideration the service life, operating and maintenance costs. External costs such as traffic disturbance, noise and CO_2 emissions are as a rule currently still lacking in the decision-makers´cost comparison or economic efficiency calculations. These costs must then be picked up by society.

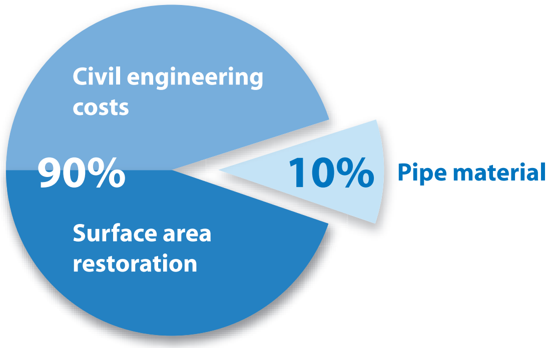


Fig 2-12: Civil engineering costs up to 90 %, of which up to 50 % are for surface area restoration. Pipe material: 10 %.

The cost relations in civil engineering also make alternative, trenchless installation techniques economically interesting. The difference in pipe price is rarely more than 15%, while 85% or more of the overall costs are determined by civil and underground engineering or restoring the surface areas. The use of trenchless installation techniques opens up considerable potential for cost reduction.

Calculation of excavation measures, no matter if in open or trenchless construction, is often based on the experience of the respective calculator, on the knowledge of calculation bases imparted from one generation of employees to the next, and is also based on rough guesses. All of these result in the choice of the installation method and the project execution. With webkalkulator24, egeplast offers an online tool to comparatively calculate different installation methods. It also offers users to compare costs incurred from butt welding on-site from a broader perspective. This proves to be helpful especially for larger outer diameters, as the cool-off times can be reduced with a second or third welding machine, thus cutting costs significantly.

Fig 2-13

Fig 2-14

The webkalkulator24 tool (www.webkalkulator24.eu) offers the different types of users a variety of approaches to study this subject:

- Comparison of different installation methods
- Comparison of different pipe systems
- Rough estimates of price quotations
- Simple adjustment for particular construction details

The basic version of the tool uses fixed values that have been set with routine calculations based on project layouts from practice. In the premium version, users can enter individual values and prices, offering a more in-depth look at the project.

The different methods can be compared to one another in just a few steps. The calculated results give an indication of the method with the lowest associated costs. The results overview displays how costs are distributed among the individual project positions. For a comparative calculation of pipe installation projects, a number of installation and rehabilitation methods are listed. The methods are assigned to different categories:

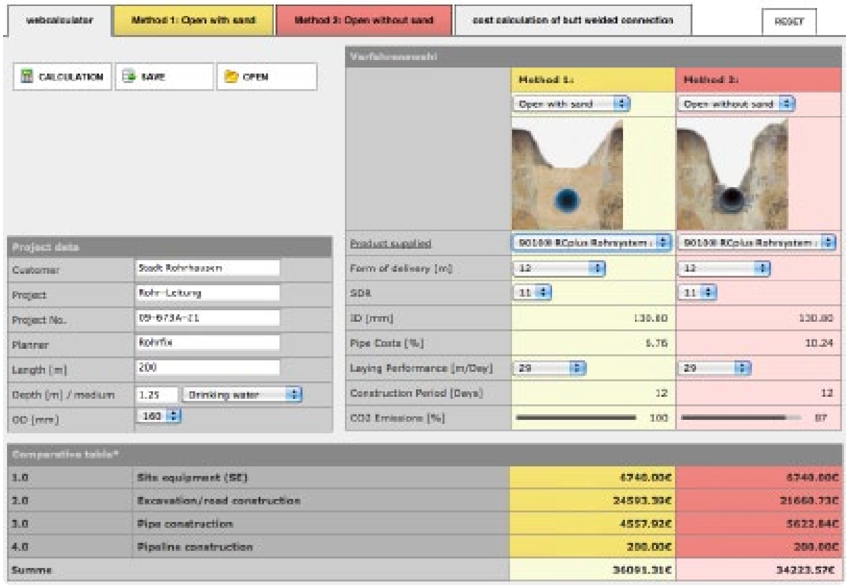


Fig 2-15: Start and results page webkalkulator24

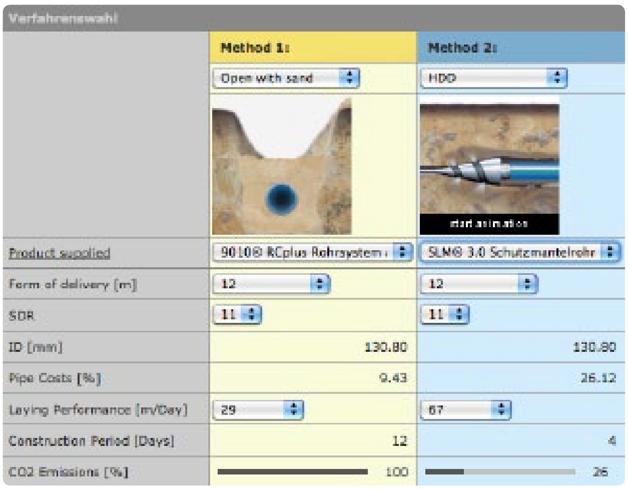


Fig 2-16

Urban areas:
Open installation with sandbedding
Open installation without sandbedding
Installation using horizontal directional drilling

Long-distance installations:
Installation by plough
Installation by milling

Rehabilitation projects:
Rehabilitation using re-lining
Renewal using burstlining

The costs associated with butt welding are basically determined by the cool-off time. One potential to increase productivity is using multiple welding machines. This can lead to significant productivity increases, especially for projects with large pipes, and ultimately lead to a reduction in the overall project cost.

A calculation and optimisation of costs associated with butt welding processes can be executed in webkalkulator24 as well. Based on the calculations already entered, an estimate of the number of possible welds in a working day can be made. Subsequently, these results can be optimised by adjusting the costs of payroll and working times, or with the number of welders and machines.

These optimised costs are then transferred to the combined total calculation.

2.2.1.4 Ecologic perspectives

A trenchless installation or rehabilitation of pipelines for supply and disposal as well as for telecommunication purposes is widely used by now. The associated positive aspects for population, infrastructure, nature, and the environment are self-evident. However, they are not always kept in mind by the tendering parties. Oftentimes, trenchless installation or rehabilitation methods are ruled out by planners and grid operator right at the beginning because of supposedly higher project costs. The same goes for considering conventional projects in open construction with sandbedding versus using slow crack resistant pipe materials, since the latter could actually reduce costs incurred in installation.

One reason for not thinking outside the box is the long-term knowledge and experience of conventional construction methods, i.e. installation in open trenches. The advantages of a trenchless installation or renewal remain unrecognized since there is no knowledge of methodology or the expected costs.

The effects of the so-called 'soft facts' with their indirect costs will also inevitably play a greater roll in decision-making in the future. Projects in urban areas executed in open construction with their traffic jams and obstructions associated with road closures and diversions are less and less accepted by citizens and local businesses. Construction times are a direct measure for the potential duration and intensity of the obstruction, and also for the costs for local population, businesses and industry.

In addition to that, the costs associated with trenchless construction methods are relevant not only directly, but also indirectly during, and especially after the construction itself. The follow-up costs resulting from open constructions are often coming into effect as direct costs for the grid operator much later, for example as repairs of surfaces or correcting damages in vegetation.

A holistic perspective of constructive measures has to include the ecologic costs, often called soft facts, next to the economic facts.

Soft facts comprise all processes in installation methods that have an effect in terms of construction technology, environment, and the economy. Construction projects produce indirect costs that can come to bear during execution, but also long after the project is concluded. These costs are mostly born by the (public) tendering party or the taxpayer. The costs also include environmental effects such as emissions or protection of resources, as well as (avoidable) effects on population and infrastructure. GSTT information sheets no. 1 and no. 11 contain further information on estimating the effects of the different methods for new installations and rehabilitations.

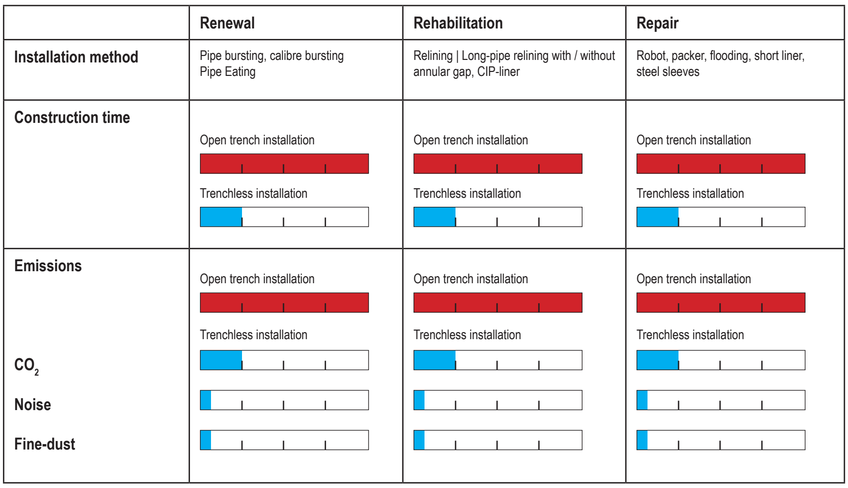


Fig 2-17

Extract from GSTT info no. 11

Polyolefin pipes are very well suited for trenchless methods. The application of trenchless techniques is characterized by a low carbon footprint and a low noise and low fine dust pollution.

2.2.2 Requirements and risks of failure

Considerable underground engineering work is involved when creating underground infrastructures. It is therefore the objective of an operator to be able to operate a new pipeline for as long as possible without damage. When correctly installed, pipes made from polyethylene offer a service life of at least 100 years. If, by contrast, they are damaged during installation, this long service life may be substantially curtailed.

2.2.2.1 Risk of failure scratches and scoring

The cause of this may be damage or weakening to the pipe wall during pipe jacking (see Fig 2-18). Since the standardised wall thickness is precisely attuned to the operating pressure, albeit supplemented by the safety factor, every weakening means a reduction in the engineered safety factor and therefore an increase in the probability of the risk event or, in the case of significant damage, even a direct reduction in pressure resistance of the new pipeline and consequently in a curtailment of the service life.

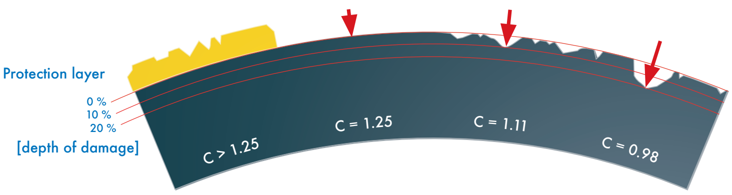


Fig 2-18:
Consideration of the safety factor C in relation to score depth

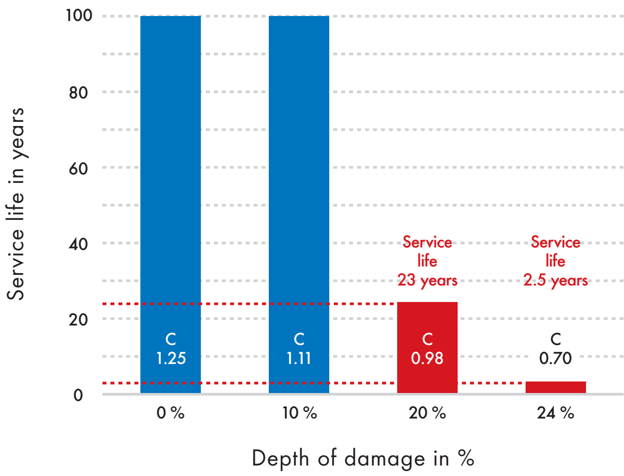


Fig 2-19:
Diagram of service life in relation to damage depth

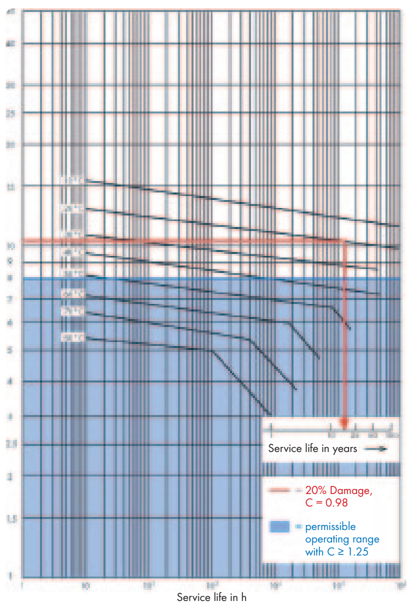


Fig 2-20: Service life in hours of an undamaged pipeline made of PE 100-RC and one weakened by 20 %

A damage depth of 10 % of the pipe wall is permitted by the codes of practice, because despite the reduction in the safety factor, a curtailment of the service life of the pipeline is not to be expected. By contrast, weakening of the pipe wall that penetrates deeper than this is dangerous.

Comparative calculation of undamaged and damaged pipe wall:
Dimension: 110 x 10,0 mm, SDR 11 drinking water pipeline PE 100-RC, admissible operating pressure 16 bar:

With damage depth of 20 % the wall thickness in this area is reduced to 8.0 mm which increases the test tension locally to 10.20 N/mm². To simplify the calculation the notch geometry and the impact on the component is not taken into consideration here. The impact on service life can be read off from the reference characteristic curves of the internal pressure creep rupture resistance (minimum curves in accordance with DIN 8075) of pipes made from PE 100. A residual service life remains of just 23 years. This consideration using the flat, i.e. ductile branch of the creep curve, only applies to the PE 100-RC materials which are resistant to stress induced cracking in accordance with PAS 1075. Earlier failure due to brittle breakages must be feared with standard PE 100 qualities that are more sensitive to notching.

2.2.2.2 Risk of failure point loads

The occurrence of point loads represents a further risk factor for operation of a PE pipeline that is not embedded in sand. These are caused, for example, by stones lying on top which press onto the pipe wall. In the case of poor material quality this can also result in premature damage caused by stress cracks in the pipe wall (see Fig 2-21)

Decisive for the service life expectation of the pipe when used under extreme operating conditions in the resistance of the pipe material to stress cracks caused by point loads if the normative service life of 100 years is to be achieved despite greater demands.

Fig 2-21: Stress crack on the inside of the pipe caused by point load and incorrect choice of material (source: HESSEL technical engineering)

2.2.3 Selection of pipe material

The installation method selected is decisive for the choice of material and consequently the risk of damage to the pipe systems deployed.

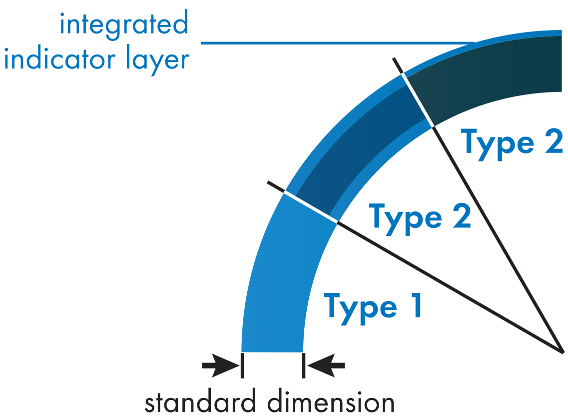


Fig 2-22: Pipes with dimensionally integrated protective layers in accordance with DIN 8074/ISO 4065 made of PE 100-RC acc. to PAS 1075 Types 1 and 2

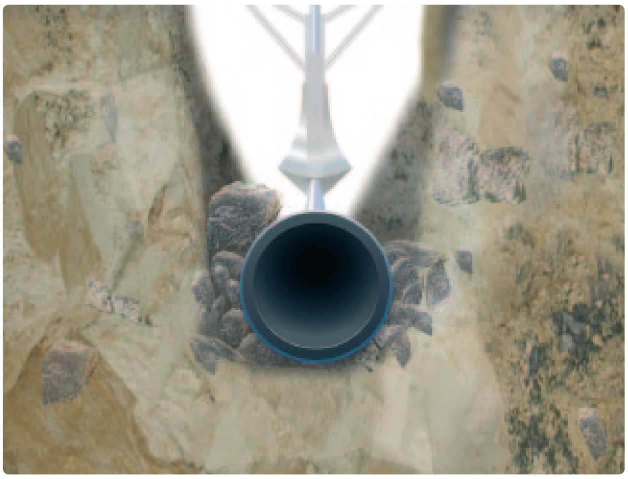


Fig 2-23: Open trench installation method without sand bed

The occurrence of point loads caused by stones or shards can be expected using the **open trench installation technique** without a sand bed which then press against the pipe wall. The use of poyethylene pipes made of RC materials with integrated protective layers and the greatest resistance to slow crack growth is essential for this type of installation. The pipes should correspond to PAS 1075 Type 1 or 2 standard. This pipe construction does not have a notch protection.

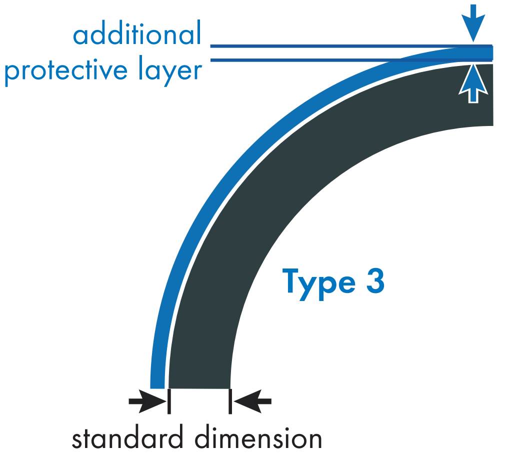


Fig 2-24: Pipes with dimensions in accordance with DIN 8074/ISO 4065 made of PE 100-RC acc. to PAS 1075 Type 3 (with addional protection layer)

Fig 2-25: Black box installation method / closed construction

Trenchless installation techniques place special stress on the pipes to be installed. Scoring and notches in the pipe cannot be avoided during new installation or renovation of old pipes. Pipes with an additional protective layer are therefore required for black box methods in order to guarantee a damage-free operation of the pipeline. Pipes with protective layer correspond to PAS 1075 Type 3.

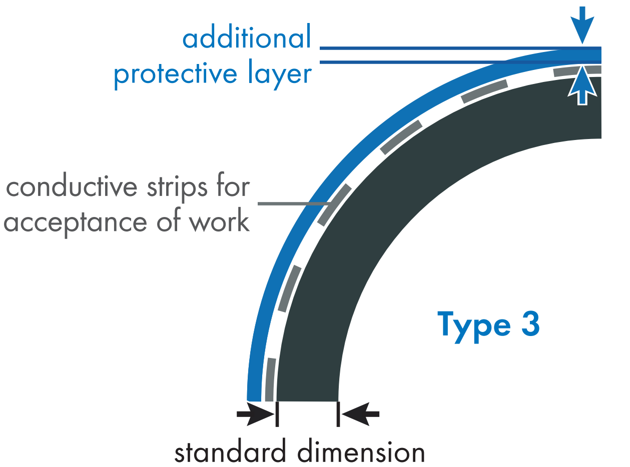


Fig 2-26: Pipes with dimensions in accordance with DIN 8074/ISO 4065 made of PE 100-RC acc. to PAS 1075 Type 3 (with additional protective layer and quality proof)

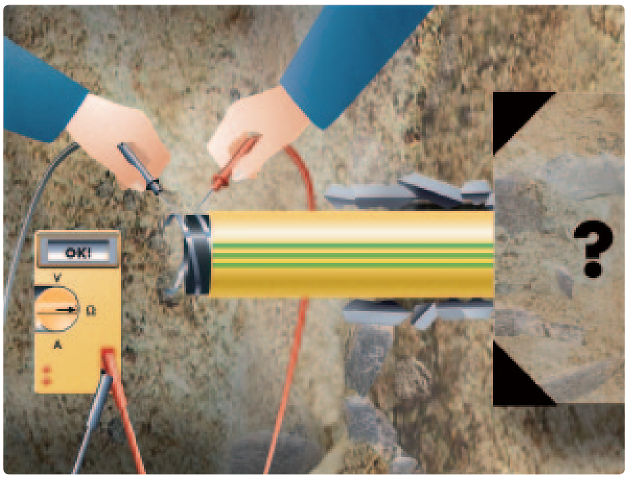


Fig 2-27: Continuity check as evidence of lack of damage to the new pipeline

The codes of practice for trenchless installation methods require complete documentation of all relevant processes in the building project. In this context valid DVGW rules recommend an intensive incoming goods inspection of pipes and pipeline parts before open trench and trenchless installation. Particularly in the case of trenchless installation it is recommended that the exposed sections of newly installed pipelines undergo a visual inspection for impermissible damage before the pressure test. This means that the sections of pipeline that cannot be seen (black box) remain untested. It is therefore not possible to prove lack of damage in this way. Pipes with integrated conductive strips therefore provide a possible way to demonstrate quality and close the inspection gap.

When using pipe systems with quality proof the recording of the continuity check serves as evidence of lack of damage to the newly installed pipeline.

2.3 Pipe Planning

2.3.1 Pipe Series Overview

The new specifications for safety coefficients and the graduation of the HDPE types into different MRS (minimum required strength) classes yield different permissible operating pressures for the same outer diameter – wall thickness ratios.

SDR designations are used to refer to the ratio of outer diameter to wall thickness. (SDR = Standard Dimension Ratio)

		Unpressurised Range					Pressure Pipes						
SDR		33		26		17.6		17		11		7.4	
PE 80 SF= 2.0	PN	2.5		3.2		4.8	2.0[1]	5.0	2.0[1]	8.0	5.0[1]	12.3	
PE 80 SF= 1.6	PN	3.1		4.0		6.0		6.2		10.0		15.3	
PE 80 SF= 1.25	PN	4.0		5.0		7.5		8.0		12.5		20.0	
PE 100 SF= 2.0	PN	3.1		4.0		6.0		6.2	5.0[1]	10.0	10.0[1]	15.3	
PE 100 SF= 1.6	PN	3.9		5.0		7.5		7.8		12.5		19.2	
PE 100 SF= 1.25	PN	5.0		6.3		9.6		10.0		16.0		25.0	
OD (mm)		s (mm)	Delivery Form	s (mm)	Delivery Form	s (mm)	Delivery Form	s (mm)	Delivery Form	s (mm)	Delivery Form	s (mm)	Delivery Form
16										3.0	S/C	2.3	S/C
20										2.0 3.0	S/C	3.0	S/C
25								1.8	S/C	2.3 3.0	S/C	3.5	S/C
32						2.0 2.3	S/C	2.0	S/C	3.0 3.0	S/C	4.4	S/C
40						2.3	S/C	2.4	S/C	3.7	S/C	5.5	S/C
50				2.0	S	2.9	S/C	3.0	S/C	4.6	S/C	6.9	S/C
63				2.5	S	3.6	S/C	3.8	S/C	5.8	S/C	8.6	S/C
75				2.9	S	4.3	S/C	4.5	S/C	6.8	S/C	10.3	S/C
90				3.5	S	5.1	S/C	5.4	S/C	8.2	S/C	12.3	S/C
110				4.2	S	6.3	S/C	6.6	S/C	10.0	S/C	15.1	S/C
125				4.8	S	7.1	S/C*	7.4	S/C*	11.4	S/C	17.1	S/C
140				5.4	S	8.0	S/C*	8.3	S/C*	12.7	S/C	19.2	S/C
160				6.2	S	9.1	S/C*	9.5	S/C*	14.6	S/C	21.9	S/C
180				6.9	S	10.2	S	10.7	S	16.4	S/C*	24.6	S/C*
200				7.7	S	11.4	S	11.9	S	18.2	S	27.4	S
225				8.6	S	12.8	S	13.4	S	20.5	S	30.8	S
250				9.6	S	14.2	S	14.8	S	22.7	S	34.2	S
280				10.7	S	15.9	S	16.6	S	25.4	S	38.3	S
315		9.7	S	12.1	S	17.9	S	18.7	S	28.6	S	43.1	S
355		10.9	S	13.6	S	20.1	S	21.1	S	32.2	S	48.5	S
400		12.3	S	15.3	S	22.7	S	23.7	S	36.3	S	54.7	S
450		13.8	S	17.2	S	25.5	S	26.7	S	40.9	S	61.5	S
500		15.3	S	19.1	S	28.4	S	29.7	S	45.4	S	68.3	S
560		17.2	S	21.4	S	31.7	S	33.2	S	50.8	S		
630		19.3	S	24.1	S	35.7	S	37.4	S	57.2	S		
710		21.8	S	27.2	S	40.2	S	42.1	S	64.5	S		
800		24.5	S	30.6	S	45.3	S	47.4	S				
900		27.6	S	34.4	S	51.0	S	53.3	S				
1000		30.6	S	38.2	S	56.6	S	59.3	S				
1200		36.7	S	45.9	S	68.0	S						

[1] = Operating pressures for gas in accordance with DVGW

S=Straight length C=Coils Drums on request *Delivery as bundled coil possible with transport as an abnormal load

Tab 2-1: Source: DIN EN 12201-2, DIN EN 1555-2, DIN 8074

2.3.2 Permissible Operating Pressures

Pipe formula

The permissible MOP (maximum operating pressure) is calculated (among others) according to DIN EN 12201:

$$MOP = \frac{20 \cdot MRS}{C \cdot (SDR - 1)}$$

$C_{Water} = 1.25$
$C_{Gas} = 2.0$
MRS: PE 100 = $10 \frac{N}{mm^2}$

The maximum operating pressures (MOP) listed below can be used according to the DVGW:

Gas and water distribution – SDR ranges – permissible operating pressures		
SDR	Gas	Water
	PE 100	PE 100
7.4	-	-
11.0	10 bar	16 bar
17.6	-	-
17.0	5 bar	10 bar

Tab 2-2: Sources: DVGW G 472; DVGW GW 335-A2; DVGW W 400-1. Note: Pipes with an outer diameter up to and including OD 63 mm in SDR 17.6 or SDR 17 may not be used in gas and water supply.

2.3.3 Flow Velocities

The flow velocity in a pipeline influences not only the efficiency of a supply system but also its operational safety.

High flow speeds cause high pressure losses while low flow speeds cause long retention times of the medium. For hygienic reasons (microbial contamination, turbidity, etc.), an appropriate water exchange has to be ensured.

As approximate values for flow speeds in practice, it can be assumed for liquids that:

w = 0.5 to 1.0 $\frac{m}{s}$ for suction pipelines

w = 1.0 to 3.0 $\frac{m}{s}$ for pressure pipelines

For gases, the flow velocity can be estimated as:

w = 10 to 30 $\frac{m}{s}$

More precise details for system components for drinking water piping can be found in DVGW Worksheet W 400-1.

2.3.4 Pressure Loss Calculation

The pressure loss in straight pipeline sections is given by:

$$\Delta p = \lambda \frac{l \cdot w^2 \cdot \rho \cdot 10^{-5}}{2 \cdot ID} \, [bar]$$

Represented as head loss:

$$h_v = \lambda \cdot \frac{l \cdot w^2}{2 \cdot g \cdot ID} \, [m]$$

with:
ID = pipe inner diameter [mm]
w = flow velocity in [$\frac{m}{s}$]
λ = pipe friction coefficient [–]
l = pipeline length [m]
ρ = density of the medium [$\frac{kg}{m^3}$]
g= acceleration due to gravity [9.81 $\frac{m}{s^2}$]

The nomogram can be used for a rough determination of pressure drops. It has been drawn up for water at 10°C and a pipe roughness K=0.007 mm.

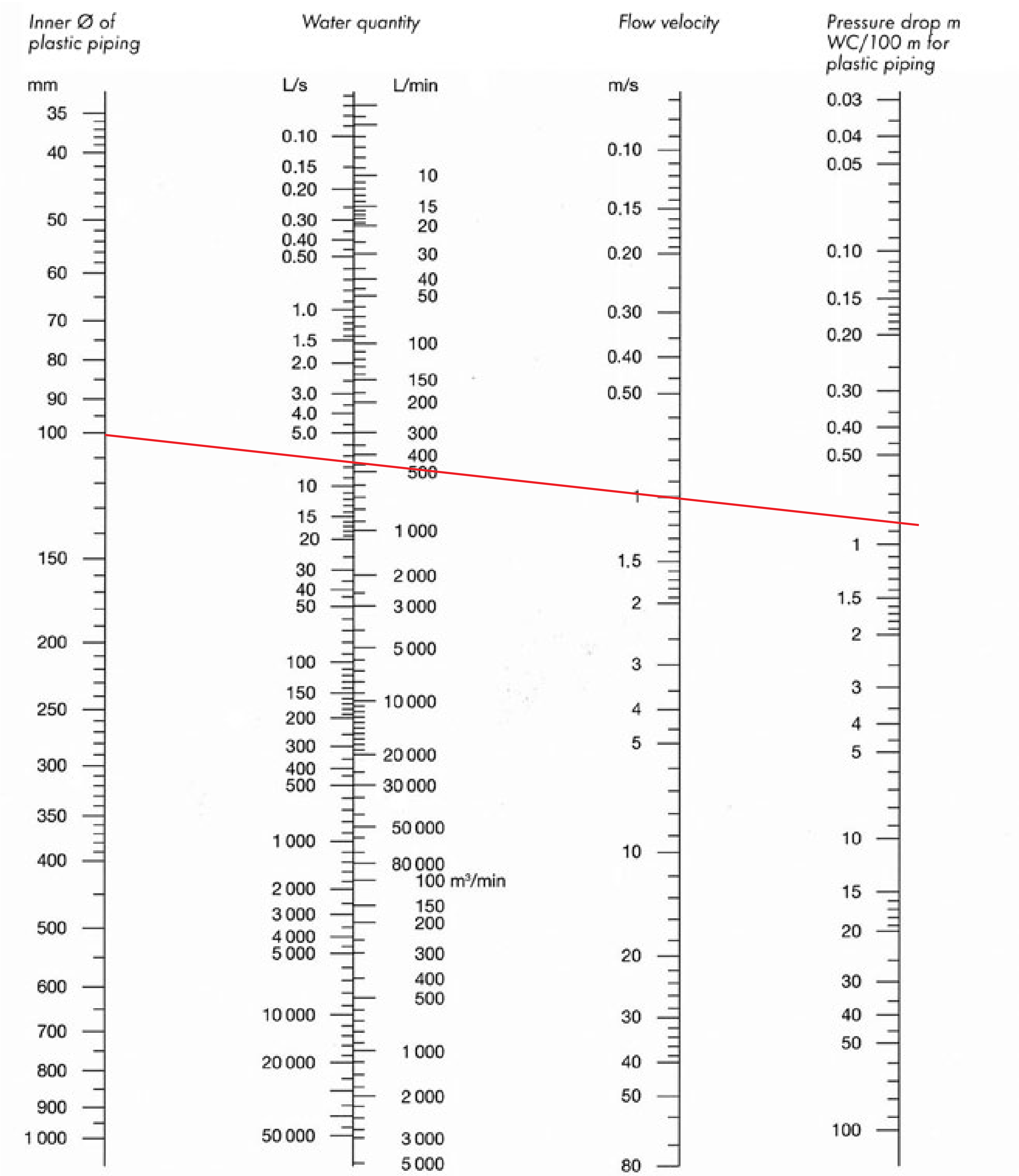


Fig 2-28 —— = Example: An inner diameter of 100 mm and a flow velocity of 1 m/s results in a volume flow of 450 l/min and a pressure drop of approx. 0.85 mWC/100 m (0.085 bar)

According to DVS 2210 Part 1, a ζ-value of $\zeta_{pipejoint}$= 0.1 [-] applies for pressure drops at pipeline joints, butt weld seams, or socket joints.

Hence one obtains the pressure drop at joints from

$$\Delta\, p_{pipejoint} = 0.1 \cdot \frac{\rho_F}{2 \cdot 10^5} \cdot w^2 \; [bar]$$

where:
ρ_F = density of the medium [$\frac{kg}{m^3}$]
$\zeta_{pipejoint}$ = 0,1 [-]
$\zeta_{fittings}$ = see DVS 2210 Part 1
w = flow velocity of the medium [$\frac{m}{s}$]

The pressure drops in valves and fittings agre given by:

$$\Delta\, p_{fittings} = \zeta_{fittings} \cdot \frac{\rho_F}{2 \cdot 10^5} \cdot w^2 \; [bar]$$

A selection of drag coefficients for various fittings can be found in the annex of DVS 2210 Part 1, see below.

Drag coefficients of valves can be obtained from the manufacturer's information.

Type	Parameter R	Drag coefficient ζ
Bend 90°	1.0 · OD	0.51
	1.5 · OD	0.41
	2.0 · OD	0.34
	4.0 · OD	0.23
Bend 45°	1.0 · OD	0.34
	1.5 · OD	0.27
	2.0 · OD	0.20
	4.0 · OD	0.15
Elbow	45°	0.30
	30°	0.14
	20°	0.05
	15°	0.05
	10°	0.04

Type	Parameter V_z/V_s	Drag coefficient ζ	
Tees (Pipe branch 90°) Flow union $V_s = V_a + V_z$		ζ_z	ζ_d
	0.0	-1.20	0.06
	0.2	-0.40	0.20
	0.4	0.10	0.30
	0.6	0.50	0.40
	0.8	0.70	0.50
	1.0	0.90	0.60

Tab 2-3: Source: DVS guideline 2210 part 1

Continuation on the next page

Continuation:

Type	Parameter V_a/V_s	Drag coefficient ζ	
Tees (Pipe branch 90°) Flow union $V_s = V_a + V_d$		ζ_a	ζ_s
	0.0	0.97	0.10
	0.2	0.90	-0.10
	0.4	0.90	-0.05
	0.6	0.97	0.10
	0.8	1.10	0.20
	1.0	1.30	0.35

Type	Parameter OD_2/OD_1	Drag coefficient ζ		
Concentric reducers (Pipe expansion) ζ-values for $\lambda_R = 0.025$	Angle α	4...8°	16°	24
	1.2	0.10	0.15	0.20
	1.4	0.20	0.30	0.50
	1.6	0.50	0.80	1.50
	1.8	1.20	1.80	3.00
	2.0	1.90	3.10	5.30
Concentric reducers (Pipe reduction) ζ-values for $\lambda_R = 0.025$	Angle α	4°	8°	20°
	1.2	0.046	0.023	0.010
	1.4	0.067	0.033	0.013
	1.6	0.076	0.038	0.015
	1.8	0.031	0.041	0.016
	2.0	0.034	0.042	0.017

Tab 2-3: Source: DVS guideline 2210 part 1

positive ζ-values = Pressure drop
negative ζ-values = Pressure increase

V_a = outgoing branch volume flow
V_d = straight volume flow
V_s = total volume flow
V_z = incoming branch volume flow
OD_1 = first diameter in flow direction
OD_2 = second diameter in flow direction

The sum of the individual pressure losses constitute the total pressure loss:

$$\Delta p_{total} = \sum \Delta p_{pipeline} + \Delta p_{component} + \Delta p_{connection} + \Delta p_{valve}$$

2.3.5 Permissible Buckling Pressures

Buckling denotes the kidney-shaped deformation of the pipe cross section under external positive pressure and/or internal negative pressure. The critical positive or negative pressure on a round pipe which is not embedded in the ground is given by:

$$p_{crit.buckl.} = \frac{E_{pipe}}{4 \cdot (1-\mu^2)} \cdot \left(\frac{e}{r_m}\right)^3$$

where:

E_{pipe} = elastic modulus of the pipe material [$\frac{N}{mm^2}$]

$E_{pipe,\ longterm}$ = 200 $\frac{N}{mm^2}$ for PE 100 and 20 °C

$E_{pipe,\ shortterm}$ = 1200 $\frac{N}{mm^2}$ for PE 100 and 20 °C

r_m = medial pipe radius [mm]

e = wall thickness of the pipe [mm]

μ = Poisson's ratio for the material; for pipes made of polyethylene μ = 0,4

Short term negative pressures down to 0 bar, i.e. a vacuum, are theoretically possible as long as the buckling behaviour is taken into consideration.

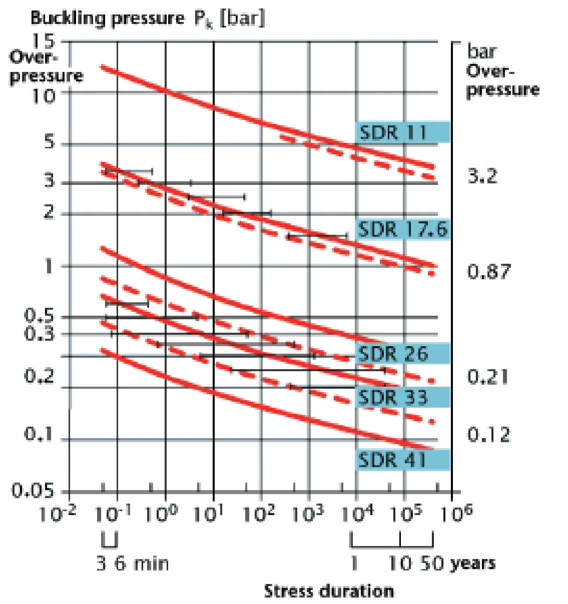


Fig 2-29: Buckling pressure of polyethylene pipes under external water pressure at 20 °C. The plotted horizontal ranges indicate onset of deformation and buckling. Source: basell Polyolefins

2.3.6 Pressure Surges

Pressure surges can be caused by the opening and closing of valves as well as the operation of pumps. Their maximum amplitude is given by:

$$p_{impact} = a \cdot w \cdot \rho \cdot 10^{-5}\ [bar]$$

where:

w = flow velocity of the medium [$\frac{m}{s}$]

ρ = density of the medium [$\frac{kg}{m^3}$]

a = velocity of the pressure wave [$\frac{m}{s}$]

$$a = \sqrt{\frac{\frac{E_M}{\rho}}{1 + \frac{E_M}{E_{pipe}} \cdot \frac{d_m}{e}}}\ \left[\frac{m}{s}\right]$$

where:

E_{pipe} = elastic modulus of the pipe material [$\frac{N}{mm^2}$]

20 °C E_{pipe} = 1680 · 10^6 N/m²

40 °C E_{pipe} = 1230 · 10^6 N/m²

60 °C E_{pipe} = 760 · 10^6 N/m²

E_M = elastic modulus of the flowing medium [$\frac{N}{mm^2}$]

E_{water} = 2100 · 10^6 N/m²

ρ = density of the medium [$\frac{kg}{m^3}$]; ρ_{water} = 1000 $\frac{kg}{m^3}$

d_m = medial diameter of the pipe [mm]

e = wall thickness of the pipe [mm]

As long as the nominal pressure is not exceeded for a long period during pressure surges, they are not harmful. The strength reserves of the pipe can be relied on for discrete, short-lasting (seconds) pressure surges. Polyethylene piping with an overall service coefficient C of 1.25 can withstand pressure peaks which exceed the nominal pressure by 50% for a short period without damage at temperatures up to 20 °C.

2.3.7 Permissible Bending Radii

The following minimum bending radii are to be observed. Elbows or other fittings should be used for smaller radii.

■ Permissible bending radii for PE 100/PE 100-RC

Pipe wall Temperatures [°C]	Smallest Permissible Bending Radius R_{min} [in mm]				
	SDR 33	SDR 26	SDR 17/17,6	SDR 11	SDR 7,4
0	100 x OD	75.0 x OD	50.0 x OD	50.0 x OD	50.0 x OD
10	70.0 x OD	52.5 x OD	35.0 x OD	35.0 x OD	35.0 x OD
20	40.0 x OD	30.0 x OD	20.0 x OD	20.0 x OD	20.0 x OD
Multiplication factor for egeplast SLM® 3.0, SLM® DCT, SLA® Barrier Pipe and 3L Leak Control: 1.5 x R_{min}					

Tab 2-4: According to KRV Installation Instructions A 135/99-15 and A 435/96-10, DVGW Worksheet GW 320, GW 321, GW 324, GW 325 and DVGW code of practice GW 323

OD = pipe outer diameter [in mm]

ⓘ **The bending radii for egeplast pipes with protective layers are based on the bending radii specified by KRV (German Plastic Pipe Association) and DVGW. The radii are increased by a factor of 1.5 due to the additional protective layer.**

For pipe wall temperatures between 0 °C and 20 °C, the permissible bending radius in each case can be determined by linear interpolation.

$$R_{interpolated} = R_{20^\circ C} + \left[\frac{R_{0^\circ C} - R_{20^\circ C}}{20^\circ C}\right] \cdot (20^\circ C - \vartheta_{pipewall})$$

where:

$R_{interpolated}$ = required bending radius [mm]
$R_{0^\circ C}$ = bending radius of the pipe at 0 °C [mm]
$R_{20^\circ C}$ = bending radius of the pipe at 20 °C [mm]
$\vartheta_{pipewall}$ = temperature of the pipe wall during installation [°C]

Example: An egeplast 90 10® RC^plus-pipe with outer diameter of 160 mm, SDR 11, should be installed at 5 °C.

The permissible bending radius is then given by:

$$R_{interpolated} = 160 \cdot \left[20 + \left[\frac{(50-20)}{20^\circ C}\right] \cdot (20^\circ C - 5^\circ C)\right]$$

■ Temporary permissible bending radii for e.g. trenchless installation methods

Pipe wall Temperatures [°C]	Temporary permissible, construction-related bending radii R_{min} [in mm] for e.g. trenchless installation methods	
	SDR 17	SDR 11
0	37.5 x OD	25 x OD
20	15 x OD	10 x OD
Multiplication factor for egeplast SLM® 3.0, SLM® DCT, SLA® Barrier Pipe and 3L Leak Control: 1.5 x R_{min}		

Tab 1-10: according to the DVGW worksheet GW 320-1

OD = pipe outer diameter [in mm]

ⓘ **In the case of a temporary, process-related reduction of the permissible bending radii, damage caused by buckling when bending or overexpanding must be constructively ruled out.**

ⓘ **The bending radii for egeplast pipes with protective layers are based on the bending radii specified by KRV (German Plastic Pipe Association) and DVGW. The radii are increased by a factor of 1.5 due to the additional protective layer.**

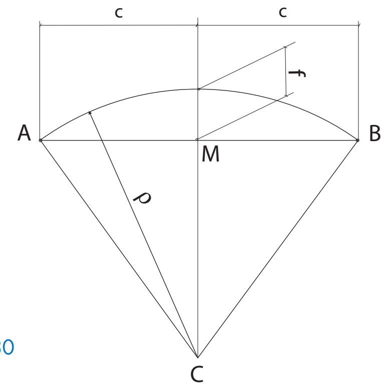


Fig 2-30

The actual bending radius in situ can be determined using the following equation:

$$\rho = \frac{f^2+c^2}{2 \cdot f}$$

Where:

ρ = bending radius [in m]
f = pass [in m]
c = half chord length [in m]

2.3.8 Determination of the construction pit measurements:

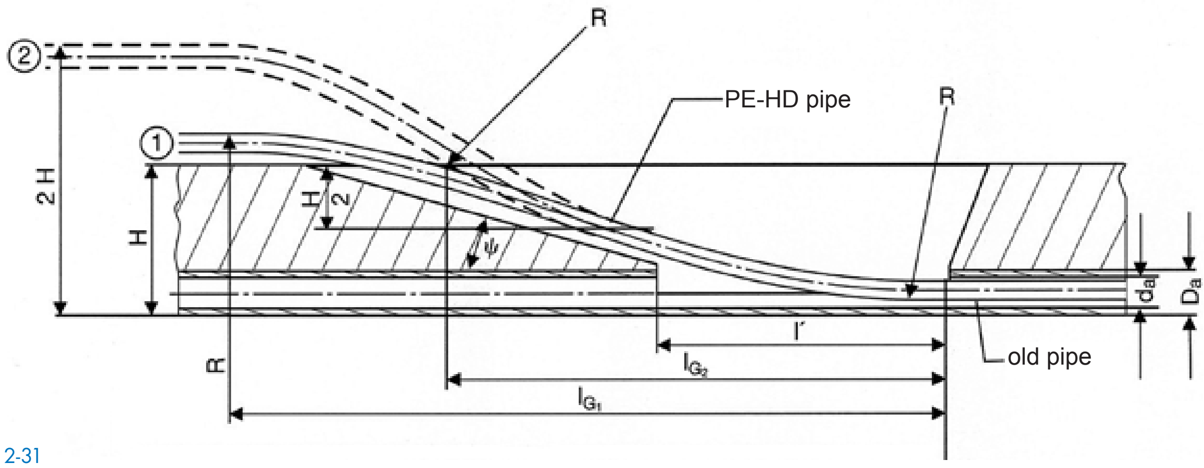


Fig 2-31

The length of the pit is determined by:

$$l_{G1} = \sqrt{H(4 \cdot R - H)}\,[mm]$$

This gives, for the various installation temperatures:

$$l_{G1.20^\circ C} = \sqrt{H(80 \cdot d_a - H)}\,[mm]$$
$$l_{G1.10^\circ C} = \sqrt{H(140 \cdot d_a - H)}\,[mm]$$
$$l_{G1.0^\circ C} = \sqrt{H(200 \cdot d_a - H)}\,[mm]$$

As a rule of thumb:

$$l_{G1} \approx 13 \cdot \sqrt{H \cdot d_a}\,[mm]$$

By lifting the pipe to the height 2·H above the site surface, the required construction pit length is reduced to:

$$l_{G2} \approx \sqrt{H(2 \cdot R - H)}\,[mm]$$

The length of the pit floor is determined by:

$$l' = \sqrt{D_a(2 \cdot R - D_a)}\,[mm]$$

or roughly:

$$l' \approx \sqrt{2 \cdot R \cdot D_a}\,[mm]$$

The slope of the entry pit is given by:

$$\tan\Psi = \frac{H - D_a}{l_G - l'}$$

where:
H = depth of the pipe bed [mm]
R = permissible bending radius [mm]
D_a = outer diameter of the old pipe [mm]
d_a = outer diameter of the new HDPE pipe [mm]

2.3.9 Permissible Pulling Forces for Pipes made of PE 100/PE 100-RC

The values apply to pipes made from PE 100 / PE 100-RC and to egeplast pipes with protective layers (since only the pressure pipe transporting the medium is exposed to strain when the pipe is inserted). These must be measured and documented. Exceeding the permissible pulling forces leads to an everlasting damage of the pipe.
Pipes with protective layers require special drill heads. Usually, to ensure that the layer constitutes no additional obstacle, pulling heads with an outer sleeve are used, which is covering the layer/layer edge. Alternatively the joint edge must be protected by design measures (e.g. by the weld seam).

Pulling force: Permissible pulling force in kN for pipes made of PE 100 and PE 100-RC at 20 °C pipe temperature.

Note: For pulling durations of > 30 minutes, the values are to be reduced by 10%; for durations of > 20 h, they should be reduced by 25%.

Outer diameter	Permissible Pulling Forces for Pipes made of PE 100/PE 100-RC			
OD [mm]	SDR 17.6 [kN]	SDR 17 [kN]	SDR 11 [kN]	SDR 7.4 [kN]
16				0.95
20			1.08	1.51
25		1.31	1.64	2.36
32	1.71	1.80	2.65	3.81
40	2.72	2.83	4.22	5.96
50	4.29	4.43	6.56	9.34
63	6.71	7.06	10.42	14.69
75	9.55	9.96	14.56	20.93
90	13.60	14.34	21.06	30.01
110	20.51	21.43	31.40	45.00
125	26.28	27.33	40.66	57.94
140	33.16	34.32	50.76	72.83
160	43.12	44.89	66.66	94.97
180	54.38	56.88	84.25	120.04
200	67.51	70.29	103.90	148.50
225	85.29	89.03	131.64	187.81
250	105.14	109.30	162.01	231.74
280	131.85	137.29	203.06	290.67
315	166.99	173.98	257.20	367.97
355	211.37	221.22	326.38	466.77
400	268.93	280.03	414.55	593.08
450	339.90	354.89	525.39	750.23
500	420.55	438.59	648.06	925.83
560	525.86	549.18	812.24	
630	666.20	695.93	1028.79	
710	845.48	882.92	1307.33	
800	1073.50	1120.14		
900	1359.59	1417.05		
1000	1679.43	1751.60		
1200	2417.05			

Tab 2-6: See also DVGW Worksheet GW 320, GW 321, GW 324, GW 325 and DVGW code of practice GW 323

Fig 2-32

Fig 2-33

Admissible tensile forces for PE materials

Assumed as admissible tensile force at 20° C pipe wall temperature:
$PE\ 100_{20°C} = 10\ [\frac{N}{mm^2}]$

The admissible tensile force can be calculated for differing temperatures as well:

$$\sigma_{permissible,\ PE\ 100,v} = 10^{\frac{\log 438000 + 38.9375 - \frac{24483.467}{273.15+T}}{-38.9789}}\ \frac{N}{mm}$$

$$\sigma_{permissible,\ PE\ 80,v} = 10^{\frac{\log 438000 + 40.9578 - \frac{23596.3495}{273.15+T}}{-37.5758}}\ \frac{N}{mm}$$

with:
T = Pipe wall temperature in [C°]

Admissible tensile force with simultaneous force and bending stress

$$F_{permissible} = \pi \cdot (OD - s) \cdot s \cdot (\sigma_{permissible} - E_{T,t} \cdot \frac{OD}{2 \cdot R})\ [N]$$

Whereby:
OD = outer diameter [mm]
s = wall thickness [mm]
$\sigma_{admissible}$ = admissible tensile force, depending on temperature and duration [N/mm²]
$E_{T,t}$ = Elasticity module, depending on temperature and duration $E_{PE100,1h,20°C}$ =450 N/mm²
R = Radius [mm]

The reduction amount of the admissible force is determined by adjusting module E. Deviations of the recommended value $E_{PE100,1h,20°C}$=450 N⁄mm² are possible; there is, however, no need for that in practice.

If a long-term module E was chosen, the reduction would turn out to be significantly lower. This would result in the need to adapt the installation method, especially the installation speed, and that would in turn not be economically reasonable. The same goes for a short-term module E, since the installation speed cannot be scaled up indefinately for technical reasons.

2.3.10 Estimation of the tensile forces

The tensile forces in trenchless installation are dependent on a number of factors. However, they can be estimated as described below.

Estimation of the tensile forces in directional drilling measures

$$F_{estimate} = L \cdot OD \cdot \pi \cdot 0.4$$

whereby:
$F_{estimate}$ = estimated value of the required tensile force [kN]
L = pipe length [m]
OD = outer diameter [m]

For a more detailed estimation, please also refer to www.hdd-planer.com.

Estimation of the tensile forces in relining measures

Installation force F (under consideration of grades) results from:

$$F = q_r \cdot l \cdot 10^3(\mu \cdot \cos\alpha \pm \sin\alpha)$$

or from conversion to l_{adm}:

$$l_{zul} = \frac{\sigma_{zul} \cdot f_s}{0.97 \cdot 10^{-5}\frac{N}{mm^2}(\mu \cdot \cos\alpha \pm \sin\alpha)} \cdot 10^{-3}\,[m]$$

whereby:

qr = value resulting from pipe weight [$\frac{N}{m}$]
l = pipe length [m]
μ = friction coefficient, depending on soil conditions up to 0.8 [-]
α = grade angle [°]
σ_{adm} = admissible tensile force, dependent on temperature and duration [$\frac{N}{mm^2}$]
fs = Weld seam factor 0.8 up to 1.0

The following maximum installation lengths can be deducted from that, depending on dimension and SDR:

l_{adm} 20 °C ≈ 680 m
l_{adm} 40 °C ≈ 425 m

As with all other trenchless installation methods, it is important to ensure a median temperature of the pipe wall as low as possible. The admissible temperature-dependent tensile forces must be observed.

2.3.11 Thermal Elongation and Contraction

Changes in length due to temperature must be taken into account when cutting PE pipes to size. When the temperature increases or decreases, 1m of PE pipe elongates or contracts accordingly by 0.2 $\frac{mm}{mK}$ (Δ 1°C=1 K).

This change in length is relevant for pipelines that are free to move (e.g. those running above ground). Pipelines made of PE that are compressed by their surroundings are fixed to the circumjacent ground by shear forces.

$$\Delta L = L \cdot \Delta\vartheta \cdot 0.2\,\frac{mm}{mK}\ [mm]$$

ΔL = change in length in [m]
Δϑ = temperature difference [K]
0.2 $\frac{mm}{mK}$ = median expansion coefficient of polyethylene

Example:
A PE pipeline of 100 m length warms during the day from 8 °C in the morning to 48 °C at midday.

This results in:

$$\Delta\vartheta = 48°C - 8°C = 40K$$

a change of length of:

$$\Delta L = 100\,m \cdot 40K \cdot 0.2\,\frac{mm}{mK} = 800\,mm = 80\,cm$$

Selected median length expansion coefficients of different materials:

Material	mm/mK
Iron	0.012
Steel, ferrite	0.011 – 0.015
Steel, austenitic	0.022 – 0.025
PE	0.2
PP	0.16

Tab 2-7

2.3.12 Fixed Point Stress

If a PE pipeline cannot expand freely, but is held in position by fix points, a force F_{FP} comes to bear on the fix points.

In general, the pipe alignment should be designed without fix point stresses. If that is not possible, the following stress factors should be considered:

- Stress factor heat expansion
- Stress factor inner pressure expansion
- Stress factor swelling (only for organic fluids and their solutions and mixtures as pipe medium)

The force F_{FP} can be determined as follows:

$$F_{FP} = A_{pipe} \cdot E_{PE} \cdot \varepsilon$$

A calculation of the longitudinal expansion is also dependent on the stress factor:

Stress factor heat expansion

$$\varepsilon = 0.2 \cdot \Delta \vartheta$$

Stress factor inner pressure expansion

$$\varepsilon = \frac{0.02 \cdot \rho}{E_{PE} \cdot \left(\frac{OD^2}{ID^2} - 1\right)}$$

Stress factor swelling

$$\varepsilon = 0.025...0,04^{\,i}$$

whereby
F_{FP} = stress at fix point [N]
A_{pipe} = front surface of the pipeline [mm²]
E_{PE} = creep module of PE100 for the relevant stress duration [N/mm²]
ε = longitudinal expansion resulting from the stress factor [-]
OD = outer diameter of the pipe [mm]
ID = inner diameter of the pipe [mm]
ρ = inner overpressure [bar]

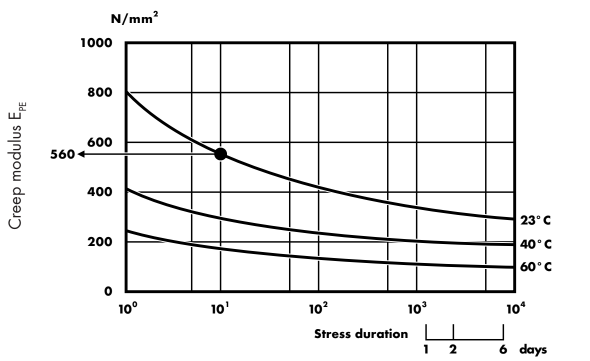


Fig 2-34: Example for PE materials with a minimal bend-creep module of 560 N/mm² acc. to DIN 8074/DIN 8075 with σ_b= 2 N/mm²

The diagram can be used to determine the creep module. The temporal dependence of the creep module is clearly visible. That leads to a much higher fix point stress due to a short-term change in the median temperature of the pipe walls, as compared to a long-term change, for example due to seasonal temperature changes. Regarding pipes suspended from bridges, this would lead to an overdimensioning of abutments and pipe guides when only considering the short-term change.

2.3.13 Abutments

In terms of buried PE pipelines, abutments are not required if their welded joints have been executed in accordance with DVS 2207-1, or if longitudinally force-locked joints have been used. However, if there are forces transferred to the ground, the abutments should be calculated using DVS work sheet GW 310.

2.3.14 Pipe guides and span lengths

The required support distances of plastics pipelines are to be determined considering the admissible bending stress under a limited bend of the pipe section. The following table lists the common span lengths of PE-HD pipes.

Span lengths (L_A) in mm at pipe wall temperature (T_R)					
Pipe OD [mm]	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
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

Tab 2-8: Pursuant to DVS 2210-1, the listed span lengths are valid for pipes with a flexural creep modulus in accordance with material type PE-HD (DIN 8074/75).

Conversion factors f1 and f2

The following conversion factors are to be considered, depending on pipe wall thickness and conveyed medium:

Material	Nominal Pressure PN	Conveyed medium				Wall thickness
		Gas	Water	others		
ρ [$\frac{g}{cm^3}$]						
		< 0,01	1,00	1,25	1,50	
Factor		f1				f2
PE-HD	6	1,47	1,00	0,96	0,92	0,91
PE-HD	10	1,30	1,00	0,96	0,92	1,00
PE-HD	16	1,21	1,00	0,96	0,92	1,07

Table 2-9: Intermediate values may be calculated by linear interpolation in acc. with DVS 2210-1

The required span length L_{nSt} results from:

$$L_{nst} = L_A \cdot f_1 \cdot f_2$$

Example:
A pipe with a dimension of 110 mm SDR 11 is supposed to be installed under the ceiling. The medium is water with a temperature of 50°C.

Deducting from table 2-8, the span length L_A at 50°C is L_A=1450 mm. Factors f_1 and f_2 are calculated from the nominal pressure PN 16 bar and the medium water with f_1=1.00 and f_2=1.07.

$$L_{nst} = L_A \cdot f_1 \cdot f_2 = 1450\,mm \cdot 1.00 \cdot 1.07 = 1551.50\,mm \approx 1550\,mm$$

In case of pipelines above the ground where a change in length cannot be compensated, and where an axial evasion is not possible, pipe guides are to be used in defined distances. The objective is to prevent the pipe from bending. With a safety factor of 2, and:

$$L_{bend} = 3.17 \sqrt{\frac{\frac{\pi}{64}(OD^4 - ID^4)}{\varepsilon \cdot A_{pipe}}}$$

whereby

L_{bend} = distance of pipe guides to prevent bends [mm]
A_{pipe} = front surface of the pipeline [mm²]
ε = longitudinal expansion resulting from the stress factor [-]
OD = outer diameter of the pipe [mm]
ID = inner diamter of the pipe [mm]

the distance to prevent bending can be calculated. If the calculated distance is smaller than the calculated span length distance L_{nST}, the distance L_{bend} has to be chosen.

In case of an application temperature ≥45 °C:

$$L_{bend,\ \geq 45^{\circ}C} = 2.53 \sqrt{\frac{\frac{\pi}{64}(OD^4 - ID^4)}{\varepsilon \cdot A_{pipe}}}$$

2.3.15 Calculation of buoyancy

Calculating the buoyancy ensures a stable position of the pipe in ground water or a drilling mud.

A buoyancy calculation is required for a mass-related trimming of the pipe to reach minimal installation forces in horizontal drilling methods. When calculating the buoyancy, the upward forces have to be offset with the downward forces. The displaced fluid here is considered the flush including loaded cuttings in existing or planned density.

The buoyancy is calculated with

$$F_{buoyancy} = V \cdot \rho \cdot g\ [N]$$

whereby

V = volume of the displaced medium [m³]
ρ = density of the displaced medium [$\frac{kg}{m^3}$]
ρ_{water} = 1000 $\frac{kg}{m^3}$
$\rho_{suspension}$ = 1020 – 1040 $\frac{kg}{m^3}$
$\rho_{PE\ 100}$ = 960 $\frac{kg}{m^3}$
g = gravity [9.81 $\frac{m}{s^2}$]

The calculation should be made for 1 m of pipe.

Fig 2-35

Example:
Protective layer pipe OD 110 mm SDR 11 (OD_{total} = 115 mm)

$$V_{pipe} = \frac{\pi}{4} OD^2 \cdot 1m = \frac{\pi}{4}(0.115\ m)^2 \cdot 1m = 0.01039\ m^3$$

$$F_{buoyancy} = 0.01039\ m^3 \cdot 1040\ \frac{kg}{m^3} \cdot 9.81\ \frac{m}{s^2} = 106 N$$

$$F_{G,pipe} = \pi(0.115\ m - 0.010\ m) \cdot 0.010\ m \cdot 1m \cdot 960\ \frac{kg}{m^3} \cdot 9.81\ \frac{m}{s^2} = 31.07\ N$$

$$F_{res} = F_{buoyancy} - F_{G,pipe}$$

$$F_{res} = 106 N - 31.07\ N = 74.93\ N$$

$F_{buoyancy} > F_{G,pipe}$ ➡ the pipe floats up

2.4 Liability Risks

The German Advisory Council on Global Change (WBGU, see annual report, 1998) defines risk as the product of occurrence frequency or occurrence probability and the seriousness of the event or extent of damage.

Here the occurrence frequency describes thew frequency with which an occurrence takes place within a defined period.

The unit representing the extent of damage depends on the respective subject matter and situation. It may consist of values that can be expressed in amounts of money (e.g. euros), but it may also involve environmental damage or damage to property or even personal injury. In particular, damage to gas pipes with gas explosions repeatedly hit the headlines. Damage to wastewater pipelines, by contarst, means environmental damage.

Currently there are no legally binding standards with respect to requirements on which pipes to select for alternative installation methods. At the same time, the generally formulated requirements contained in higher-ranking laws/standards and codes of practice must be satisfied, e.g. the stipulations of the "Basic safety considerations" for pipelines in accordance with Annex I of the DGRL Pressure Equipment Directive 97/23/EC and the requirements arising from the German Ordinance on Industrial Health and Safety (BetrSichV).

For this reason egeplast has commissioned the law firm FRESHFIELDS BRUCKHAUS DERINGER to examine the question of the liability of diverse market actors (pipe manufacturer, planner, company processing the pipes and network operator) in the installation of pipes without sand bed and using the trenchless method.

Possible claims are examined in respect of production faults, damage due to insufficient suitability of the pipes for the method selected, planning or specification errors and damage during pipe jacking.

Overview of the liability risks for market actors

	Planner		Processing company		Network operator
	Contractual (vis-à-vis customer)	Tortious (also vis-à-vis third parties)	Contractual (vis-à-vis customer)	Tortious (also vis-à-vis third parties)	also vis-à-vis third parties
Subject matter	• Faulty planning (this also includes the selection of unsuitable building materials/installation methods) o Inspection obligation o Alert customer to concerns • In accordance with Section 5.4.2 German Association of Gas and Water Engineers (DVGW) Code of Practice GW 321 additional external pipe protection for specific ground conditions	Damage resulting from **culpably** faulty planning or selection of unsuitable materials/installation methods	• Damage during installation • Inspection duty to ascertain whether building materials and subsoil are suitable (load test if doubts exist) • In accordance with Section 5.4.2 DVGW Code of Practice GW 321 additional external pipe protection for specific ground conditions • Modification of warranty rights possible by agreement on VOB/B (German Construction Contract procedures)	Damage resulting from culpable damage during installation or violation of the duty to inspect building materials and foundations	• Culpable damage resulting from the selection of the wrong products (-) When making use of external expertise • Liability of the owner of a pipeline system for damage to property or personal injury caused by the system regardless of negligence (-) if the system corresponds to the recognised state of the art
Quality assurance	Evidence of installation free defects through the use of pipes with integrity test				Invitation to tender to the effect that documentation of installation that is free from defects must be provided during acceptance on the basis of pipes with quality check

Tab 2-10: Potential liability risks of planners, processing companies and network operators (source: expert optinion produced by FRESHFIELDS BRUCKHAUS DERINGER)

Currently there are no (legally) binding standrads which set out detailed technical regulations for pipe selection for alternative installation methods or which describe the requirements of the installation itself. For this reason high demands are placed on those involved in terms of the selection of materials and methods in order to comply with the generally formulated requirements of applicable laws, guidelines and ordinances. One of the most common sources of error for liability for planners, processing companies and network operators is the choice of unsuitable materials or installation method. Section 5.4.2 of the German Association of Gas ans Water Engineers (DVGW) Code of Practice GW 321, for example, is decicive for pipeline construction, according to which an additional external protection for the pipe, e.g. polyolefin outer layer, must be used under certain ground conditions.

It is therefore only possible to recommend the use of pipe systems where their suitability and installation free from defects can be unequivocally recognised and documented from a technical perspective. Planners, processing companies and network operators may be liable for up to 30 years insofar as the damage did not occur beforehand.

2.5 Standards and codes of practice

■ Codes of practice

Harmonised technical principles and rules are necessary for safe and reliable gas and water provision (and also for wastewater disposal). These promote rationalisation and quality assurance, serve the safety of people and property and thereby benefit the public [GW100]. In Germany the technical codes of practice are generally created by the technical scientific associations such as DIN and DVGW, and in Europe by the European standardisation institue CEN. In Germany the DVGW codes of practice are prescribed as the binding benchmark in gas and water technologies.

DIN

DVGW

PAS

Generally recognised state of the art

The generally recognised state of the art describes the prevalent opinion on technical rules governing the design and execution of works systems that are not exposed to scientific controversy and which have therefore been recognised as being theoretically correct and established; they are also in particular familiar among the technicians who have been trained and who have up-to-date knowledge in the group of rules and who are decisive for the application of the rules concerned and who, on the basis of their ongoing, practical experience, recognise these to be technically suitable, appropriate and necessary (Munich Comment [MÜKO], German Civil Code [BGB], 4th Edition, Section 633, Number 17 among others). This benchmark lags behind the aspirations for further technical development:

State of the art

The state of the art consistes of rules that can not yet be regarded as generally recognised but which reflect the state of technical findings at a defined period of time and which have gained an entry to operational practice (MüKO, loc cit., Section 633 Number 19).

A Publicly Available Specification (PAS) represents one possibility for defining an established state of the art that has not yet gained entry to classic technical rules. The publication of this industry standard by the German standardisation institute, the Deutsche Institut für Normung e.V., gives it special authority and provides an opportunity for the monitoring of a described minimum quality by an independent certfier.

DVGW regulations

DVGW work sheet GW 335 lines out the quality requirements for polyethylene pipes for conventional installations in sandbeds. For alternative installation methods, DVGW has published methodologies and guidelines as work and information sheets in its GW 32x series. The quality requirements for alternatively layed pipes are not yet fully covered by technical rules. Currently, DVGW regulations only demand the pipes to conform to the installation method and offer some recommendations. Consequently, polyethylene pipes installed in trenchless construction methods are still subject to the same requirements as pipes for sandbedding. This does not accomodate the current state of the art.

DVS information sheets / guidelines

DVS information sheets and guidelines are valid for connecting plastics pipe through welding. These rules apply regardless of the method of installation.

■ Codes of practice governing installation methods, pipe material and connection technology

Type of installation	Codes of practice on installation methods	Specifications and recommendation of codes of practice for installation methods for the pipe material to be deployed	DVS connection technology guidelines DVS 2207-1 Evaluation of the welded joint in accordance with DVS 2202-1
Open trench pipe installation using sand	W 400 – 2 (water) G 472 (gas) DIN EN 805	• GW 335 • max. 10 % scratch depth	0.1 x t (thickness), however max. 0.5 mm for evaluation group 1 Lack of fusion in HM due to scoring in the pipe surface is prohibited in all 3 evaluation groups. A definition of depth of score was dropped in the replacement of DVS 2202
Open trench pipe installation without sand / ploughing / milling	GW 324 W 400 – 2 (water) G 472 (gas)	• max. 10 % scratch depth • Point load resistance and protection against impermissible groove formation depending on the subsoil	0.1 x t (thickness), however max. 0.5 mm for evaluation group 1 Lack of fusion in HM due to scoring in the pipe surface is prohibited in all 3 evaluation groups. A definition of depth of score was dropped in the replacement of DVS 2202
New installation using pipe jacking **Horizontal directional drilling (black box method)**	GW 321 W 400 – 2 (water) G 472 (gas)	• max. 10 % scratch depth • Polyolefin layers as external protection for the pipe recommended	0.1 x t, however max. 0.5 mm in evaluation group 1 Lack of fusion in HM due to scoring in the pipe surface is prohibited in all 3 evaluation groups. A definition of depths of score was dropped in the replacement of DVS 2202
New installation using pipe jacking **Impact moles (black box method)**	GW 325 W 400 – 2 (water) G 472 (gas)	• max. 10 % scratch depth • Suitable external protection for the pipe may be required depending on the subsoil and embedding conditions	00.1 x t, however max. 0.5 mm in evaluation group 1 Lack of fusion in HM due to scoring in the pipe surface is prohibited in all 3 evaluation groups. A definition of depths of score was dropped in the replacement of DVS 2202
Renovation using pipe jacking **Relining (black box method)**	GW 320 -1 (with annular gap) W 400 – 2 (water) G 472 (gas)	• max. 10 % scratch depth	0,1 x s however max. 0.5 mm in evaluation group 1 Lack of fusion in HM due to scoring in the pipe surface is prohibited in all 3 evaluation groups. A definition of depths of score was dropped in the replacement of DVS 2202
Renovation using pipe jacking **Pipe bursting (black box method)**	GW 323 W 400 – 2 (water) G 472 (gas)	• max. 10 % scratch depth • Polyolefin layers as external pipe protection recommended • PE 100 with FNCT > 3300 h	0,1 x s however max. 0.5 mm in evaluation group 1 Lack of fusion in HM due to scoring in the pipe surface is prohibited in all 3 evaluation groups. A definition of depths of score was dropped in the replacement of DVS 2202
Renovation using pipe jacking **PE reduction method (black box method)**	GW 320 – 2 (without annular gap) W 400 – 2 (water) G 472 (gas)	• max. 10 % scratch depth	0,1 x s 0.1 x t, however max. 0.5 mm in evaluation group 1 Lack of fusion in HM due to scoring in the pipe surface is prohibited in all 3 evaluation groups. A definition of depths of score was dropped in the replacement of DVS 2202

Tab 2-12: Codes of practice governing installation methods, pipe material and connection technology

Rules and standards (In alphabetical order)

- **ASTM D 1929, 2011**
  Test Method for Ignition Temperature of Plastics

- **DIN 2000, 10.00**
  Guidelines for drawing up requirements for the design, construction, operation and maintenance of public drinking water supply systems (DVGW Code of practice)

- **DIN 4102**
  Fire behaviour of building materials and elements

- **DIN 4124, 01.12**
  Excavations and trenches – Slopes, casing and strutting

- **DIN 8074, 12.11**
  Polyethylene (PE) Pipes –PE 63, PE 80, PE 100, HDPE – Dimensions

- **DIN 8075, 12.11**
  Polyethylene (PE) Pipes PE 63, PE 80, PE 100, HDPE – General Quality Requirements and Testing

- **DIN 16928, 04.79**
  Pipes of Thermoplastic Materials; Pipe Joints, Elements for Pipes, Laying; General Directions

- **DIN 18196, 05.11**
  Earthworks and foundations - soil classification for civil engineering purposes

- **DIN EN 1555-1, 12.10**
  Plastics piping systems for the supply of gaseous fuels – Polyethylene (PE) - Part 1: General

- **DIN EN 1555-2, 12.10**
  Plastics piping systems for the supply of gaseous fuels – Polyethylene (PE) - Part 2: Pipes

- **DIN EN 1555-3, 08.11**
  Requirements for polyethylene molded parts for welded joints and for molded parts for mechanical joints – Gas supply

- **DIN EN 12007-1, 08.00**
  Gas infrastructure – pipelines for maximum operating pressure up to and including 16 bar, Part 1: General functional requirements

- **DIN EN 12007-2, 08.00**
  Gas infrastructure – pipelines for maximum operating pressure up to and including 16 bar, Part 1: Special functional requirements for polyethylene

- **DIN EN 12201-1, 11.11**
  Plastic piping systems for water supply and for drainage and sewerage under pressure – polyethylene (PE) – Part 1: General

- **DIN EN 12201-2, 11.11**
  Plastic piping systems for water supply and for drainage and sewerage under pressure – polyethylene (PE) – Part 2: Pipes

- **DIN EN 12201-3, 11.11**
  Plastic piping systems for water supply and for drainage and sewerage under pressure – polyethylene (PE) – Part 3: Fittings

- **DIN EN 12201-5, 11.11**
  Plastic piping systems for water supply and for drainage and sewerage under pressure – polyethylene (PE) – Part 5: Fitness for purpose of the system

- **DIN EN 805, 03.00**
  Water supply – Requirements for systems and components outside buildings

- **DIN EN ISO 14688-1, 06.11**
  Geotechnical investigation and testing – identification and classification of soil – Part 1: Identification and description

- **DIN EN ISO 14688-2, 06.11**
  Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles of soil classification

- **DIN EN ISO 14689-1, 06.11**
  Geotechnical investigation and testing – Identification and classification of soil – Part 1: Identification and description

- **DIN EN ISO 178, 04.11**
  Flexural testing - plastics

- **DIN EN ISO 179-1, 11.10**
  Plastics – Determination of Charpy impact properties – Part 1: Non-instrumented impact test

- **DVGW G 459-1, 07.98**
  Gas service pipes for operating pressures up to 4 bar – design and construction

- **DVGW G 469, 06.10**
  Pressure testing methods for gas transmission/gas distribution

- **DVGW G 472, 08.00**
  Polyethylene gas pipelines with an operating pressure up to and including 10 bar (PE 80, PE 100 and PE-Xa) –Construction

- **DVGW GW 320-I, 02.09**
  Replacement of gas and water pipelines through pulling in or pushing in pipes with annular gap

- **DVGW GW 320-II, 06.00**
  Rehabilitation of gas and water pipelines by PE relining with annular space – requirements, quality assurance and verification

- **DVGW GW 321, 10.03**
  Horizonal directional water-jet drilling procedures for gas and water pipelines – requirements, quality assurance and verification

- **DVGW GW 323, 07.04**
  Trenchless renovation of gas and water supply lines through pipe bursting – requirements, quality assurance and verification

- **DVGW GW 324, 08.07**
  Milling and ploughing procedure for gas and water pipelines – requirements, quality assurance and testing

- **DVGW GW 325, 03.07**
  Trenchless installation methods for gas and water connecting pipelines – requirements, quality assurance and testing
- **DVGW GW 330, 11.00**
  Welding of pipes and pipeline sections made of polyethylene (PE 80, PE 100 and PE-Xa) for gas and water mains – teaching and test plan
- **DVGW GW 331, 10.94**
  Welding supervision for welding on PE-HD pipelines for gas and water mains – teaching and test plan
- **DVGW GW 332, 09.01**
  Squeeze-off polyethylene pipes in gas and water supply
- **DVGW GW 335-A 2, 11.05**
  Plastic piping systems for gas and water distribution; requirements and testing – pipes made of PE 80 and PE 100
- **DVGW W 400-1, 02.15**
  Code of practice for water distribution systems (TRWV) – Planning
- **DVGW W 400-2, 09.04**
  Code of practice for water distribution systems (TRWV) – Construction and testing
- **DVS-Standard 2202-1, 07.06**
  Faults in Welded Joints in Thermoplastic Plastics – Features, Description, Evaluation
- **DVS-Standard 2203-1, 01.03**
  Testing of welded joints of thermoplastic sheets and pipes; Test methods – Requirements
- **DVS-Standard 2203-2, 08.10**
  Testing of Welded Joints of Thermoplastics – Tensile Test
- **DVS-Standard 2203-3, 04.11**
  Testing of Welded Joints of Thermoplastics – Tensile Impact Test
- **DVS-Standard 2203-4, 07.97**
  Testing of Welded Joints of Thermoplastics Plates and Tubes – Tensile Creep Test
- **DVS-Standard 2203-5, 08.99**
  Testing of Welded Joints of Thermoplastics Plates and Tubes – Technological Bend Test
- **DVS-Standard 2207-1, 08.15**
  Welding of Thermoplastics – Heated Tool Welding of Pipes, Pipeline Components and Sheets Made of PE
- **DVS-Standard 2210-1, 04.97**
  Thermoplastic industrial piping systems – project planning and installation of above ground piping systems
- **EN ISO 1167-1, 05.06**
  Pipes and molded parts made of thermoplastics for the conveyance of fluids – Resistance to internal overpressure
- **EN ISO 1167-3, 02.08**
  Pipes and molded parts made of thermoplastics for the conveyance of fluids – Resistance to internal overpressure – Preparation
- **EN ISO 1167-4, 02.08**
  Pipes and molded parts made of thermoplastics for the conveyance of fluids – Resistance to internal overpressure – Preparation
- **EN ISO 3126, 05.05**
  Plastics pipe systems – Plastics pipe components – Determination of dimensions
- **KRV Installation Instructions A 135/99-15, 6th Edition**
  for High Density (PE 80 and PE 100) Polyethylene Pipelines for Drinking and Water Supply Outside Buildings"
- **KRV Installation Instructions A 435/96-10, 5th Edition**
  for Polyethylene (PE) Pipelines for Gas Distribution Outside Buildings
- **PAS 1031, 09.04**
  Material Polyethylene (PE) for the manufacture of pressure pipes and -fittings - requirements and tests
- **PAS 1075, 04.09**
  Pipes made from Polyethylene for alternative installation techniques - Dimensions, technical requirements and testing
- **R 14.3.1 DA, 01.98**
  PE 80 and PE 100 Pressure Pipes in General, Gütegemeinschaft Kunststoffrohre e.V.
- **R 14.3.1 G, 01.98**
  PE 80 and PE 100 Pressure Pipes for Gas Applications, Gütegemeinschaft Kunststoffrohre e.V.
- **R 14.3.1 TW, 01.98**
  PE 80 and PE 100 Pressure Pipes for Drinking Water Applications, Gütegemeinschaft Kunststoffrohre e.V.

The list of standards and guidelines is only provided for information purposes and makes no claim to completeness.

2.6 Supervision of construction

2.6.1 Pipe Storage

All the pipes made of PE 100 and PE 100-RC offered by egeplast are stabilised for 2 years against sunlight for outdoor storage in Europe. Nevertheless it is recommended to protect the piping from direct exposure to solar radiation. Before using pipes which have been stored outside for more than two years, a separate confirmation of serviceability is to be carried out (e.g. internal pressure creep test according to DVGW GW 335, Part A2).

The piping should be stored such that it cannot be contaminated. The pipes are not allowed to come into contact with fuels, solvents, oils, greases, colourings, or sources of heat.

Unfavourable storage conditions can result in professional installation being possible only with difficulty. The piping should be stored on a straight surface as possible, away from sharp or pointed objects. If the piping is stacked, the individual tiers should be staggered, and wooden spacers should not be used. The pipe stack is to be secured against sideways slippage. The height of the stack should not exceed 1.5 m. For nominal diameters of above 500, only two tiers should be stacked. Bundled coils should be stacked in a lying position. Packaging strips should only be removed shortly before installation. Dragging of the pipes and bundled coils over the ground is not permitted.

2.6.2 Inspection of Pipes

Pipes are to be checked for sound condition and complete labelling in accordance with the DVGW regulations before they are placed in the pipe trench.

Scores, scratches and abrasions are permissible on the PE pipes up to 10% of the minimum wall thickness. Pipes with damage extending this limit may not be installed.

2.6.3 Leak Tightness Tests

2.6.3.1 Drinking Water in Accordance with DIN EN 805/DVGW Worksheet W 400-2

ⓘ Each of the standards and guidelines is applicable in its currently valid form.

Test pressure

For all pipelines, the system test pressure (STP) is calculated from the maximum design pressure (MDP) as follows:

For calculating the pressure surge:
$STP = MDP_c + 1$ bar

If the pressure surge is not calculated:
$STP = MDP_a \cdot 1.5$ or
$STP = MDP_a + 5$ bar
The smaller value applies in each case.

The minimum test pressure MDP is specified according to DVGW Worksheet W 400-2 to be 10 bar. Pipelines made of PE 100 SDR 17 may be tested only using a test pressure of STP ≤ 12 bar. For pipelines made of HDPE with volumes >20 m³ as well as pipelines made of PE 100 SDR 17, it is recommended in Worksheet W 400-2 that the standard procedure be used. However, systems >20 m³ can be checked in contraction procedure with suitable measuring and testing equipment.

■ Contraction procedure

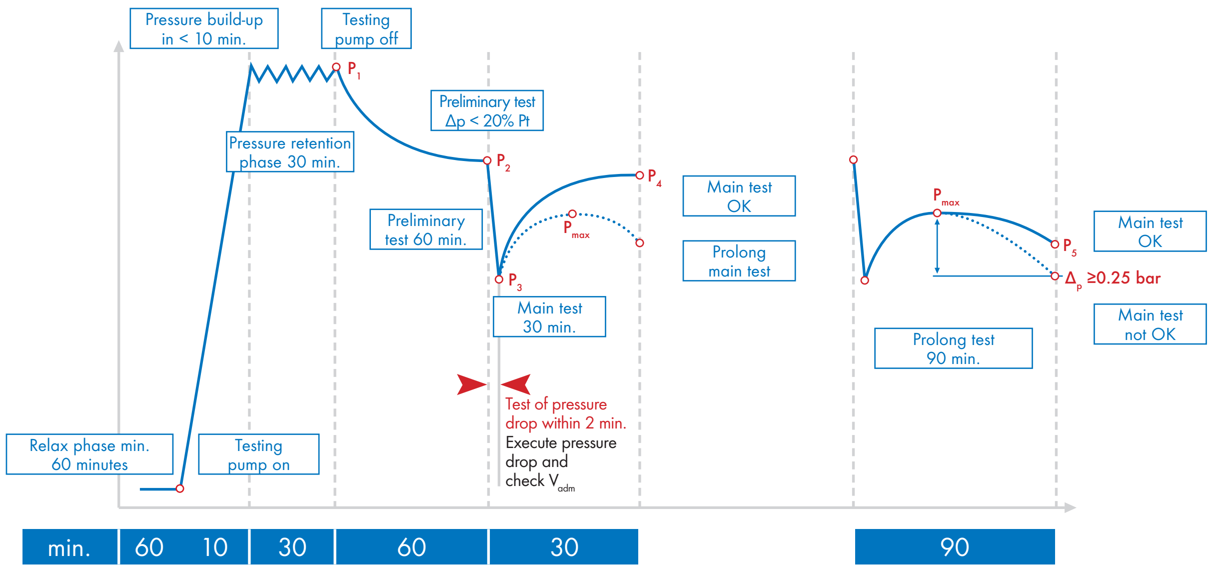


Fig 2-36

Preliminary test

After air-free filling (flushing speed > 1 m/s) and, if necessary, pigging of the pipeline, a one hour relaxation period is effected by opening the shut-off valve at the high point of the line. The pipeline is closed, brought up to the system test pressure STP within 10 minutes, and kept at this pressure for a period of 30 minutes by continuous pumping. Following this there is a one hour relaxation phase during which the pressure in the pipeline is permitted to sink by the maximum of 20% of the test pressure STP. If the pressure drop is greater, then either leakage is present, or the pipeline was exposed to an impermissible increase in temperature. The test should then be discontinued. It is imperative that a one hour relaxation time be allowed before repeating the preliminary test. After successful completion of the preliminary test, the main test may be carried out.

Main test with integrated pressure drop testing

The expansion of the pipeline is brought to an end by a rapid pressure reduction p_{ab} within less than 2 minutes.

The pressure reduction to be applied is specified in the following table.

Pipe Material	Elastic Modulus in $\frac{N}{mm^2}$	SDR	Pressure Reduction P_{ab}
PE 100	1200	17	2.0
PE 100	1200	11	3.2

Tab 2-13: Applied pressure reduction p_{ab} in bar

The volume V_{ab} of water drained is to be measured using suitable instruments. The pressure is to be recorded without interruption throughout the entire test duration, and the pressure rise occurring after the pressure reduction is to be monitored during the half-hour contraction period. Air-free conditions are considered satisfied if the drained water volume V_{ab} is smaller than or equal to the highest permissible water volume V_{zul}

Required is:

$$V_{ab} \leq V_{zul} \text{ with } V_{zul} = V_k \cdot L$$

where:

V_k = water volume calculated according to formula or table [$\frac{ml}{m}$]

$$V_k = 0.1 \cdot f \cdot \frac{\pi \cdot ID^2}{4} \cdot p_{ab} \cdot \left(\frac{1}{E_W} + \frac{ID}{E_R \cdot s} \right)$$

V_{zul} = highest permissible water volume in ml

p_{ab} = pressure reduction according to table [bar]

OD= pipe outer diameter in mm

ID = pipe inner diameter in mm

E_W = compression modulus of water [2027 $\frac{N}{mm^2}$]

E_R = elastic modulus of the pipe n [PE 100= 1200 $\frac{N}{mm^2}$]

s = wall thickness assuming median pipe wall tolerances

f = 1.05 compensation factor for air and temperature dependent E modulus variations as well as the effect of contraction

L = length of the tested section [m]

OD	PE 100 SDR 17	PE 100 SDR 11
32		1.28
40		1.95
50		3.10
63		4.95
75	8.30	7.22
90	12.01	10.35
110	18.02	15.57
125	23.76	20.04
140	29.81	25.39
160	38.93	32.90
180	49.26	41.79
200	60.81	51.74
225	76.96	65.41
250	95.90	81.27
280	120.17	102.17
315	151.94	129.22
355	192.81	164.48
400	246.02	208.76

Tab 2-14: Calculated water volumes V_k in $\frac{ml}{m}$

The tested pipeline is considered to be tight if a slightly increasing to fl at pressure change is observed in the course of the half-hour test period t_k. The test period can be extended up to 1.5 hours in case of doubt. In this case, the pressure drop Δp_{zul} relative to the highest value measured during the test period may not amount to more than 0.25 bar.

- Internal pressure testing according to the standard procedure for all pipe materials

Preliminary test

The test pressure for PE pipelines is maintained for a duration in accordance with Table 2-15 by repeated pumping (after a pressure drop of 1-2 bar at the latest).

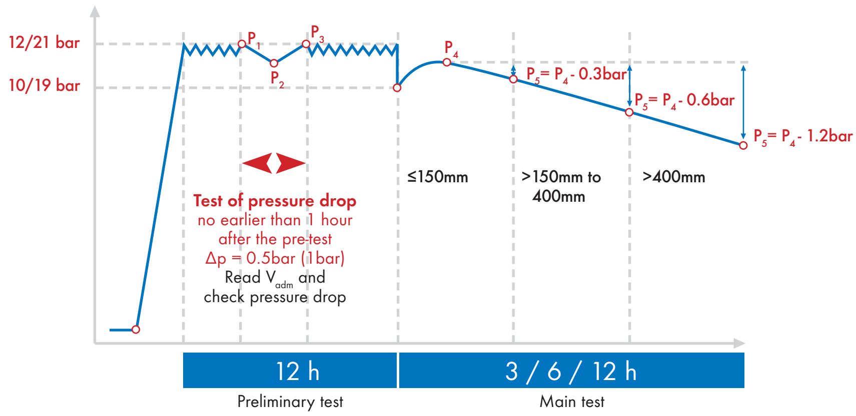


Fig 2-37: Schematic process of the normal procedure

Pressure drop test

The pressure drop test serves to determine if the pipeline has been sufficiently emptied of air. Following the preliminary test, and preferably within 1 hour of the start of the preliminary test, a quantity ΔV of water is to be taken and measured.

The pressure drop should amount to at least Δp=0.5 bar. Pressure reductions of over 1 bar are reasonable for small nominal diameters and short test sections. The maximum permissible volume change ΔV_{zul} is defined by the following equation:

$$\Delta V_{zul} = 0.1 \cdot f \cdot \frac{\pi \cdot ID^2}{4} \cdot L \cdot \Delta p \cdot \left(\frac{1}{E_W} + \frac{ID}{E_R \cdot s} \right)$$

where:

ΔV_{zul} = highest permissible water volume [in ml]

Δp= measured pressure reduction (0.5 bar or 1 bar)

ID = pipe inner diameter [in mm]

E_W= compression modulus of water $[2027 \frac{N}{mm^2}]$

E_R = elastic modulus of the pipe $[PE\,100 = 1200 \frac{N}{mm^2}]$

s = wall thickness assuming median pipe wall tolerances

f = 1.05 compensation factor for unavoidable air pockets

L = length of the tested section [m]

Air-free conditions are considered satisfied if the drained water volume ΔV is smaller than or equal to the highest permissible water volume ΔV_{zul}. Should this not be the case, the pipe section to be tested must be deaerated again.

Main test

The main test takes place subsequent to the preliminary test and the pressure drop test. The test pressure is restored, and the pressure drop over the test period is documented. The permissible pressure drop and the duration of the main test is given by in the following Table 2-15. The test is considered passed if the detected pressure drop is smaller than the maximum permissible pressure drop.

Pipe Material	MDP bar	DN	Preliminary Test		Main Test		Permissible Pressure Drop bar/h
			Pressure/ STP bar	Time h	Pressure/ STP bar	Time h	
PE 100 SDR 11	16	≤ 150	21	12	19	3	0.1
PE 100 SDR 11	16	200 to 400	21	12	19	6	0.1
PE 100 SDR 11	16	> 400	21	12	19	12	0.1
PE 100 SDR 17	10	≤ 150	12	12	10	3	0.1
PE 100 SDR 17	10	200 to 400	12	12	10	6	0.1
PE 100 SDR 17	10	> 400	12	12	10	12	0.1

Tab 2-15: Characteristic values for pressure testing according to the standard procedure

Note: A description of the procedure is also given in DIN EN 805.

Basic information regarding pressure tests

The pipeline should be tested in its entirety and may be tested in subsections only if necessary. The layout of the test sections has to ensure that the test pressure is attained at the lowest point of each section. The test pressure has to amount to at least 1.1-times the highest system operation pressure (MDP) at the highest point of each test section. Test sections can therefore already be derived from the height profile of the pipeline alignment. Using an SDR 11 pipeline as example, the result is a maximum height difference of 34 m within one test section.

Example: PE 100 SDR 11; MDP_a = 16 bar

$$STP_{min} = 1.1 \cdot MDP = 1.1 \cdot 16\,bar = 17.6\,bar$$

$$\Delta\, STP = STP - STP_{min} = 21\,bar - 17.6\,bar = 3.4\,bar$$

Fig 2-38

These sections should be considered as early as in the design phase in order to accomodate for a smooth approval procedure of the line.

The required amounts of water, especially for the contraction test, need to be considered, just as a damage-free discharge of the testing medium after the test.

It is also recommended to supplement the filling water a desinfectant, dosage and type of which in accordance with the drinking water regulations.

As there is usually not enough water available for an air-free flushing of the pipe, a pigging should be a part of the test planning right from the start.

Even if water as test medium is mostly incompressible, the occurring forces and the respective resulting damages should not be underestimated, and should be included in a safety concept for pressure tests. DVGW work sheet GW 310 "Concrete abutments, assessment bases" offers the following formula to calculate the forces affecting the end cap.

$$N_k = 0.1 \cdot STP \cdot \frac{\pi \cdot OD^2}{4}\ [N]$$

For an OD 63 mm pipe and a test pressure of 21 bar, the result is:

$$N_k = 0.1 \cdot 21\,bar \cdot \frac{\pi \cdot (63\,mm)^2}{4} = 6546\,N = 6.55\,kN$$

accordingly about 667 kg.

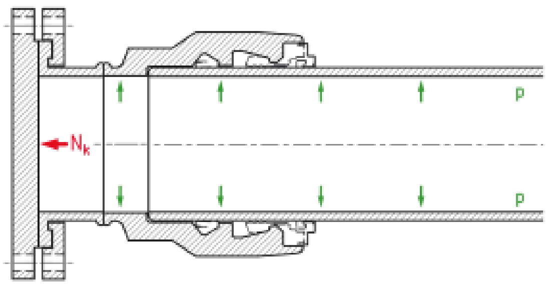


Fig 2-39: Source: DVGW work sheet GW 310

2.6.3.2 Gas Pipelines in Accordance with DVGW Worksheet G 469

Once a pipeline or installation has been completed it is necessary to prove that it is suitable for operation at the intended and permissible operating pressure. In this context the G 469 code of practice describes the pressure testing methods to be used for gas supply pipelines and installations. Pressure tests are used to evaluate the stability and/or leak tightness of the inspected system and form part of the proof of safety of the pipelines or installations.

As a rule, pressure tests are differentiated according to the use of test medium, whereby liquid media (water) or gaseous media (air, operating gas) can basically be used.

Summary of the methods in accordance with DVGW code of practice G 469:

Test medium / Test procedure	Water		Air	Operating gas
	once	twice		
	1	2	3	4
Visual inspection method	A1	A2	A3	A4
Pressure measurement method		B2	B3	–
Precision pressure measurement method		–	C3	–
Pressure/volume measurement method		D2		–

Tab 2-16

Selected methods are described briefly below; more detailed information and other procedures can be found in the abovementioned code of practice.

- Pressure measurement method with air B3

With this method the evaluation of leak tightness is obtained using the pressure change determined by fine measurement during the pressure test. This procedure is therefore particularly used for buried pipelines that cannot be accessed for inspection, and is used on pipelines that are completely buried where possible. If this is not the case the temperature influence on exposed parts of the pipeline must be taken into consideration.

The test pressure must exceed the maximum permissible operating pressure by at least 2 bar.

During measurement the pressure in the pipeline must be logged using a recording manometer. The pressure must be measured using a mechanical recording manometer with hidden test pressure range +/- 1 bar or using an electronic recording manometer as well as control manometers whose measurement range is around 1.5 times the test pressure.

For measuring instruments that are used for pressure testing, the measurement uncertainty must be determined and documented by evidence. For example a permissible pressure change of 50 mbar requires a manometer with a measurement certainty smaller than or equal to 17 mbar.

The duration of the pressure test can be calculated as follows:

$$t = 0.5\,\frac{h}{m^3} \cdot x \cdot V_{geo}$$

where:

t = test duration in hours

V_{geo} = geometric volume in m^3

The minimum test duration is 30 minutes, and the minimum test duration for exposed pipelines is 2 hours.
The permissible pressure change is 50 mbar.

Measurements are taken after applying test pressure (maximum pressure increase 3 bar/min up to test pressure) and after reaching a state of equilibrium. 1 h waiting time for each 1 bar test pressure can be assumed as reference point for temperature equalisation after filling. A compressor with aftercooling can shorten the time required.

- Pressure / volume measurement process D

The conducting of the pressure/volume measurement process is described in the VdTÜV 1060 pipeline instructions "Richtlinien für die Durchführung des Stresstests" (Guidelines for conducting the stress test).
This process is carried out as water pressure test and corresponds largely to pressure measurement method B.
When conducting this test the pipes and pipe elbows are subjected to stress up to the tensile yield point taking into account the permissible integral plastic deformation.

This test
- in particular enables weak points to be discovered, with the advantage of an integrated and meaningful final test;
- helps to improve notching and crack-type faults in the sense that the notching and crack peaks that have been created are plasticised and rounded off;
- provides an opportunity for relieving tension in weld seams which, in terms of results, is equivalent to thermal relief.

When conducting this pressure/volume measurement process it is necessary to follow it immediately with a leak tightness test at reduced test pressure in the same way as for the B2 pressure testing method.

▪ Precision pressure testing procedure with air C3

The calculation basis for test pressure STP is the maximum admissible operating pressure (MOP), pursuant to the formula:

$$STP = 1.1 \cdot MOP$$

However, the test pressure STP has to exceed the maximum operating pressure MOP by 2 bar.

$$STP = MOP + 2bar$$

The respectively higher value is valid.

Air should be filled in with a maximum of 3 bar/min. Using cooled compressors is highly recommended. In order to work under mostly stable test conditions, a rough value of 1 hour for each bar of test pressure should be observed to provide for temperature equalisation.

The test duration is determined by:

$$t_{min} = 0.5 \frac{h}{m^3} \cdot V_{geo}$$

whereby V_{geo} = geometric volume of the pipe

but at least 2 hours with measuring soil temperature, or at least 24 hours without measuring soil temperature. Whether the test is carried out with or without measuring and calculating soil temperature is determined by the expert, which also goes for the duration of the measuring.

After the relax phase, a discharge test is executed in order to determine measuring precision. The resulting change in pressure has to amount to 1 mbar when discharging 1/1000 of the volume through a gas counter or a calibrated pressure test container. The expert may change the discharge volume to 10/1000 if the pipe volume is below 1 m^3. In order to reach the required measuring precision, a change in pressure of 10 mbar ± 1 mbar has to be reached. The gas volume ist measured after the relax phase using appropriate measuring equipment.

The test is carried out by evaluating the line pressure during the test time (under consideration of temperature changes if required). Exposed pipe parts are to be protected against temperature influences.

The admissible pressure change during test time is

$$\Delta_{pzul} = \pm p_{abs} \cdot 1.4 \cdot 10^3 \, [mbar]$$

The evaluation is conducted including a temperature compensation

$$\Delta t_f = \left(\frac{V_a}{100}\right) \cdot (T_{f1} - T_{f2}) \, [K]$$

$$\Delta p_a = \left(\left(\frac{p_{abs\,1}}{T_{f1}}\right) \Delta T_f\right) [mbar]$$

$$\Delta p = p_{abs\,1} - p_{abs\,2} - p_a \, [mbar]$$

whereby
V_a = relative share of the volume of the exposed pipe [%]
p_{abs} = absolute pressure in the pipe [mbar]
Δ_p = change in pressure [mbar]
Δ_{pa} = change in pressure caused by temperature influence [mbar]
Δ_{pzul} = admissibe pressure change caused by temperature influence [mbar]
T_f = temperature of the exposed pipe parts [K]
ΔT_f = temperature change of the exposed pipe parts [K]

Index 1 and 2 at the beginning and end of the measuring period

If the absolute pressure is not measured then a change of the air pressure during the test period has to be considered accordingly.

Using test procedure C3, approval is made by an expert.

The norms and guidelines in their respective current versions apply.


20
10
30
300
S
400
100
500
psi
bar
0


1.25x
170/-
10/0.25 P

3 Approvals and Quality Control

Quality, environmental and energy management

For decades we have set benchmarks regarding the production of plastic pipe systems through intelligent innovation. We understand sustainability here to also refer to acting in the interests of future generations. We recognise responsibility towards our customers, our employees and society at large.

It is our aim to continually improve the quality and environmental impact of our products and services. Economical use of resources is extremely important to us, as is the well-being of our staff through occupational health and safety.

The quality assurance team at egeplast therefore not only ensures the permanent quality of products, processes and raw materials, but also compliance with regulations for environmental protection and the conservation of energy resources.

Quality

In order to be able to offer our customers consistently high quality, egeplast has introduced a quality management system throughout the enterprise to guarantee the high quality standards of products, raw materials and processes.
Whilst quality assurance is based on national and international rules and standards, egeplast goes beyond these rules and standards when ensuring quality. Qualified, motivated employees conduct further inspections and tests every day using the most up-to-date technology.

Products and processes are not just checked. The quality throughout the company is planned beforehand and constantly monitored to prevent potential faults in advance instead of rectifying them afterwards. The quality management system is improved continuously to satisfy the most demanding standards in the long-term.

Inspection by neutral external test institutes supplements our own comprehensive checks.

Quality refers not only to products and the raw materials used, however. At egeplast, quality is ensured throughout the entire processing of the order – from order receipt and management, through to final delivery and follow-up.

Environment

egeplast recognises a responsibility towards the environment, and goes to great lengths to achieve the environmentally friendly production of the technically demanding pipe systems. The egeplast environmental programme is not only concerned with nature, but is also mindful of the energy and materials used and not least the people who, through their labour, ensure the responsible production of the pipe system. All employees involved pay attention to the responsible use of energy, materials and water.

egeplast had its Environment Management Systen certified in accordance with DIN EN ISO 14001 for the first time in 2009 by SKZ.

Energy

The production of PE pipes is based on the use of electricity for operation of the necessary extruders. The required transformers are installed in the immediate vicinity of the extruders, in order to eliminate electricity transmission losses. We use modern air-cooled transformers for this purpose, in order to avoid the safety risks associated with oil-cooled systems.

The real energy challenge can be found, however, in cooling of the production lines. The extruded pipes must be cooled to below 20° C while passing through the production system. This requires significant quantities of cooling water. The energy in this water is very largely recovered, and in addition, the water is routed in a closed cooling circuit. The cooling system is based on three elements: up to an ambient temperature of 13° C, air-coolers perform the major portion of the work. Once the outdoor temperature rises, the groundwater-cooling system is switched in. At a depth of two to three meters, the cooling-water is routed through the groundwater in PE cooling coils, and thus cooled. The third element, finally, takes the form of a heat-exchanger with a rating of 1 MW, which makes use of recirculating low-level groundwater as the cooling fluid.

This extremely modern system in addition permits significant energy savings for heating of staff amenities and washrooms, and also the production shop.

In addition to renewed certification of the environmental management system in accordance with DIN EN ISO 14001:2009, the egeplast energy management system was certified under DIN EN ISO 50001-2011 for the first time. This makes egeplast a pioneer in the area of energy efficiency. In just two years, egeplast has been able to reduce both the energy and the water required to manufacture one metre of pipe by a double-digit percentage value.

4 Abbreviations and Definitions

Definitions according to DIN EN 805

<table>
<tr><th>Abbreviations[1]</th><th>German</th><th>English</th><th>French</th><th></th></tr>
<tr><td>DP</td><td>Systembetriebsdruck</td><td>design pressure</td><td>pression de calcul en régime permanent</td><td rowspan="3">system related</td></tr>
<tr><td>MDP</td><td>Höchster System-betriebsdruck</td><td>maximum design pressure</td><td>pression maximale de calcul</td></tr>
<tr><td>STP</td><td>Systemprüfdruck</td><td>system test pressure</td><td>pression d'épreuve du réseau</td></tr>
<tr><td>PFA</td><td>Zulässiger Bauteilbe-triebsdruck</td><td>allowable operating pressure</td><td>pression de fonction-nement admissible</td><td rowspan="3">component related</td></tr>
<tr><td>PMA</td><td>Höchster zulässiger Bauteilbetriebsdruck</td><td>allowable maximum operating pressure</td><td>pression maximale admissible</td></tr>
<tr><td>PEA</td><td>Zulässiger Bauteil-prüfdruck auf der Baustelle</td><td>allowable site test pressure</td><td>pression d'épreuve admissible sur chantier</td></tr>
<tr><td>OP</td><td>Betriebsdruck</td><td>operating pressure</td><td>pression de fonction-nement</td><td rowspan="2">system related</td></tr>
<tr><td>SP</td><td>Versorgungsdruck</td><td>service pressure</td><td>pression de service</td></tr>
<tr><td colspan="5">[1] = valid for all languages</td></tr>
<tr><td>DN/OD</td><td colspan="4">nominal diameter, relating to the outer diameter</td></tr>
<tr><td>DN/ID</td><td colspan="4">nominal diameter, relating to the inner diameter</td></tr>
<tr><td>OD</td><td colspan="4">outer diameter</td></tr>
<tr><td>ID</td><td colspan="4">inner diameter</td></tr>
<tr><td>LCL</td><td colspan="4">lower confidence limit</td></tr>
<tr><td>MFR</td><td colspan="4">melt mass-flow rate</td></tr>
<tr><td>MRS</td><td colspan="4">minimum required strength</td></tr>
<tr><td>OIT</td><td colspan="4">oxidation induction time</td></tr>
<tr><td>PE</td><td colspan="4">polyethylene</td></tr>
<tr><td>PFA</td><td colspan="4">permissible component operating pressure (fr: pression de fonctionnement admissible)</td></tr>
<tr><td>PN</td><td colspan="4">nominal pressure</td></tr>
<tr><td>S</td><td colspan="4">pipe series S according to ISO 4065</td></tr>
<tr><td>SDR</td><td colspan="4">standard dimension ratio</td></tr>
</table>

Tab 4-1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5 Service

Please allow our sales staff or the staff in Application Technology to explain to you exactly what the benefits of egeplast products are – and how these solutions can assist your business achieve more investment security.

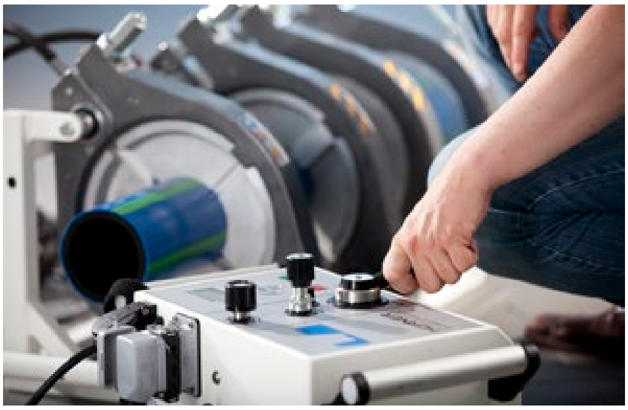
Consulting in Project Planning

Online Planning Aid, free of charge

Provision of Tender Documents

Support during Construction Work on Site

Rental of Welding Machinery and Clamping Jaws, Accessories



Seminars

Notices

Polyethylene as a pipe material is, in comparison to traditional materials, still quite new, although one can already look back on more than fifty years of experience with it. Because of its problem-free installation, outstanding properties for long term usage and high cost effectiveness, polyethylene is material number one for supply applications today. Over the course of the years, PE materials have been consistently optimised with regard to the quality and functionality of the pipes. A series of regulatory codes and standards which specify the field of application for PE pipes have also emerged.

This technical brochure should give designers and operatives an overview of the most important engineering rules. The basic calculations for pipeline planning are introduced, and an outline of the most important installation procedures is given. Details given in this brochure reflect the state of the art. No claim is made with regard to their completeness, they are intended for instruction and guidance; no obligation may be derived from it. Mistake and subject to change reserved.

Our customer service will be pleased to answer any further questions regarding the installation or use of our products, or any other questions. In addition, our customer and applications engineering services are pleased to be at your disposal to provide any technical guidance that you may want.

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Please note that the guarantee does not apply if and insofar the instructions contained in this technical brochure for the correct installation, joining and use of our products are not followed precisely. Relevant safety regulations, current standards and codes of practice must be complied with.

The sale and delivery of our products are subject exclusively to our respectively applicable current general terms and conditions, which you can call up on our website (www.egeplast.de/www.egeplast.eu).

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Notices

Notices

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