

# AGRULINE

ROHRSYSTEME FÜR GAS,  
WASSER & ABWASSER

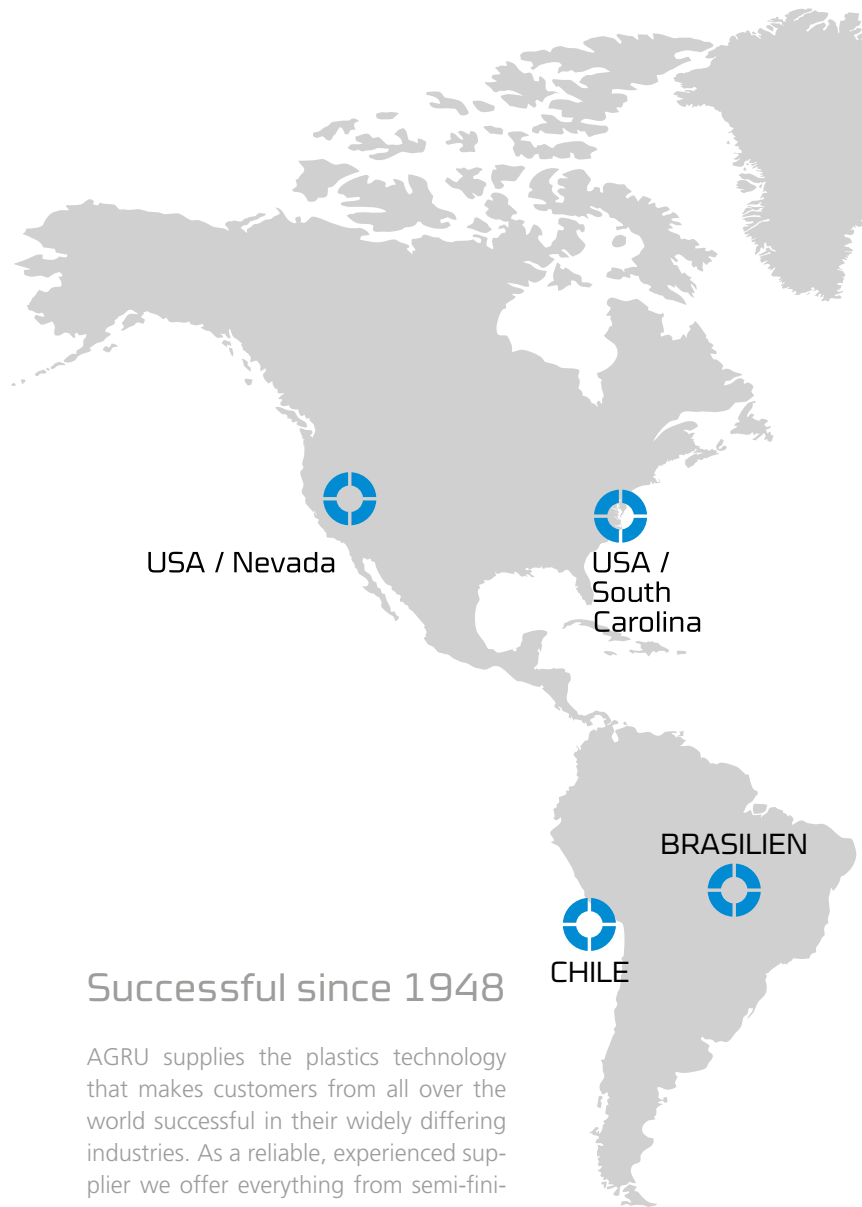
PIPING SYSTEMS  
FOR NATURAL GAS,  
WATER & SEWAGE



 **agru**  
The Plastics Experts.

OUR  
PRODUCTS  
ARE AS  
MANIFOLD  
AS YOUR  
DEMANDS.

# The Plastics Experts.



## Seit 1948 erfolgreich

AGRU liefert Kunststofftechnik, die Kunden aus unterschiedlichen Industriebereichen weltweit erfolgreich macht. Als zuverlässiger, erfahrener Lieferant bieten wir vom Halbzeug bis zum technologisch optimierten Spritzgussformteil alles aus einer Hand. Wir kennen die Herausforderungen aus tausenden Projekten und entwickeln unsere Produkte und Dienstleistungen laufend weiter. Kompromisslose Qualität, herausragender Kundennutzen und hohe Betriebssicherheit sind dabei unsere Maximen. Maßgeschneiderte Kundenlösungen und anwendungsorientierte Neuentwicklungen realisieren wir mit höchster Flexibilität - präzise und kostengünstig. Unsere engagierten Mitarbeiter mit Kunststoffkompetenz machen AGRU zu einem erfolgreichen Global Player.

Alles aus einer Hand anzubieten, unterscheidet uns von Vielen. Wir verarbeiten ausschließlich hochwertige, thermoplastische Kunststoffe. Und wenn es um Lösungskompetenz bei Materialauswahl und Verlegung geht, sind wir Ihr bester Ansprechpartner.

## Successful since 1948

AGRU supplies the plastics technology that makes customers from all over the world successful in their widely differing industries. As a reliable, experienced supplier we offer everything from semi-finished products through to technologically optimised injection mouldings, all from a single source. We handle the challenges from thousands of projects and evolve our products and services on a rolling basis. Uncompromising quality, outstanding customer benefit and high operational dependability are our maxims. We implement custom solutions and application-oriented new developments with the highest flexibility - with precision and economically. Our dedicated employees with plastics expertise make AGRU successful as a global player.

Our ability to supply everything from a single source sets us apart. We use only top-grade thermoplastic polymers as our raw materials. When it comes to application-technical consulting, we are your best partner in the field.

 AUSTRIA | GERMANY | POLAND

 CHINA

# AGRU PLANTS IN 7 COUNTRIES

**AGRU KUNSTSTOFFTECHNIK  
AUSTRIA**



**AGRU OBERFLÄCHENTECHNIK  
AUSTRIA**



**AGRU-FRANK  
GERMANY**



**TWS  
POLAND**



**AGRU NEVADA  
FERNLEY, NV/USA**



**AGRU AMERICA  
GEORGETOWN, SC/USA**



**AGRU AMERICA  
ANDREWS, SC/USA**



**XXL PIPE PRODUCTION FACILITY  
CHARLESTON, SC/USA**



**AGRU PIPELINE TECHNOLOGY  
CHINA**



**AGRU CHILE  
QUILICURA, SANTIAGO, CHILE**



**AGRU BRASIL  
BARUERI - SÃO PAULO - BRAZIL**



# PRODUCTS

## AGRUCEM INDUSTRIE INDUSTRIAL PIPING SYSTEMS



### ROHRSYSTEME / PIPING SYSTEMS

Rohr- und Doppelrohrsysteme aus PP, PEHD-el, PPs, PPs-el, PVDF und ECTFE für industrielle Anwendungen wie den Transport von aggressiven Medien und kontaminiertem Abwasser. Rohrsysteme aus PE 100 blau für diverse Druckluftanwendungen.

Piping systems and double containment piping systems made of PP, HDPE-el, PPs, PPs-el, PVDF and ECTFE for industrial applications such as transport of aggressive media and contaminated sewage water. Piping system made of PE 100 blue for various compressed air applications.

## AGRULINE



### ROHRSYSTEME / PIPING SYSTEMS

PE 100-RC Rohrsysteme für Gas- und Wasserversorgung sowie Abwasserentsorgung und PE 100-RC Rohrsysteme für grabenlose und sandbettfreie Verlegung erhältlich in Dimensionen bis zu  $d_a$  3500 mm.

PE 100-RC piping systems for gas and potable water distribution as well as sewage water disposal and PE 100-RC piping systems for trenchless and sandbed-free installation available in dimensions up to OD 3500 mm.

## PURAD



### ROHRSYSTEME / PIPING SYSTEMS

Rohrsysteme in PVDF-UHP, PP-Pure, Polypure und ECTFE für den Transport von hochreinen Medien der Halbleiter- und Pharmaindustrie sowie der Getränke- und Lebensmittelindustrie.

PVDF-UHP, PP-Pure, Polypure and ECTFE piping systems for the distribution of ultra-pure-water in semiconductor, pharmaceutical and food industry.

## Zulassungen / Certifications



## HALBZEUGE SEMI-FINISHED PRODUCTS



### HALBZEUGE / SEMI-FINISHED PRODUCTS

Rundstäbe, Blöcke, Linerrohre, Schweißdrähte, Platten und Formteile aus thermoplastischen Kunststoffen wie PP, PE, PPs, PPs-el, PEHD, PEHD-el, PVDF, ECTFE, FEP und PFA passend für den Apparate- und Behälterbau.

Sheets, bars, blocks, liner pipes welding rods and fittings made of PP, PE, PPs, PPs-el, HDPE, HDPE-el, PVDF, ECTFE, FEP and PFA for the manufacturing of tanks and for use in apparatus engineering.

## LINING SYSTEMS



### DICHTUNGSBAHNEN / GEOMEMBRANES

Dichtungsbahnen und Abdichtungen aus PEHD, PE-VLD, PE-LLD und FPP sowie Drainage Systeme aus PE und PP für Deponien, Tunnel und Teiche.

Geomembranes made of HDPE, VLDPE, LLDPE and FPP as well as drainage systems made of PE and PP for the use in landfills, tunnels, ponds, hydraulic engineering.

## BETONSCHUTZ CONCRETE PROTECTION



### BETONSCHUTZPLATTEN / CONCRETE PROTECTIVE LINERS

Betonschutzplatten und Profile aus PE, PP, PVDF und ECTFE sind der passende Schutz für Ihr Bauwerk gegen chemische Korrosion.

Concrete protective liners and assembly profiles made of PE, PP, PVDF and ECTFE for the protection of your concrete structures from wear and chemical corrosion.

## SCHWEISSEN WELDING



### SCHWEISSTECHNIK / WELDING SYSTEMS

Schweißmaschinen in verschiedensten Dimensionen für die professionelle Infrarot-, Stumpf-, Induktions- und Heizwendelschweißung.

Welding machines in various dimensions for professional infrared-, butt- and induction welding.





## Innovation sichert Erfolg

Forschung und Entwicklung haben einen sehr hohen Stellenwert im Unternehmen. Ziel der Forschung ist der absolute Kundennutzen im Sinne kontinuierlicher Verbesserung und neuer Marktanforderungen.

Die Mission erster zu sein.

Europas erster Produzent von Formteilen im Spritzguss. Die weltweit erste Kalandrierung von extrabreiten Dichtungsbahnen. AGRU setzt nun mit einem Reinraumwerk für Reinstmedien-Rohrsysteme neue Maßstäbe.

## Innovation - the key to success

AGRU's plastics engineers are focused on the future. Only those who today are dealing with the customer- and target-group-specific requirements of tomorrow will be successful in the future.

We claim to be the first.

Europe's first to produce fittings in injection moulds; the world's first to calender liners many meters wide. Once again the company has set new standards by building a clean-room plant for ultra-pure media piping systems.

**GROUND-BREAKING INNOVATIONS HAVE BEEN A HALLMARK OF AGRU SINCE ITS EARLIEST DAYS.**

## Qualität

Kompromisslose Qualität, herausragender Kundennutzen und hohe Betriebssicherheit sind unsere Maximen. In mehr als 50 Jahren hat AGRU einen Pool an Fachwissen aufgebaut, das in der Branche einmalig ist. Diese „Lebenserfahrung“ fließt in anwendungsorientierte Innovation, hochtechnologische Produktion sowie herausragende Service- und Logistikleistungen ein.

Wir sind stolz auf viele nationale und internationale Zertifikate, Zulassungen und unser nach ISO 9001:2008 zertifiziertes Qualitätssystem – im Sinne unserer Kunden für weltweiten Einsatz.

## Quality

Operational reliability, on-time delivery and maximum customer benefit are our maxims. Over more than 50 years, the plastics experts have accumulated a wealth of expertise unique in the industry. This lifetime of experience flows into application-oriented innovation, high-tech production and outstanding service and logistics performance.

We are proud of our numerous national and international certificates, approvals and certified quality system ISO 9001:2008 – for our customers and for worldwide application.

AGRU  
IS KNOWN  
FOR ITS HIGH  
QUALITY  
STANDARDS  
AROUND THE  
WORLD.





# AGRU - A TRUSTED PARTNER.

## Zuverlässigkeit

Unterschiedliche Werkstoffe, Technologien und Produkte sowie ein weltumspannendes Partnernetzwerk machen AGRU zum zuverlässigen Komplettanbieter. Vor allem für Großprojekte und Sonderlösungen bietet AGRU damit seinen Kunden einen One-Stop-Shop. AGRU ist ein Synonym für Kundennutzen und dafür bekannt, die Kundenwünsche effizient, kostengünstig und mit höchster Flexibilität zu erfüllen. Maßgeschneiderte, kundenorientierte technische Lösungen, „Out-of-the-box-Denken“ und jahrzehntelange Kunststoffverarbeitung sind dafür notwendig.

## Reliability

Different materials, technologies and products plus a worldwide network of partners all contribute to making AGRU a single-source supplier. For large-scale projects and special solutions in particular, AGRU is able to offer its customers a one-stop shop. AGRU has built a reputation for satisfying its customers' wishes efficiently, cost-effectively and with superlative flexibility. Customer-oriented technical solutions, the ability to think outside the box and decades of hands-on experience are what it takes.





**MAXIMUM  
CUSTOMER  
BENEFIT.**

## Service

Die Wirtschaftlichkeit einer technischen Lösung entscheidet sich oft beim eingesetzten Werkstoff. Nur wenn das Ausgangsmaterial perfekt an die Einsatzbedingungen angepasst ist, können Chemikalien- und Temperaturbeständigkeit sowie die physische Belastbarkeit voll erfüllt werden. Die anwendungsspezifische Materialauswahl ist eine Kernkompetenz von AGRU. Als professioneller Ansprechpartner rund ums Thema Kunststoff zeigt AGRU die wirtschaftlichste Lösung für jede noch so große Herausforderung auf.

## Service

Very often, the material used turns out to be definitive in terms of the ultimate profitability of an engineering solution. Only if the raw material is perfectly matched to the real-world conditions of use can physical toughness and resistance to chemicals and temperature effects be fully to specification. Application-specific material selection is one of AGRU's core competences. As a professional partner for everything associated with plastics, AGRU can point out the most economical solution for any problem, no matter how big the challenge.



## Technologieführerschaft

Am Stand der Technik zu produzieren, Prozesse zu verbessern und die Ergebnisse zu optimieren, ist bei AGRU der Garant für Wettbewerbsfähigkeit. In unseren Werken rund um den Globus beweisen wir Tag für Tag Kosten- und Qualitätsführerschaft. Der technologische Vorsprung bewirkt, dass AGRU-Lösungen stets zu den besten ihrer Branche zählen.



## Technology leadership

Producing at the cutting edge of technology, improving processes and optimising results are part and parcel of AGRU's guarantee of competitiveness. Day in, day out, we demonstrate our cost and quality leadership in our plants all over the globe. The technological edge means that AGRU solutions are consistently among the best in their field.



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Standards and approvals

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Standards and approvals

Installation guide

Connection technology

Calculation guide

Material properties

## 1 General properties

### 1.1 Polyethylene (PE)

As a result of the continuous development of PE resins, the efficiency of PE pipes and fittings has been improved significantly. Due to that fact new international standards (ISO 9080, EN 1555, EN 12201) were introduced, which lead to higher permissible operating pressures.

Polyethylene for pipes and fittings is no longer classified by its density (e.g. PE-LD, PE-MD, PE-HD) but it is now divided into MRS-classes (MRS = minimum required strength).

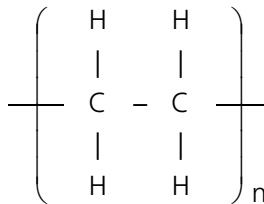


Figure A.1: Chemical structure of polyethylene.

#### 1.1.1 Advantages of PE

- High flexibility
- Homogeneous weldable
- Low weight
- Convenient transportation (e.g. coiled bundles)
- UV resistance (with carbon black)
- Excellent chemical resistance
- Excellent weather-resistance
- Excellent radiation resistance
- Excellent abrasion resistance
- Minimal deposits and no ingrowth possible due to lower frictional resistance
- Lower pressure losses in comparison to e.g. metals
- Resistant against pressure surges (up to 200% of the MOP)
- Application at lower temperatures
- Resistant to rodents
- Low microbial growth
- Physiologically safe

### 1.2 PE 100 polyethylene type

These materials are also known as polyethylene types of the third generation (Minimum Required Strength MRS = 10 MPa).

PE 100 materials are advanced type PE-HD materials which show an altered, bimodal molecular weight distribution due to a modified polymerisation process. Because of that PE 100 types have a higher density and improved mechanical properties such as stiffness or hardness. The creep strength and the resistance against rapid crack propagation are increased significantly.

Therefore, PE 100 is suitable for the production of large diameter pressure pipes. These can achieve the same pressure rating with smaller wall thickness compared to conventional pressure pipes made of PE-HD (PE80).

### 1.3 PE 100-RC polyethylene type

Regarding the pressure resistance and the processability there are no differences between PE 100-RC materials and PE 100 materials.

The primary difference, compared to the standard PE 100 materials, is the high resistance against the slow crack growth. This property allows a safe sandbed-free installation as well as a use of alternative installation technologies for underground piping systems.

During a sandbed-free installation the excavated material (soil, gravel, ballast) can be reused for the filling if it is compressible acc. to the current standards.

Guideline for the grain size of the excavated material (source: ÖVGW QS-W 405):

DIM OD <63 mm	up to 22 mm grain size
DIM OD >63 mm	up to 100 mm grain size

PE 100-RC therefore provides extended protection against:

- point loads,
- crack initiation,
- slow crack growth (SCG).



## 1.4 PE 4710 polyethylene type

PE 4710 is a material classification by American ASTM standards. The performance of PE 100 and PE 4710 classified materials can be considered to be equal to each other. Due to the different design factor of PE 4710 and PE 100 materials, PE 100 materials can be operated with 15% higher pressure for gas and water applications. The raw materials used for AGRU FM approved products comply with PE 100 as well as PE 4710 requirements.

## 1.5 PE-Xa cross-linked polyethylene type

PE-Xa resin is produced by cross-linking the polyethylene with peroxide at high pressures. During the process the individual polyethylene molecules form a three-dimensional network.

The cross-linking process ensures a uniform cross-linking throughout the entire cross section of the pipe, even for thick-walled pipes.

After the cross-linking process the PE-Xa material cannot be re-melted and is referred to as a thermo-elastic material. It combines the positive properties of the thermoplastic and elastomeric materials.

PE-Xa pipes have following properties:

- Notch resistance
- Point loads resistance
- Stress cracking resistance
- High resistance against slow crack growth
- High resistance against abrasion
- High impact strength at extremely low temperatures
- High flexibility at low temperatures
- Suitable for operating temperatures up to 95 °C
- High memory-effect

These material properties lead to additional practical advantages during the installation:

- Suitable for trenchless installation and rehabilitation (pipes on coils):
- Especially for areas with high soil settlement
- Very high operating safety

Because of these properties PE-Xa pipes can be installed in areas with a maximum safety requirements, such as underground installation of natural gas or water pipelines.

## 1.5.1 Resistance to slow crack growth

Point loads on the outside of the pipe (e.g. caused by stones) can lead to stress concentrations and elongations on the inside of the pipe.

These could lead to tiny capillary cracks within the structure (stress corrosion cracking), which causes a premature failure of non-cross-linked PE pipes.

Compared to normal pipe a PE-Xa pipe has a much higher resistance against the crack initiation. Therefore PE-Xa pipes can be installed without a sand bed.

## 1.5.2 Notch behaviour

During the underground installation and possibly during the operation of the system, notches might occur in the pipe surface.

PE-Xa has a substantially higher resistance to scratches and slow crack growth than pipes, made of standard PE-HD.

Long-term pressure tests have proven that the minimum test duration according to DIN 16892 are outperformed even with a notch up to 20 % of the nominal wall thickness.

PE-Xa pipes are especially suitable for trenchless installation methods where damages of the pipe surface cannot be avoided during the installation process.

## 1.5.3 Reduced Rapid crack propagation (RCP)

Rapid crack propagation is the tendency of plastics pipes to develop brittle cracks under high pressures, compressed media and low temperatures. These cracks propagate in the pipe wall at high speed into long cracks.

Even at temperatures of -50 °C and 16 bar pressure no rapid crack propagation was observed for the pipes made of PE-Xa.

## 2 Material-specific properties

### 2.1 PE 100 and PE 100-RC

#### 2.1.1 Material properties

The values mentioned are **guidelines** for the particular material.

	Properties	Standard	Unit	PE 100	PE 100-RC
mechanical / physical	MRS Classification	ISO 9080	N/mm <sup>2</sup>	10	10
	Specific density at 23 °C	ISO 1183	g/cm <sup>3</sup>	0.96 <sup>2)</sup>	0.96 <sup>2)</sup>
	Melt flow rate (MFR 190/5)	ISO 1133-1	g/10min	~0.3 <sup>1)</sup>	~0.3 <sup>1)</sup>
	MFI range			T003	T003
	Tensile stress at yield	ISO 527	MPa	≥23	≥23
	Elongation at yield	ISO 527	%	≥9	≥9
	Elongation at break	ISO 527	%	>350 <sup>2)</sup>	≥350 <sup>2)</sup>
	Impact strength unnotched (at -30 °C)	ISO 179	kJ/m <sup>2</sup>	no break	no break
	Impact strength notched (at +23 °C)	ISO 179	kJ/m <sup>2</sup>	≥13 <sup>3)</sup>	≥13 <sup>3)</sup>
	Impact strength notched (at -30 °C)	ISO 179	kJ/m <sup>2</sup>	10	10
	Shore-D hardness (3 sec)	ISO 868	1	~60	~60
	Flexural strength (3.5 % flexural strain)	ISO 178	MPa	≥21	≥21
	Young's Modulus	ISO 527	MPa	≥1000	≥1000
thermal	Stress cracking resistance (FNCT)	ISO 16770 EN 12814-3	h	≥300 <sup>3)</sup>	≥8760 <sup>3)</sup>
	Heat deflection temperature HDT/B	ISO 75	°C	75	75
	Linear coefficient of thermal expansion	DIN 53752	K <sup>-1</sup> × 10 <sup>-4</sup>	1.8 <sup>4)</sup>	1.8 <sup>4)</sup>
	Thermal conductivity (at 20 °C)	DIN 52612	W / (m×K)	~0.4	~0.4
	Flammability	UL 94 DIN 4102	- -	94-HB B2	94-HB B2
Application temperature	-	°C	-40 to +60 *		
electric	Volume resistivity	VDE 0303	Ω × cm	>10 <sup>16</sup>	>10 <sup>16</sup>
	Surface resistivity	VDE 0303	Ω	>10 <sup>13</sup>	>10 <sup>13</sup>
	Dielectric coefficient at 1 MHz	DIN 53483	-	2.3	2.3
	Electric strength	VDE 0303	kV/mm	70	70
general	Physiologically inert	EEC 90/128	-	yes	yes
	UV stabiliser	-	-	carbon black	
	Color	-	-	black	black

Table A.1: Specific material properties of PE 100 and PE 100-RC

Guidelines from:

- 1) DVS 2207-1 2) EN 12201 3) DVS 2205-1 suppl.1 4) DVS 2210-1

\* depending on the application area and operating time (see chapter 2.1.3)

## 2.1.2 Hydrostatic long-term strength

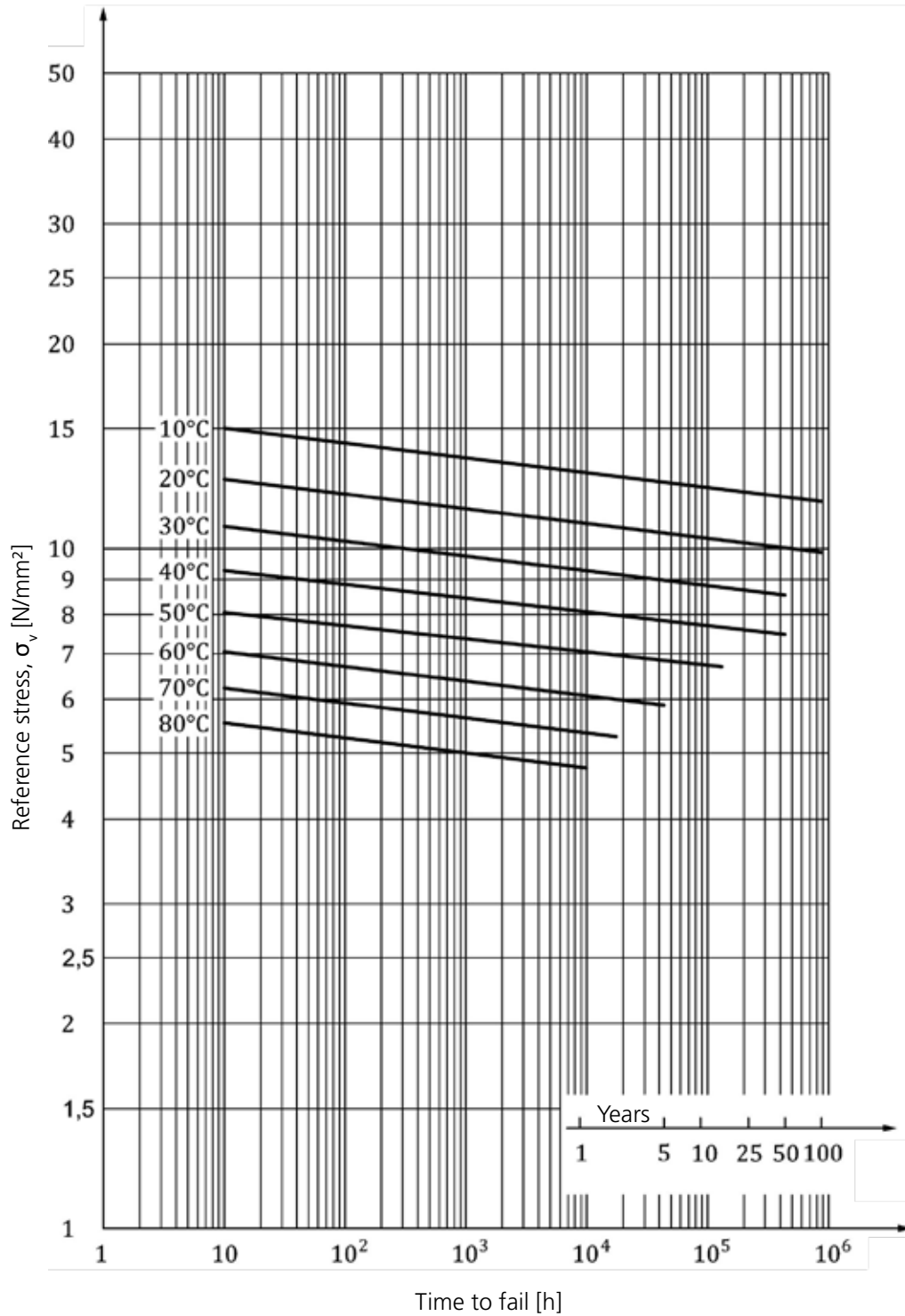


Figure A.2: Hydrostatic long-term strength (hoop stress graph) for PE 100 and PE 100-RC  
(Source: DIN 8075:2018-08, ISO 15494:2015-01)

## 2.1.3 Maximum operating pressure MOP

Temperature [°C]	Operating time [a]	max. operating pressure [bar]									
		water								gas	
		SDR 41	SDR 33	SDR 26	SDR 21	SDR 17	SDR 11	SDR 9	SDR 7,4	SDR 17	SDR 11
	ISO-S 20	ISO-S 16	ISO-S 12,5	ISO-S 10	ISO-S 8	ISO-S 5	ISO-S 3,2	ISO-S 3,2	ISO-S 8	ISO-S 5	
10	5	5,0	6,3	7,9	10,0	12,6	19,9	25,1	31,6	7,9	12,5
	10	4,9	6,2	7,8	9,8	12,4	19,6	24,7	31,1	7,7	12,3
	25	4,8	6,1	7,7	9,6	12,1	19,2	24,2	30,5	7,6	12,0
	50	4,8	6,0	7,5	9,5	12,0	18,9	23,9	30,0	7,5	11,8
20	5	4,2	5,3	6,7	8,4	10,6	16,8	21,1	26,6	6,6	10,5
	10	4,2	5,2	6,6	8,3	10,4	16,5	20,8	26,2	6,5	10,3
	25	4,1	5,1	6,5	8,1	10,2	16,2	20,4	25,7	6,4	10,1
	50	4,0	5,0	6,3	8,0	10,0	16,0	20,0	25,0	6,3	10,0
30	5	3,6	4,5	5,7	7,2	9,0	14,3	18,0	22,7	5,6	8,9
	10	3,5	4,5	5,6	7,1	8,9	14,1	17,7	22,3	5,6	8,8
	25	3,5	4,4	5,5	6,9	8,7	13,8	17,4	21,9	5,4	8,6
	50	3,4	4,3	5,4	6,8	8,6	13,6	17,1	21,6	5,4	8,5
40	5	3,1	3,9	4,9	6,2	7,8	12,3	15,5	19,5	4,9	7,7
	10	3,0	3,8	4,8	6,1	7,6	12,1	15,3	19,2	4,8	7,6
	25	3,0	3,8	4,7	6,0	7,5	11,9	15,0	18,8	4,7	7,4
	50	2,9	3,7	4,7	5,9	7,4	11,7	14,7	18,5	4,6	7,3
45	5	2,9	3,6	4,6	5,7	7,2	11,5	14,4	18,2	4,5	7,2
	10	2,8	3,6	4,5	5,7	7,1	11,3	14,2	17,9	4,5	7,1
	25	2,8	3,5	4,4	5,5	7,0	11,1	13,9	17,5	4,4	6,9
50	5	2,7	3,4	4,3	5,4	6,7	10,7	13,5	16,9	4,2	6,7
	10	2,6	3,3	4,2	5,3	6,6	10,5	13,3	16,7	4,2	6,6
	15	2,6	3,3	4,2	5,2	6,6	10,4	13,1	16,5	4,1	6,5
55	5	2,5	3,2	4,0	5,0	6,3	10,0	12,6	15,8	3,9	6,2
	10	2,5	3,1	3,9	4,9	6,2	9,8	12,4	15,6	3,9	6,2
60	5	2,4	3,0	3,7	4,7	5,9	9,4	11,8	14,8	3,7	5,9

Table A.2: Maximum operating pressure of PE 100 and PE 100-RC (Source: DIN 8075: 2018, ISO 15494: 2015-01).

The data shown in the table above is applicable to water and gas. The values were calculated from the creep modulus curve with the safety coefficient of  $C = 1.25$  (water) and  $C = 2$  (gas).

For the calculation of the operating pressure in piping systems installed above ground we recommend multiplying the values from the table by a system reduction coefficient  $f_s = 0.8$  (This value contains installation influences such as welded joints, flanges or bending loads).

## 2.1.4 Creep modulus curves

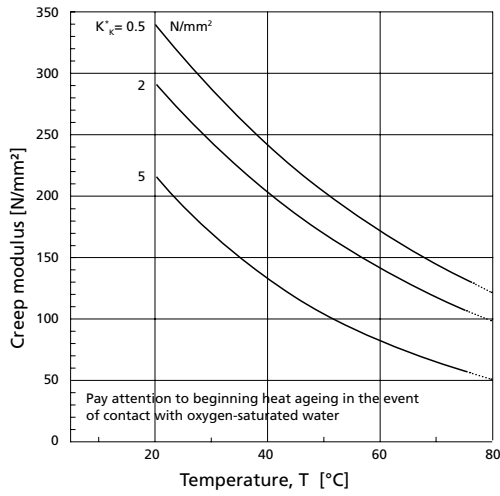


Figure A.3: Creep modulus of PE 100 and PE 100-RC for 1 year. (Source: DVS 2205-1)

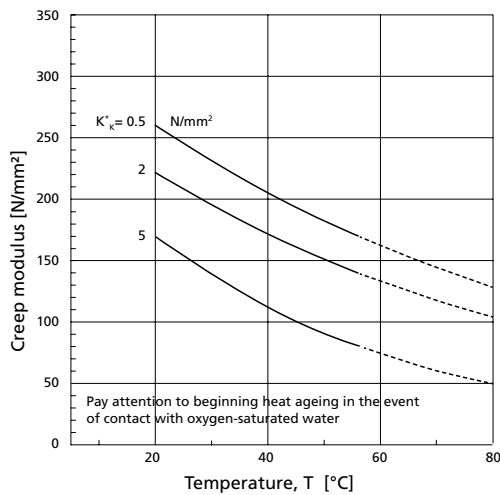


Figure A.4: Creep modulus of PE 100 and PE 100-RC for 10 years. (Source: DVS 2205-1)

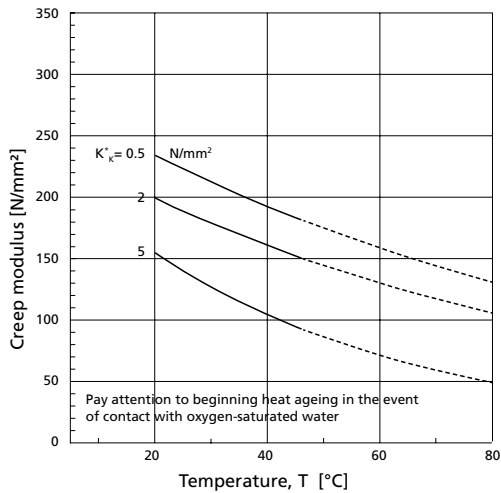


Figure A.5: Creep modulus of PE 100 and PE 100-RC for 25 years. (Source: DVS 2205-1)

The calculated creep modulus stated in the figures A3 to A5 has to be additionally reduced by a safety coefficient of  $\geq 2$  for stability calculations.

The influences of chemical attack or eccentricity and ovality have to be taken into account separately.

## 2.1.5 Isochronous stress/strain diagram

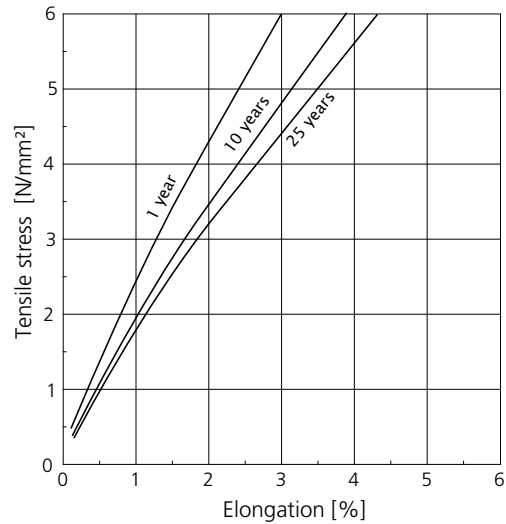


Figure A.6: Isochronous stress/strain diagram of PE 100 for 23°C.

## 2.2 PE-Xa

### 2.2.1 Material properties

	Property	Testing standard	Unit	PE-Xa
mechanical / physical	MRS Classification	ISO 9080	N/mm <sup>2</sup>	9.5
	Specific density at 23 °C	ISO 1183	g/cm <sup>3</sup>	0.94
	Melt flow rate	ISO 1133	g/10min	
	MFR 190/5			n/a
	MFR 190/2.16			n/a
	MFR 230/5			n/a
	Tensile stress at yield (at 20 °C)	ISO 527	MPa	19 - 26
	Elongation at break	ISO 527	%	350 - 550
	Impact strength unnotched at +23 °C	ISO 179	kJ/m <sup>2</sup>	no fracture
	Impact strength unnotched at -30 °C	ISO 179	kJ/m <sup>2</sup>	no fracture
	Impact strength notched at +23 °C	ISO 179	kJ/m <sup>2</sup>	no fracture
	Impact strength notched at -30 °C	ISO 179	kJ/m <sup>2</sup>	no fracture
	Flexural strength (3.5 % flexural stress)	ISO 178	MPa	20
Modulus of elasticity at 20 °C	ISO 527	MPa	600-900	
thermal	Vicat-softening point VST/B/50	ISO 306	°C	133
	Linear coefficient of thermal expansion	DIN 53752	K <sup>-1</sup> × 10 <sup>-4</sup>	1.4
	Thermal conductivity at 20 °C	DIN 52612	W / (m×K)	0,35
	Flammability	UL 94	-	94-HB
		DIN 4102	-	B2
Application temperature	-	°C	-50 to +95	
electrical	Specific volume resistance	VDE 0303	Ω × cm	>10 <sup>15</sup>
	Specific surface resistance	VDE 0303	Ω	>10 <sup>13</sup>
	Relative dielectric constant at 1 MHz	DIN 53483	-	2,3
	Dielectric strength	VDE 0303	kV/mm	60 - 90
general	Physiologic non-toxicity	EEC 90/128	-	yes
	UV stabilisation	-	-	limited
	Colour	-	-	yellow, blue

Table A.3: Specific material properties of PE-Xa

## 2.2.2 Hydrostatic long-term strength

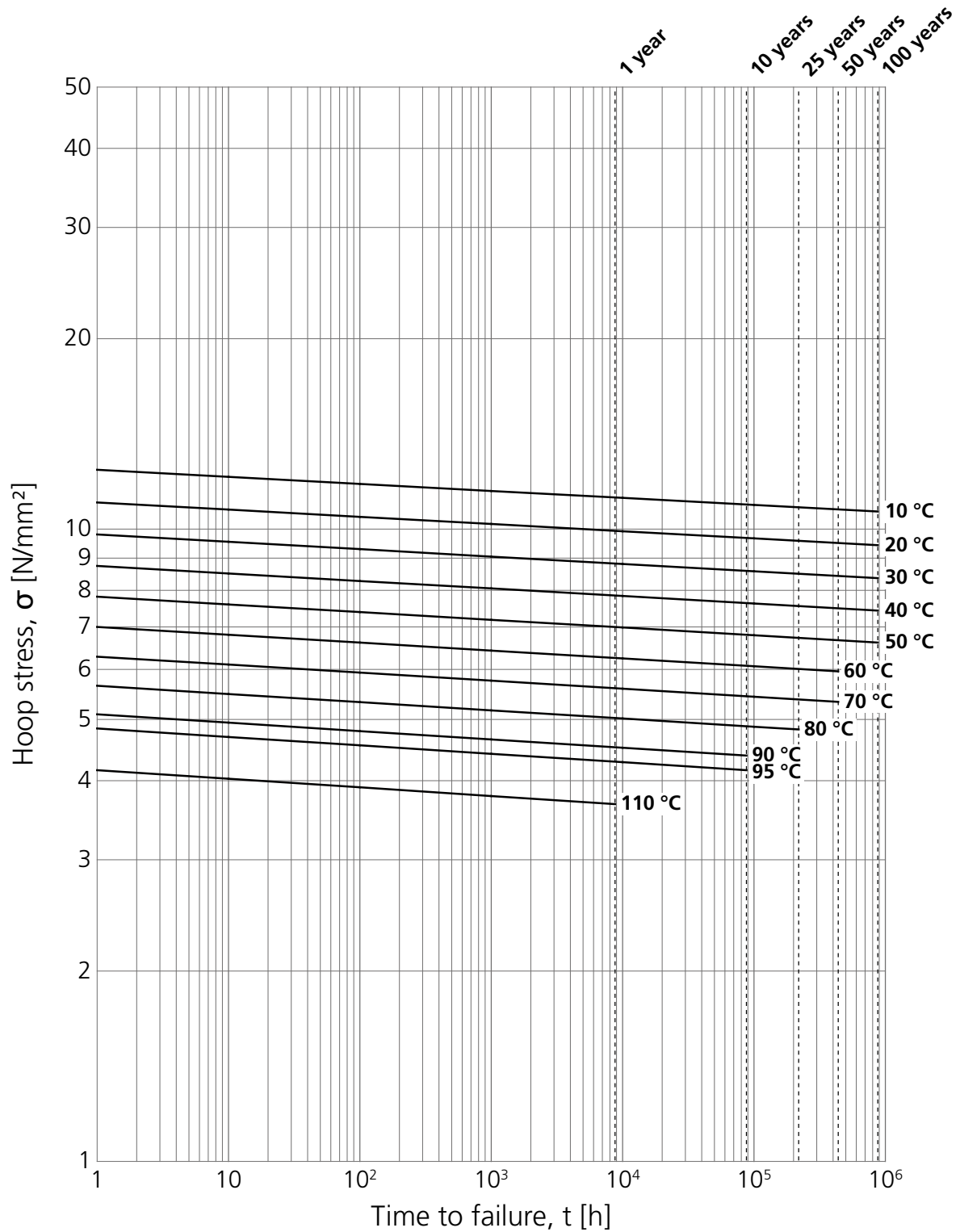


Figure A.7: Hydrostatic long-term strength (hoop stress graph) for PE-Xa (Source: DIN 16893).

## 2.2.3 Maximum operating pressure MOP

Temperature [°C]	Operating time [a]	max. operating pressure [bar]	
		Water	Gas
SDR 11 / ISO-S 5			
10	1	17.9	11.2
	5	17.5	10.9
	10	17.4	10.9
	25	17.2	10.8
	50	17.1	10.7
20	1	15.8	9.9
	5	15.5	9.7
	10	15.4	9.6
	25	15.2	9.5
	50	15.1	9.4
30	1	14.0	8.8
	5	13.8	8.6
	10	13.7	8.6
	25	13.5	8.4
	50	13.4	8.4
40	1	12.5	7.8
	5	12.2	7.6
	10	12.1	7.6
	25	12.0	7.5
	50	11.9	7.4
50	1	11.1	6.9
	5	10.9	6.8
	10	10.8	6.8
	25	10.7	6.7
	50	10.6	6.6
60	1	9.9	6.2
	5	9.7	6.1
	10	9.7	6.1
	25	9.5	5.9
	50	9.5	5.9
70	1	8.9	5.6
	5	8.7	5.4
	10	8.6	5.4
	25	8.5	5.3
	50	8.5	5.3
80	1	8.0	5.0
	5	7.8	4.9
	10	7.7	4.8
	25	7.6	4.8
	50	7.6	4.8
90	1	7.2	4.5
	5	7.0	4.4
	10	6.9	4.3
95	1	6.8	4.3
	5	6.6	4.1

Table A.4: Maximum operating pressure of PE-Xa (Source: DIN 16893).

The data shown in the table above is applicable to water and gas. The values were calculated from the creep modulus curve with the safety coefficient of  $C = 1.25$  (water) and  $C = 2$  (gas).

## 3 Comparison pressure ratings

Table A.5 shows the comparison of the SDR, S series and PN pressure ratings (valid for 20 °C, 50 years durability and  $C = 1.25$  (water)).

SDR	S	PN-pressure rating (water)		
		PE100 / PE100-RC	PE-Xa	PE 80
41	20	4	-	3,2
33	16	5	-	4
26	12,5	6,3	-	5
17	8	10	-	7,5
11	5	16	12,5	8
9	4	20	-	12,5
7,4	3,2	25	20	20

Table A.5: Comparison pressure rating (Source: EN 12201-2, DVGW G400-1, DVGW G472).



## 4 Resistance of polyethylene

### 4.1 Physical resistance

#### 4.1.1 Physiological safety

Polyethylene complies with the relevant food law requirements (according to ÖNORM B 5014 Part 1, BGA, KTW guidelines).

PE pipes and fittings are verified regarding drinking water suitability and registered according to DVGW guideline W270.

#### 4.1.2 Behaviour at radiation exposure

Pipes made of polyethylene may be used in the field of high energy radiation. PE pipes are well established as drainages for radioactive sewage from laboratories as well as cooling water systems for nuclear power plants.

Common radioactive sewage contains sources of beta and gamma rays. PE piping systems do not become radioactive, even after many years in use.

Also PE pipes are not damaged in the vicinity of higher radioactivity, provided that they aren't exposed to a regularly spread radiation dose larger than  $<10^4$  Gray during their entire operation time.

#### 4.1.3 Behaviour with abrasive fluids

In general, thermoplastic pipes are better suited for the conveying of fluid-solid-mixtures than concrete or steel pipes. This is confirmed by several test results as well as positive application experiences.

For the testing of the abrasive behavior the Darmstadt tipping trough test can be used. During the experiment, a 1 meter long pipe (half-pipe cut lengthwise) is used, which is filled with a sand-gravel-water mix (46 vol-% silica sand/gravel, grain size up to 30 mm). After being filled, the pipe is tipped with a frequency of 0.18 Hz.

The local decrease of the wall thickness after a certain time is used as a measure for the abrasion.

The advantage of thermoplastic pipes for the transport of solids in open channels can be clearly seen from the test results.

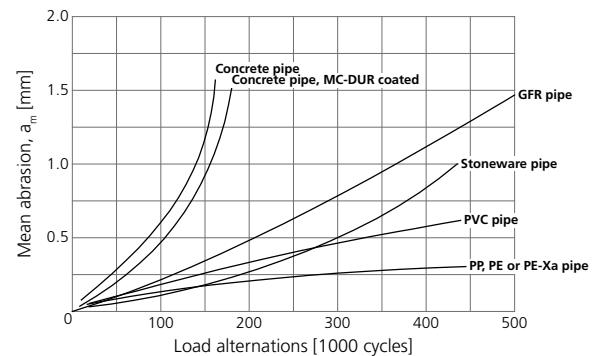


Figure A.8: Abrasion behaviour according to Darmstadt method (DIN EN 295-3). Source: Technical University of Darmstadt

### 4.2 Chemical resistance

Compared to metals, where an attack of chemicals leads to an irreversible chemical change of the material, for plastics, the physical changes of the application reduce the utility value. Such physical changes are e.g. swelling and solution processes where the structure of the plastics can be changed in a way that effects the mechanical properties. Reduction factors have to be considered when designing facilities or parts of them.

PE is resistant to diluted solutions of salts, acids and alkalis if these are not strongly oxidizing agents. A good resistance to many solvents such as alcohols, esters and ketones is given as well.

During the contact with solvents (aliphatic or aromatic compounds, chlorinated hydrocarbon) a strong swelling can be expected, especially at higher temperatures. Nevertheless the destruction of the materials is unusual.

The chemical resistance of the material can be strongly reduced by stress cracking corrosion due to surface-active fluids (chromic acid, concentrated sulphuric acid).

## 4.2.1 Bases

### 4.2.1.1 Alkaline lye

Aqueous alkali solutions (e.g. caustic potash, caustic soda solutions), don't react with PE even at higher temperatures and with higher concentrations. Therefore it can be used in PE-systems without any problems.

### 4.2.1.2 Sodium hypochlorite

Since this base contains active chlorine, only a limited resistance can be expected at room temperature.

At higher temperatures and a concentration of higher than 3 mg/l PE is only suitable for non-pressurised piping systems.

### 4.2.1.3 Hydrocarbons

PE is resistant against hydrocarbons (petroleum and other fuels) up to temperature of 40 °C (conveyance of the fluids) and up to 60 °C (storage of the fluids).

At temperatures higher than 60 °C PE has a limited resistance, because the swelling exceeds 3 %.

## 4.2.2 Acids

### 4.2.2.1 Sulphuric acid

Concentrations up to approximately 78 % only slightly change the properties of PE. Concentrations higher than 85 % cause oxidation at room temperature.

### 4.2.2.2 Hydrochloric and hydrofluoric acids

PE is chemically resistant to concentrated hydrochloric and hydrofluoric acids.

At concentrations higher than 20 % (HCl) or 40 % (HF) a diffusion of the acid is possible.

Even though PE isn't damaged itself, secondary damages are caused to the surrounding steel constructions. For that purpose, double containment piping systems have proven their reliability.

### 4.2.2.3 Nitric acid

Nitric acid with higher concentrations causes an oxidizing effect on materials. Therefore mechanical properties are reduced at higher concentrations.

### 4.2.2.4 Phosphoric acid

PE is resistant against this medium at higher concentrations and at higher temperatures.

## 4.2.3 Gases

PE has been used successfully for decades to transport natural gas and biogas. PE is also ideally suitable for hydrogen up to 100 Vol.-%.

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## 1 SDR - Standard Dimension Ratio

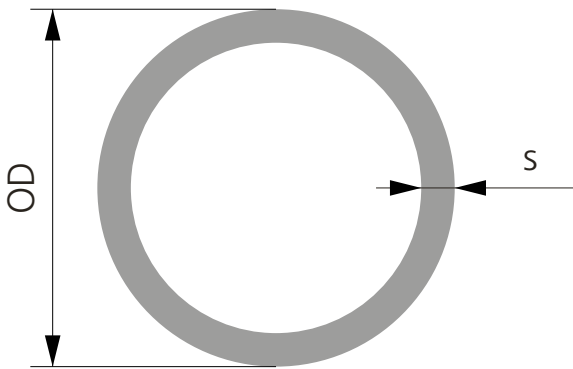


Figure B.1: Dimensions of a pipe.

$$SDR = \frac{OD}{s}$$

Formula B.1: SDR.

- OD outer diameter [mm]
- s wall thickness [mm]
- SDR outer diameter to wall thickness-ratio [1]

## 2 S-Series

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

Formula B.2: S-Series.

- S ISO S-Series [1]
- SDR standard dimension ratio [1]

## 3 Maximum operating pressure

$$MOP = \frac{20 \cdot \sigma}{c \cdot (SDR - 1)}$$

Formula B.3: Maximum operating pressure.

- c minimum safety factor [1]
- MOP maximum operating pressure [bar]
- SDR standard dimension ratio [1]
- $\sigma$  hoop stress [N/mm<sup>2</sup>]

	Minimum safety factor [1]	
	Potable water / sewage	Natural gas
PE 100, PE 100-RC	1.25	2.0
PE-Xa	1.25	2.0

Table B.1: Minimum safety factor.

For the hoop stresses see chapter A "Hydrostatic long-term strength".

## 4 Wall thickness

Strength calculations of thermoplastic plastic pipelines are generally based on long-term values. These strength values, which depend on the temperature, are derived from the hydrostatic long-term strength curve (see chapter A).

After the calculation of the arithmetical wall thickness the operating wall thickness is specified by using the nominal pressure or the SDR-class.

Safety margins for the wall thickness have to be taken into account (e.g. for the outdoor operation of the PE pipeline without UV protection or for the transport of abrasive substances).

$$s_{\min} = \frac{p \cdot OD}{20 \cdot \sigma_s + p}$$

Formula B.4: Minimum wall thickness.

$$\sigma_s = \frac{\sigma}{c}$$

Formula B.5: Design stress.

- c minimum safety factor [1]
- OD outer diameter [mm]
- p operating pressure [bar]
- $s_{\min}$  minimum wall thickness [mm]
- $\sigma$  hoop stress [N/mm<sup>2</sup>]
- $\sigma_s$  design stress [N/mm<sup>2</sup>]

For the hoop stress see chapter A "Hydrostatic long-term strength".

If required, the formula can be used to calculate the hoop stress  $\sigma$  or the operating pressure p.

## 5 Buckling pressure (low pressure)

In certain cases piping systems are exposed to external high pressure (low pressure inside the pipe):

- In-water installations or pipes buried below the groundwater level
- Systems for vacuum applications, e.g. suction pipes

$$p_k = \frac{10 \cdot E_c}{8 \cdot (1 - \mu^2)} \cdot \left( \frac{s}{r_m} \right)^3$$

Formula B.6: Buckling pressure (safety factor 2).

$$r_m = \frac{OD - s}{2}$$

Formula B.7: Mean radius.

The buckling stress can be calculated with following formula:

$$\sigma_k = 0,1 \cdot p_k \cdot \frac{r_m}{s}$$

Formula B.8: Buckling stress.

$E_c$	creep modulus for 25 years [N/mm <sup>2</sup> ]
OD	outer diameter [mm]
$p_k$	critical buckling pressure [bar]
$r_m$	mean pipe radius [mm]
$s$	wall thickness [mm]
$\mu$	Transversal contraction factor 0.38 [1]
$\sigma_k$	critical buckling stress [N/mm <sup>2</sup> ]

For the creep modulus see section A "Creep modulus curves".

Time period [years]	Temperature [°C]			
	20	30	40	50
1	290	250	200	170
10	220	190	170	150
25	200	180	160	-

Tabelle A.1: Guidelines for long term creep modulus for PE 100 and PE 100-RC from the creep modulus curves chapter 2.1.4 (stress: 2 N/mm<sup>2</sup>) (Source: DVS 2205-1)

Temperature [°C]	Operating period [a]	Permissible buckling pressure [bar]							
		SDR 7,4	SDR 9	SDR 11	SDR 17	SDR 21	SDR 26	SDR 33	SDR 41
20	1	13,423	6,719	3,376	0,854	0,429	0,212	0,107	0,054
	10	10,183	5,097	2,561	0,648	0,325	0,161	0,081	0,041
	25	9,257	4,634	2,328	0,589	0,296	0,146	0,074	0,037
30	1	11,571	5,792	2,910	0,736	0,370	0,183	0,092	0,047
	10	8,794	4,402	2,212	0,559	0,281	0,139	0,070	0,036
	25	8,331	4,170	2,095	0,530	0,266	0,132	0,066	0,034
40	1	9,257	4,634	2,328	0,589	0,296	0,146	0,074	0,037
	10	7,869	3,939	1,979	0,500	0,251	0,124	0,062	0,032
	25	7,406	3,707	1,863	0,471	0,237	0,117	0,059	0,030
50	1	7,869	3,939	1,979	0,500	0,251	0,124	0,062	0,032
	10	6,943	3,475	1,746	0,442	0,222	0,110	0,055	0,028

Table B.2: Permissible buckling pressure for PE 100(-RC)

The data stated in the table applies to the medium water. A safety coefficient of 2.0 (minimum safety coefficient for stability calculations) has been taken into account for the calculation.

The stated buckling pressures have to be reduced by the corresponding reduction factors for chemical influences or ovality.

## 6 Pipe cross-section

Flow processes are calculated by means of the continuity equation. For the fluids with constant volume flow, following equation is used.

$$\dot{V} = 0.0036 \cdot A \cdot v$$

Formula B.9: Volume flow.

For gases and vapours, the material flow remains constant. Therefore, the following equation can be used for the calculation.

$$\dot{m} = 0.0036 \cdot A \cdot v \cdot \rho$$

Formula B.10: Mass flow.

If the constants used in the above-mentioned equations are combined, you receive the formula for the required pipe cross section.

$$ID = 18.8 \cdot \sqrt{\frac{Q_1}{v}}$$

Formula B.11: Inner pipe diameter - m<sup>3</sup>/h.

$$ID = 35.7 \cdot \sqrt{\frac{Q_2}{v}}$$

Formula B.12: Inner pipe diameter - l/s.

A	free pipe cross-section [mm <sup>2</sup> ]
ID	inner pipe diameter [mm]
$\dot{m}$	mass flow [kg/h]
$Q_1$	flow rate [m <sup>3</sup> /h]
$Q_2$	flow rate [l/s]
$\dot{V}$	volume flow [m <sup>3</sup> /h]
v	flow velocity [m/s]
$\rho$	medium density depending on pressure and temperature [kg/m <sup>3</sup> ]

Reference values for the flow velocities:

- Fluids:
  - Suction side: v ≈ 0.5 up to 1.0 m/s
  - Pressure side: v ≈ 1.0 up to 3.0 m/s
- Gases:
  - v ≈ 10 up to 30 m/s

## 7 Hydraulic pressure losses

Flowing media will experience pressure losses and therefore energy losses within the conveying system. The main factors for the losses are:

- Length of the piping system
- Pipe cross section
- Roughness of the pipe surface
- Geometry of fittings, mountings and finished joints or couplings
- Viscosity and density of the fluid

The whole pressure loss results from the sum of the following individual losses:

$$\Delta p_{ges} = \Delta p_R + \Delta p_{RF} + \Delta p_{RA} + \Delta p_{RV}$$

Formula B.13: Total pressure loss.

$\Delta p_{ges}$	total pressure loss [bar]
$\Delta p_R$	pressure loss in straight pipes [bar]
$\Delta p_{RA}$	pressure loss in mountings [bar]
$\Delta p_{RF}$	pressure loss in fittings [bar]
$\Delta p_{RV}$	pressure loss in finished joints or couplings [bar]

### 7.1 Pressure loss in straight pipes

The pressure loss in the straight pipes is inversely proportional to the pipe cross section.

$$\Delta p_R = \lambda \cdot \frac{L}{ID} \cdot \frac{\rho}{2 \cdot 10^2} \cdot v^2$$

Formula B.14: Pressure loss in straight pipes.

ID	inside diameter of pipe [mm]
L	length of piping system [m]
$\Delta p_R$	pressure loss in straight pipes [bar]
$\lambda$	pipe frictional index 0.02 (sufficient in most cases) [1]
v	flow velocity [m/s]
$\rho$	medium density [kg/m <sup>3</sup> ]

Pressure loss in pipes can also be calculated with the empirical Hazen-Williams equation (source: NFPA 13). Please note, that the equation is only valid for water.

$$p_m = 6.05 \cdot \left( \frac{Q_m^{1.85}}{C^{1.85} \cdot d_m^{4.87}} \right) 10^5$$

$p_m$	frictional resistance [bar/m pipe]
C	design coefficient (PE-HD = 150)
$Q_m$	flow rate [L/min]
$d_m$	actual internal diameter [mm]



## 7.2 Pressure loss in fittings

Inside the fittings friction, deflection and detachment cause considerable pressure losses

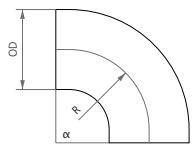
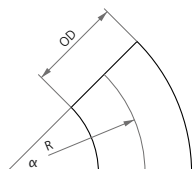
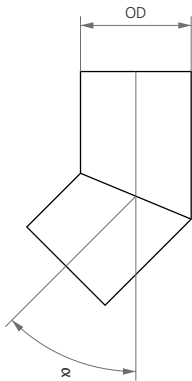
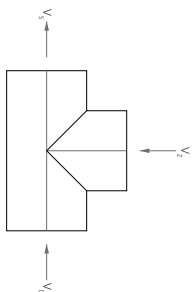
The resistance coefficients, used for the calculation can be taken from the following chapter or from the technical literature.

$\Delta p_{RF}$  pressure loss in fittings [bar]  
 $\zeta$  resistance coefficient for fittings [1]  
 $v$  flow velocity [m/s]  
 $\rho$  medium density [kg/m<sup>3</sup>]

$$\Delta p_{RF} = \zeta \cdot \frac{\rho}{2 \cdot 10^5} \cdot v^2$$

Formula B.15: Pressure loss in fittings.

### 7.2.1 Resistance coefficients for the fittings

Fitting	Parameter	Resistance coefficient [1]		Flow
Bend 90°	R	$\zeta$		
	1.0 × OD	0.51		
	1.5 × OD	0.41		
	2.0 × OD	0.34		
	4.0 × OD	0.23		
Bend 45°	R	$\zeta$		
	1.0 × OD	0.34		
	1.5 × OD	0.27		
	2.0 × OD	0.20		
	4.0 × OD	0.15		
Elbow	$\alpha$	$\zeta$		
	90°	~ 1.20		
	45°	0.30		
	30°	0.14		
	20°	0.05		
	15°	0.05		
	10°	0.04		
Tee 90°	$V_z / V_s$	$\zeta_z$	$\zeta_D$	
(confluence)	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	

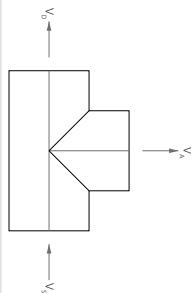
Fitting	Parameter	Resistance coefficient [1]		Flow
Tee 90°	$V_A / V_S$	$\zeta_A$	$\zeta_S$	
(bifurcation)	0.0	0.97	0.10	
	0.2	0.90	-0.10	
	0.4	0.90	-0.05	
	0.6	0.97	0.10	
	0.8	1.10	0.20	
	1.0	1.30	0.35	

Table B.3: Resistance coefficient for fittings - part 1 (Source: DVS 2210-1).

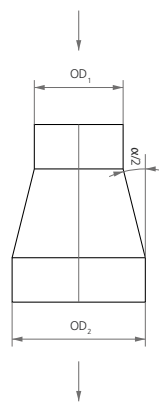
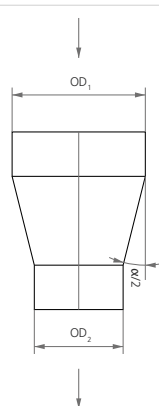
Fitting	Parameter	Resistance coefficient [1]			Flow
Reduction	$OD_2 / OD_1$	$4^\circ > \alpha < 8^\circ$	$\alpha < 16^\circ$	$\alpha < 24^\circ$	
(pipe expansion)	1.2	0.10	0.15	0.20	
	1.4	0.20	0.30	0.50	
	1.6	0.50	0.80	1.50	
	1.8	1.20	1.80	3.00	
	2.0	1.90	3.10	5.30	
Reduction	$OD_1 / OD_2$	$\alpha < 4^\circ$	$\alpha < 8^\circ$	$\alpha < 20^\circ$	
(pipe construction)	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	

Table B.4: Resistance coefficient for fittings - part 2 (Source: DVS 2210-1).

Positive  $\zeta$ -values represent a pressure drop, whereas negative  $\zeta$ -values represent a pressure increase.

- $V_A$  outgoing volume flow
- $V_D$  continuous volume flow
- $V_S$  total volume flow
- $V_Z$  additional volume flow

## 7.3 Pressure loss in mountings

The resistance coefficients, used for the calculation can be taken from the following chapter or from the technical literature.

$\Delta p_{RA}$  pressure loss in mountings [bar]  
 $\zeta$  resistance coefficient for mountings [1]  
 $v$  flow velocity [m/s]  
 $\rho$  density of medium [kg/m<sup>3</sup>]

$$\Delta p_{RA} = \zeta \cdot \frac{\rho}{2 \cdot 10^5} \cdot v^2$$

Formula B.16: Pressure loss in mountings.

### 7.3.1 Resistance coefficients for the mountings

Nominal diameter DN	Resistance coefficient $\zeta$ [1]							
	Diaphragm valve	Straight valve	Angle seat valve	Gate valve	PE ball valve	Butterfly valve	Check valve	Swing type check valve
25	4.0	2.1	3.0	0.1 - 0.3	0.1 - 0.15	0.3 - 0.6	2.5	1.9
32	4.2	2.2	3.0				2.4	1.6
40	4.4	2.3	3.0				2.3	1.5
50	4.5	2.3	2.9				2.0	1.4
65	4.7	2.4	2.9				2.0	1.4
80	4.8	2.5	2.8				2.0	1.3
100	4.8	2.4	2.7				1.6	1.2
125	4.5	2.3	2.3				1.6	1.0
150	4.1	2.1	2.0				2.0	0.9
200	3.6	2.0	1.4				2.5	0.8

Table B.5: Resistance coefficients for the mountings (Source: DVS 2210-1)).

#### 7.3.1.1 Annotation

The mentioned hydraulic resistance coefficients are reference values and are suitable for approximate calculations of pressure loss. For material-related calculations the values of the particular manufacturer should be used.

## 7.3.2 Selection criteria for the mountings

Selection criteria	Assessment					
	Diaphragm valve, straight valve, angle seat valve	Gate valve	PE ball valve	Butterfly valve	Check valve	Swing type check valve
Flow resistance	big	low	Dimension- and manufacturer dependent	moderate	big	moderate
Aperture and closing time	medium	medium	short	short	short	short
Operation moment	low	low	moderate (without gear) low (with gear)	moderate	-	-
Wear	moderate	low	low	moderate	moderate	moderate
Flow regulation	suitable	less suitable	less suitable	less suitable	-	-
Face-to-face length acc. to F-row	medium	big	welded directly into the pipeline	big	medium	big
Face-to-face length acc. to K-row	-	-		low	-	low

Table B.6: Selection criteria for the mountings (Source: DVS 2210-1).

F-row Flange design (DIN 3202-1)

K-row Inter-flange design (DIN 3202-3)

## 7.4 Pressure loss in finished joints or couplings

An exact calculation of the pressure loss is not possible, because the types and the qualities of the joints (welding joints, unions and flange joints) may vary.

It is recommended to use a resistance coefficient of  $\zeta_{RV} = 0.1$  for the consideration of the joints (butt and socket welding) and flanges in the pressure loss calculation.

$$\Delta p_{RV} = \zeta \cdot \frac{\rho}{2 \cdot 10^5} \cdot v^2$$

Formula B.17: Pressure loss in finished joints or couplings.

$\zeta$  resistance coefficient for the mountings [1]  
 $v$  flow velocity [m/s]  
 $\rho$  density of the medium [kg/m<sup>3</sup>]

## 8 Elongation

Elongations of plastic piping systems are caused by the changes in the operating or test process. Following influence factors are possible:

- Elongation due to temperature change
- Elongation due to internal pressure
- Elongation due to chemical influence

### 8.1 Elongation caused by temperature change

If the piping system is exposed to different temperatures (operating or ambient temperatures) its position changes depending on the moving possibilities of each pipeline. A pipeline is assumed as the distance between two restraints.

The elongation is calculated as follows:

$$\Delta L_T = \alpha \cdot L \cdot \Delta T$$

Formula B.18: Elongation due to temperature change.

$L$  pipe length [m]  
 $\alpha$  coefficient of linear expansion [mm/(m×K)]  
 $\Delta L_T$  elongation due to temperature change [mm]  
 $\Delta T$  temperature difference [K]

For the determination of  $\Delta T$  the lowest and the highest possible pipe wall temperature  $T_R$  during the installation, operation or standstill has to be considered.

	Linear expansion coefficient $\alpha$
PE 100 & PE 100-RC	0.18
PE-Xa	0.14

Table B.7: Linear expansion coefficient.

### 8.2 Elongation caused by internal pressure

The elongation due to internal pressure of a closed and friction-free installed piping system is:

$$\Delta L_p = \frac{0.1 \cdot p \cdot (1 - 2 \cdot \mu)}{E_c \cdot \left( \frac{OD^2}{ID^2} - 1 \right)} \cdot L$$

Formula B.19: Elongation due to internal pressure.

$E_{C,100 \text{ min}}$  creep modulus [N/mm<sup>2</sup>]  
 $ID$  pipe inside diameter [mm]  
 $L$  length of piping system [mm]  
 $OD$  pipe outside diameter [mm]  
 $p$  operating pressure [bar]  
 $\Delta L_p$  elongation by internal pressure [mm]  
 $\mu$  Poisson ratio 0.38 [1]

## 9 Restraint load

Restraints (fixed points) should prevent a sliding or moving of the piping system in every direction. Furthermore restraint serve as compensations for the reaction forces when using compensators (sliding sockets and push-fit fittings). A restraint has to be dimensioned for all possible forces:

- Stress through restrained thermal expansion
- Weight of the vertical piping systems
- Specific weight of the fluid
- Operating pressure
- Inherent resistance of the compensators

Restraints which haven't been determined should be placed in a way that the direction changes in the pipeline are used for the absorption of the elongations.

Possible restraints are the edges of the fitting sockets or special restraint fittings.

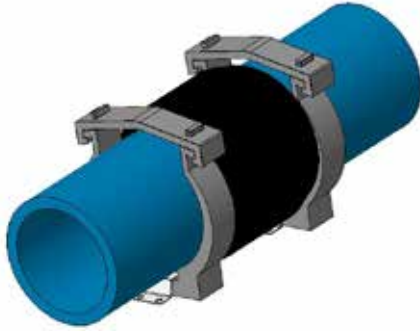


Figure B.2: PE 100-RC E-socket Restraint.

Swinging clips or the clamping of the pipes are not suitable as restraints.

## 9.1 Rigid system

Restraining the elongation of a piping system leads to a fixed system.

Rigid or fixed piping length has no compensation elements. and has to be treated as a special case during the dimensioning.

Following parameters have to be calculated:

- Restraint load
- Permissible guiding element distance in consideration of the critical buckling length
- Occuring tensile and compressive stresses

The highest restraint loads occur on the straight, axially fixed pipe sections. In general it is calculated using the following formula.

$$F_{FP} = A_R \cdot E_C \cdot \epsilon$$

Formula B.20: Dog bone load.

- $A_R$  annular surface of the pipe wall [mm<sup>2</sup>]  
 $E_C$  creep modulus for  $t = 100$  min [N/mm<sup>2</sup>]  
 $F_{FP}$  restraint loads in the fixed pipe section [N]

$\epsilon$  prevented longitudinal expansion (by heat expansion, internal pressure) [1]

Mean temperature $T_m$ [°C]	Creep modulus 100 min [N/mm <sup>2</sup> ]
10	810
20	630
30	450
40	310
50	240
60	180

Table B.8: Creep moduli for 100 minutes (Source: DVS 2210-1 suppl. 1).

### 9.1.1 Load by thermal expansion

$$\epsilon = \alpha \cdot \Delta T$$

Formula B.21: Thermal expansion.

- $\alpha$  coefficient of linear expansion [0,00018 (1/K) for PE]  
 $\Delta T$  max. temperature difference [K]  
 $\epsilon$  prevented longitudinal extension [1]

### 9.1.2 Load by internal pressure

$$\epsilon = \frac{0,1 \cdot p \cdot (1 - 2 \cdot \mu)}{E_C \cdot \left( \frac{d_a^2}{d_i^2} - 1 \right)}$$

Formula B.22: Extension due to the internal pressure.

- $p$  operating pressure [bar]  
 $\mu$  Poisson's ratio 0.38 [1]  
 $E_C$  creep modulus for  $t = 100$  min [N/mm<sup>2</sup>]  
 $OD$  pipe outside diameter [mm]  
 $ID$  pipe inside diameter [mm]  
 $\epsilon$  prevented longitudinal extension by internal pressure [1]

### 9.1.3 Load by swelling

Caution: a fixed system where a material swelling is possible, should be generally avoided. Reason: the swelling causes a material weakening.

## 10 Expansion bends

Changes in length are caused by changes in operating or ambient temperature. If the piping systems are installed above ground, the axial movements have to be compensated sufficiently.

In most cases, changes of direction of the pipe sections can be used for the absorption of the elongations. Otherwise, expansion bends have to be installed.

The minimum length of the expansion bend is calculated as follows:

$$L_s = k \cdot \sqrt{\Delta L \cdot d_a}$$

Formula B.23: Minimum length of expansion bends.

$L_s$	min. length of the expansion bend [mm]
$k$	material specific proportionality factor [1]
$\Delta L$	system length of the expansion bend [mm]
OD	pipe outside diameter [mm]

If the result cannot be realised, compensators with minimal friction coefficient have to be used. Depending on the construction, they may be applied as axial, lateral or angular compensators.

PE k-value	0 °C	10 °C	30 °C	40 °C	60 °C
	multiple temperature changes				
	16	17	23	28	-
single temperature change					
	12	12	16	17	-

Note: for the calculation of the k-values an installation temperature of 20 °C was taken into account. At lower temperatures the impact strength of the material has to be considered.

The k-values can be reduced by 30% for pressureless pipes (e.g. ventilation).

Between two restraints, a compensator has to be installed. An appropriate guiding of the piping at the loose points has to be ensured. For that matter the resulting reaction forces have to be taken into account.

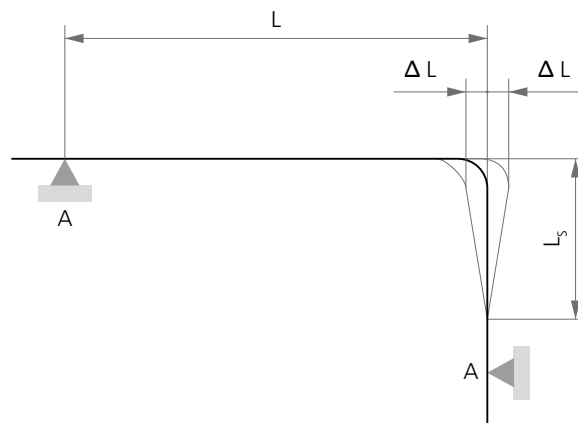


Figure B.3: L-compensation.

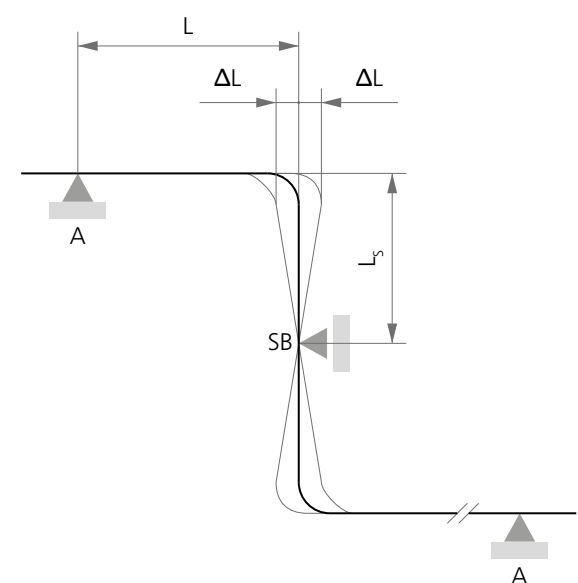


Figure B.4: Z-compensation.

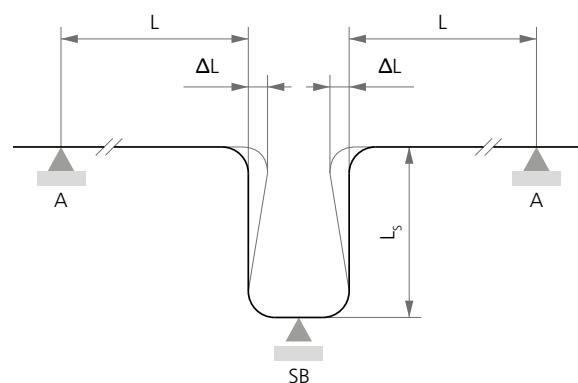


Figure B.5: U-compensation.

- A restraints
- SB slide bearing

## 10.1 Calculation of straight lengths

OD [mm]	change in length $\Delta L$ [mm]								
	50	100	150	200	250	300	350	400	500
16	750	1050	1300	1500	1650	1850	1950	2100	2350
20	850	1200	1450	1650	1850	2050	2200	2350	2600
25	950	1300	1600	1850	2100	2300	2450	2600	2950
32	1050	1500	1850	2100	2350	2550	2800	2950	3300
40	1200	1650	2050	2350	2600	2850	3100	3300	3700
50	1300	1850	2300	2600	2950	3200	3450	3700	4150
63	1500	2100	2550	2950	3300	3600	3900	4150	4650
75	1600	2300	2800	3200	3600	3900	4250	4550	5050
90	1750	2500	3050	3500	3900	4300	4650	4950	5550
110	1950	2750	3350	3900	4350	4750	5150	5500	6100
125	2100	2950	3600	4150	4600	5050	5450	5850	6500
140	2200	3100	3800	4400	4900	5350	5800	6200	6900
160	2350	3300	4050	4700	5200	5700	6200	6600	7400
180	2500	3500	4300	4950	5550	6050	6550	7000	7800
200	2600	3700	4550	5200	5850	6400	6900	7400	8250
225	2800	3900	4800	5550	6200	6800	7300	7800	8750
250	2950	4150	5050	5850	6500	7150	7700	8250	9200
280	3100	4400	5350	6200	6900	7550	8150	8750	9750
315	3300	4650	5700	6550	7300	8000	8650	9250	10350
355	3500	4900	6000	6950	7750	8500	9200	9800	11000
400	3700	5200	6400	7400	8250	9050	9750	10400	11650
450	3900	5550	6800	7800	8750	9600	10350	11050	12350
500	4150	5850	7150	8250	9200	10100	10900	11650	13000
560	4400	6200	7550	8750	9750	10700	11550	12350	13800
630	4650	6550	8000	9250	10350	11350	12250	13100	14600

Table B.9: Straight lengths in mm for PE pipes calculated acc. to formula A.23 with k-value=26 (rounded up in 50 mm steps).



## 11 Pipe spans

When calculating the pipe spans of a thermoplastic piping system the permissible bending stress as well as a limited deflection of the pipeline have to be taken into account. For the maximum deflection a guidance value of  $L_A/500$  is normally assumed.

Using the above mentioned deflection value the permissible pipe span can be calculated with the following equation.

$$L_A = f_{LA} \cdot \sqrt[3]{\frac{E_C \cdot J_R}{q}}$$

Formula B.24: Pipe spans for installations above ground.

The factor  $f_{LA}$  is determined depending on the pipe outside diameter. The relation between both parameters is as follows:

$$\text{min} \leftarrow \text{OD} \rightarrow \text{max}$$

$$0.92 \leftarrow f_{LA} \rightarrow 0.80$$

Usual support distances are stated in the following chapter.

In the rigid piping systems (see chapter Restraints) a critical buckling length has to be calculated. The critical buckling length is compared to the permissible pipe spans, whereupon the smaller value has to be considered.

$$L_{Kn, zul} = 3,17 \cdot \sqrt{\frac{W \cdot d_a}{2 \cdot \varepsilon \cdot A_R}}$$

$E_C$	creep modulus for 25 years [N/mm <sup>2</sup> ] (consider the reduction factor $\geq 2$ , see 2.1.4)
$f_{LA}$	deflection factor (0.80 - 0.92) [1]
$J_R$	moment of inertia of the pipe [mm <sup>4</sup> ]
$L_A$	permissible pipe span [mm]
$q$	line load (pipe, filling and additional weight) [N/mm]
$L_{Kn, zul}$	critical buckling length [mm]
$W$	section modulus of the pipe [mm <sup>3</sup> ]
$d_a$	outer diameter of the pipe (OD) [mm]
$\varepsilon$	prevented longitudinal extension [1]
$A_R$	pipe wall cross section [mm <sup>2</sup> ]

If the operating temperature is higher than 45 °C, the calculated pipe span  $L_{Kn}$  has to be reduced at least by 20 %.

The table below is for the approximate calculation with different transport media and different SDR classes. The input variables are:

- PE pipe
- SDR 11
- Transport medium: water

medium and wall thickness factors [1]			
SDR	$f_{wall}$	$f_{medium}$	
		water	gas
33	0,75	1	1,65
17,6/17	0,91	1	1,47
11	1	1	1,30
7,4	1,07	1	1,21

## 11.1 Guidelines for pipe spans for installation above ground and water (PE 100 & PE 100-RC)

### 11.1.1 SDR 11

OD [mm]		Guidelines pipe spans $L_A$ [mm] (installation above ground, for water, PE100 / PE100-RC)				
		20 °C	30 °C	40 °C	50 °C	60 °C
20	11	600	600	550	450	400
25	11	700	650	600	600	550
32	11	800	800	700	700	600
40	11	950	900	800	800	700
50	11	1150	1100	950	900	800
63	11	1300	1250	1150	1100	950
75	11	1450	1400	1300	1200	1100
90	11	1650	1550	1450	1350	1250
110	11	1800	1750	1650	1550	1400
125	11	1900	1850	1750	1700	1500
140	11	2050	2000	1900	1800	1650
160	11	2250	2100	2000	1900	1750
180	11	2350	2250	2100	2000	1900
200	11	2500	2400	2300	2200	2050
225	11	2650	2550	2450	2350	2250
250	11	2850	2750	2600	2500	2300
280	11	3000	2900	2800	2600	2400
315	11	3150	3050	2950	2800	2550
355	11	3400	3300	3150	3000	2800
400	11	3600	3450	3350	3150	2950
450	11	4000	3850	3600	3550	3350
500	11	4250	4100	3850	3800	3600
560	11	4550	4400	4150	4100	3850
630	11	4900	4700	4500	4400	4150
710	11	5300	5050	4850	4750	4550
800	11	5750	5500	5250	5150	4900
900	11	6200	5950	5700	5600	5300
1000	11	6650	6350	6100	6000	5700
1200	11	7500	7200	6900	6800	6400
1400	11	8300	8000	7650	7550	7200
1600	11	9100	8700	8400	8200	7800
1800	17	8800	8400	8100	7950	7500
2000	17	9450	9150	8700	8500	8100
2250	17	10200	9900	9400	9200	8800
2500	17	10950	10650	10100	9900	9400

Table B.10: Guidelines for pipe spans (dim 20-400 mm from DVS 2210-1, dim 450-1400 calculated with  $f_{LA}=0,86$ ), rounded up in 50 mm steps.

## 12 Nominal stiffness

The ring stiffness SN describes the carrying capacity of the pipe crown. SN (unit: kN/m<sup>2</sup>) means stiffness number and is divided into classes, which are determined experimentally. 21 days after the pipe production, the pipe is deformed to ca. 3% and the surface load, needed for the deformation is measured. A pipe with a nominal stiffness SN 2 can withstand a surface load of 2 kN/m<sup>2</sup> at a deformation of < 3%.

The influence of the stiffness on flexible plastic piping systems is overestimated. The pipe must offer a sufficient stiffness during the installation to bear the loads resulting from the compaction. With a good compaction work within the embedment the soil carries the occurring loads. Due to the deformation of the pipe (usually 2 - 3 %) the load isn't transferred to the pipe. After a period of approximately 2 years (relaxation) the pipe lies load-free in the soil. A nominal stiffness of 8 kN/m<sup>2</sup> is regarded as optimal and sufficient.

The ring stiffness is classified into the following grades after EN 12201-2:

SDR	ISO S	SN [kN/m <sup>2</sup> ]
41	20	1,3
33	16	2,5
26	12,5	5,3
21	10	10,4
17	8	20,3
13,6	6,3	41,7
11	5	83,3
9	4	162,8
7,4	3,2	317,9
6	2,5	668,7

Table B.11: Initial stiffness of pipes (calculated with Young's Modulus E = 1000 MPa)

## 13 Flow characteristics (Nomogram)

The following flow characteristics nomogram is used for the rough estimate of the flow velocity, pressure loss and flow rate.

When fittings are used in the pipeline, then up to 20 m of pipe length are added for each tee, reducer and 90° elbow, about 10 m of pipe for each bend (r = d) and about 5 m of pipe length for each bend (r = 1.5 × d). That estimation applies to an average flow velocity

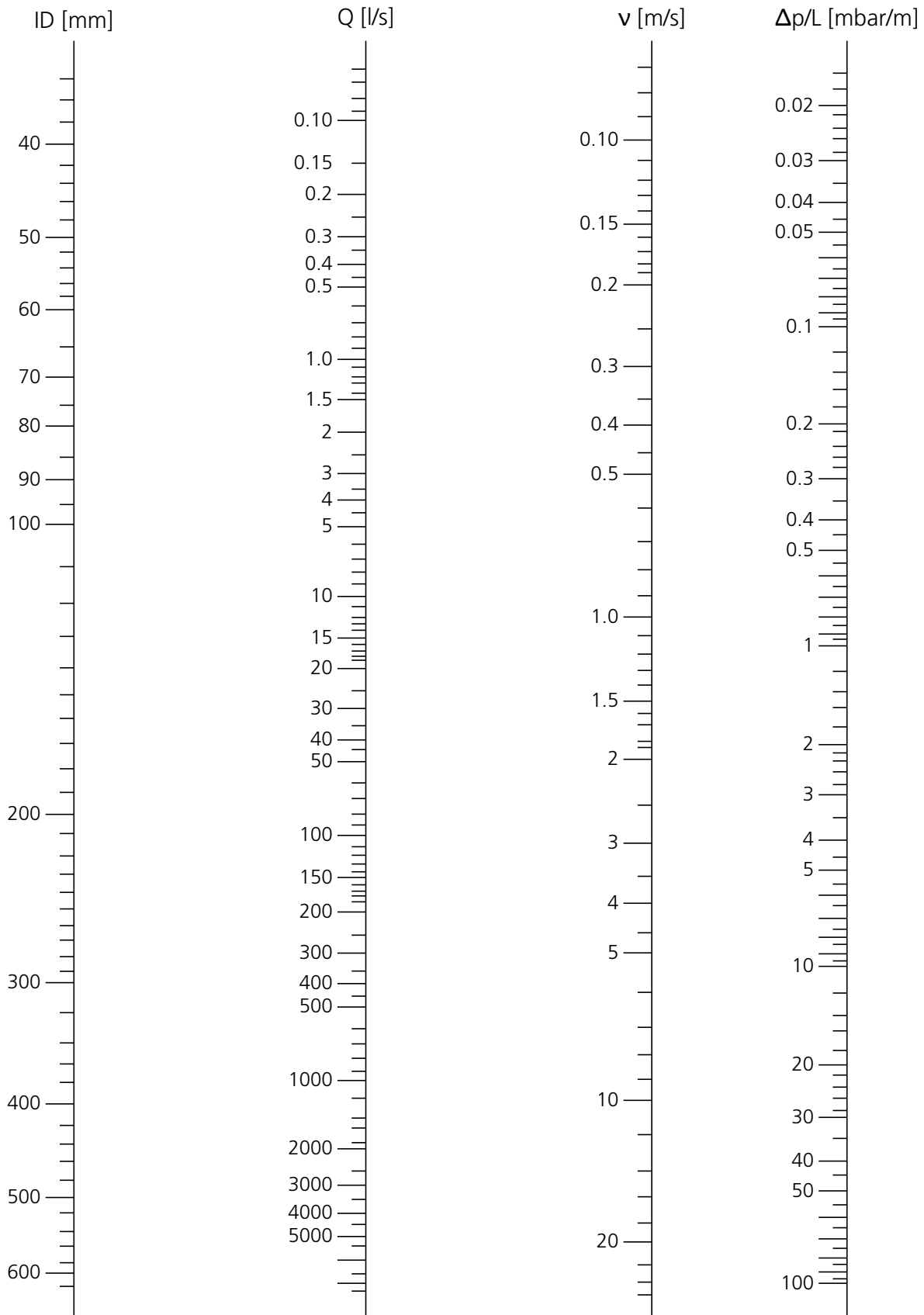


Figure B.6: Flow characteristics nomogram.

ID inside diameter of the pipe [mm]  
 $Q_2$  flow rate [l/s]  
 v flow velocity [m/s]  
 $\Delta p/L$  pressure loss per meter pipe length [mbar/m]

## 14 Calculation aids

### 14.1 Conversion table

	<b>Pa = N/m<sup>2</sup></b>	<b>MPa</b>	<b>bar</b>	<b>mm WC</b>
1 Pa = N/m <sup>2</sup>	1	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-2</sup>
1 MPa = 1 N/mm <sup>2</sup>	10 <sup>6</sup>	1	10	1.02 · 10 <sup>5</sup>
1 bar	10 <sup>5</sup>	0,1	1	1.02 · 10 <sup>4</sup>
1 mm WC	9.81	9.81 · 10 <sup>-6</sup>	9.81 · 10 <sup>-5</sup>	1

Tabelle A.2: Conversion pressure units

	<b>mm</b>	<b>cm</b>	<b>dm</b>	<b>m</b>	<b>km</b>
1 mm	1	10 <sup>-1</sup>	10 <sup>-2</sup>	10 <sup>-3</sup>	10 <sup>-6</sup>
1 cm	10	1	10 <sup>-1</sup>	10 <sup>-2</sup>	10 <sup>-5</sup>
1 dm	10 <sup>2</sup>	10	1	10 <sup>-1</sup>	10 <sup>-4</sup>
1 m	10 <sup>3</sup>	10 <sup>2</sup>	10	1	10 <sup>-3</sup>
1 km	10 <sup>6</sup>	10 <sup>5</sup>	10 <sup>4</sup>	10 <sup>3</sup>	1

Tabelle A.3: Conversion length units

	<b>mm<sup>2</sup></b>	<b>cm<sup>2</sup></b>	<b>dm<sup>2</sup></b>	<b>m<sup>2</sup></b>
1 mm <sup>2</sup>	1	10 <sup>-2</sup>	10 <sup>-4</sup>	10 <sup>-6</sup>
1 cm <sup>2</sup>	10 <sup>2</sup>	1	10 <sup>-2</sup>	10 <sup>-4</sup>
1 dm <sup>2</sup>	10 <sup>4</sup>	10 <sup>2</sup>	1	10 <sup>-2</sup>
1 m <sup>2</sup>	10 <sup>6</sup>	10 <sup>4</sup>	10 <sup>2</sup>	1

Tabelle A.4: Conversion area units

	<b>t</b>	<b>kg</b>	<b>g</b>	<b>mg</b>
1 t	1	10 <sup>3</sup>	10 <sup>6</sup>	10 <sup>9</sup>
1 kg	10 <sup>-3</sup>	1	10 <sup>3</sup>	10 <sup>6</sup>
1 g	10 <sup>-6</sup>	10 <sup>-3</sup>	1	10 <sup>3</sup>
1 mg	10 <sup>-9</sup>	10 <sup>-6</sup>	10 <sup>-3</sup>	1

Tabelle A.5: Conversion mass units

	<b>mm<sup>3</sup></b>	<b>cm<sup>3</sup></b>	<b>dm<sup>3</sup></b>	<b>m<sup>3</sup></b>
1 mm <sup>3</sup>	1	10 <sup>-3</sup>	10 <sup>-6</sup>	10 <sup>-9</sup>
1 cm <sup>3</sup>	10 <sup>3</sup>	1	10 <sup>-3</sup>	10 <sup>-6</sup>
1 dm <sup>3</sup> = 1l water	10 <sup>6</sup>	10 <sup>3</sup>	1	10 <sup>-3</sup>
1 m <sup>3</sup>	10 <sup>9</sup>	10 <sup>6</sup>	10 <sup>3</sup>	1

Tabelle A.6: Conversion volume units

OD [mm]	DN	inch
10	6	-
12	8	-
16	10	-
20	15	1/2
25	20	3/4
32	25	1
40	32	1 <sup>1/4</sup>
50	40	1 <sup>1/2</sup>
63	50	2
75	65	2 <sup>1/2</sup>
90	80	3
110	100	4
125	100	4 <sup>1/2</sup>
140	125	5
160	150	6
180	150	7
200	200	8
225	200	9
250	250	10
280	250	11
315	300	12
355	350	14
400	400	16
450	500	18
500	500	20
560	600	22
630	600	25
710	700	28
800	800	32
900	900	36
1000	1000	40
1200	1200	48

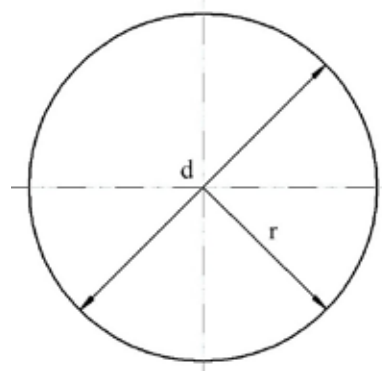
Relation between the outer diameter (OD), the nominal diameter, and the inch dimensions.

1	3.28	39.37
metre	feet	inch
[m]	[ft]	[in]
1	0.264	0.035
litre	gallons	cubic feet
[l]	[Ga]	[ft³]
1	2.204	9.81
kilogram	pounds	Newton
[kg]	[lbs]	[N]
1	14.505	100
bar	pound/sq. inch	kilopascal
[bar]	[psi]	[kPa]

Tabelle A.7: Conversion SI-units

## 14.2 Formula

### 14.2.1 Circle



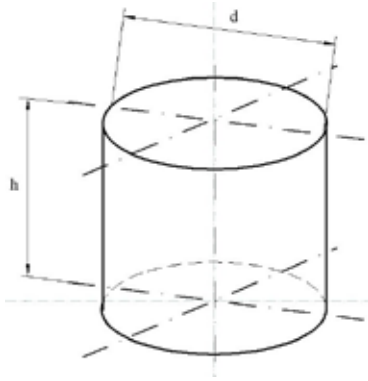
Area

$$A = \frac{\pi}{4} \cdot d^2 = \pi \cdot r^2$$

Circumference

$$U = 2 \cdot \pi \cdot r = \pi \cdot d$$

### 14.2.2 Cylinder



Lateral area

$$A_m = 2 \cdot \pi \cdot r \cdot h$$

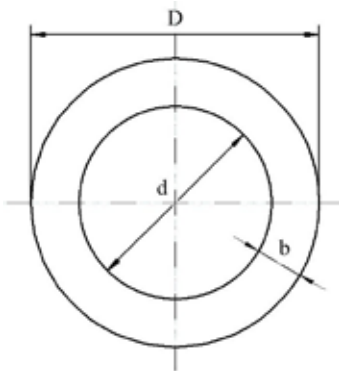
Surface

$$A_o = 2 \cdot \pi \cdot r \cdot (r + h)$$

Volume

$$V = \frac{\pi}{4} \cdot d^2 \cdot h$$

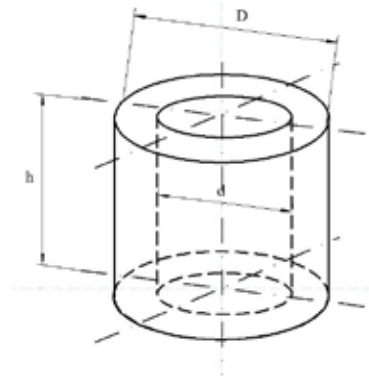
### 14.2.3 Circular ring



Area

$$A = \frac{\pi}{4} \cdot (D^2 - d^2)$$

### 14.2.4 Hollow cylinder (pipe)



Volume

$$V = \frac{\pi}{4} \cdot h \cdot (D^2 - d^2)$$

A area [mm<sup>2</sup>]

A<sub>m</sub> lateral area [mm<sup>2</sup>]

A<sub>o</sub> surface [mm<sup>2</sup>]

V volume [mm<sup>3</sup>]

U circumference [mm]

r radius [mm]

D diameter (outside) [mm]

d diameter (inside) [mm]

h height [mm]

b wall thickness [mm]

<b>1</b>	<b>General requirements</b>	125
<b>2</b>	<b>Heated tool butt welding (HS)</b>	127
<b>3</b>	<b>Heated tool socket welding</b>	130
<b>4</b>	<b>Electro-fusion welding DIM 20-500 mm monofilar</b>	132
<b>5</b>	<b>Electro-fusion welding Dim 560-1400 SDR 11 - 17 bifilar</b>	134
<b>6</b>	<b>Electro-fusion welding Dim 560-1600 SDR 26 bifilar - without pre-heating</b>	134
<b>7</b>	<b>Saddles</b>	135
<b>8</b>	<b>Pressure test</b>	137



Standards and approvals

Installation guide

Connection technology

Calculation guide

Material properties

## 1 General requirements

(applies to all welding processes)

The quality of welded joints depends on the qualification of the welder, the suitability of the utilized equipment and devices as well as on compliance with the welding standards. The welded joint can be tested by means of non-destructive and/or destructive methods.

The welding work must be monitored. Type and range of supervision has to be agreed between the contract partners. It is recommended to record the welding data in welding protocols or on data carriers.

Every welder has to be trained and has to be in possession of a valid qualification certificate. The intended application range may be decisive for the kind of qualification. For the industrial piping system construction, the technical code DVS 2212-1 is valid.

The equipment and devices which are used for welding must comply with the requirements in DVS 2208-1 and/or ISO 12176-1 (buttwelding) and 12176-2 (electro-socket welding). The welding of plastics for indoor applications is described in the technical codes DVS 1905-1 and -2.

### 1.1 Requirements for welding

The welding zone must be protected against bad weather influences (e.g. wind, moisture).



Figure C.1: Preparation of the welding zone acc. to DVS

If it is ensured by suitable measures (e.g. preheating, tent, heating) that the conditions are suitable for welding, work may be carried out at any outside temperature insofar as the welder is not hindered in his handling. (fig. C.1)

An additional proof must be provided by carrying out sample welds under the mentioned conditions

If the semi-finished product (pipe or fitting) is heated up unevenly under influence of sunshine, a temperature compensation in the area of the welding joint can be reached by covering. A cooling down during the welding process by ventilation has to be avoided. During welding the pipe ends have to be closed additionally to avoid stack effect.

PE-HD-pipes from coils are oval and bent immediately after uncoiling. The pipe end must be prepared before welding, e.g. by careful heating up with a hot-air equipment and/or use of a suitable clamping res. re-rounding device.

The joining zones of the components to be welded must be undamaged and have to be free of contaminations (e.g. dirt, grease, shavings).

Before welding the joining areas have to be cleaned with a special cleaning agent (PE cleaning agent consisting of isopropanol, acetone or ethanol acc. to DVGW VP 603)

Caution: Pipes and fittings contaminated with silicone grease cannot be cleaned with most of the cleaning agents. In that case brake cleaner fluid can be used. However the suitability has to be checked with the manufacturer and additional welds have to be carried out.

During all welding procedures the welding area has to be free of flexural stresses (e.g. by careful storage, roller blocks). Also a correct axial alignment has to be ensured.

Agro welding guidelines are valid for the welding of pipes and fittings made of thermoplasts stated in the table C.1.

material	weldability
PE-80, PE-100, PE-100 RC	MFR(190/5)= 0.2 - 1.7 (g/10 min)  0.2 - 1.3 (g/10 min) for welding of branches

Table C.1: Thermoplasts for the welding (Source: DVS 2207-1)

## 1.2 Requirements welding machines

All welds have to be carried out using welding machines and devices, which fulfill the requirements of DVS 2208-1.

The welding device or machine must be inspected at certain intervals by an expert and the heating elements must be cleaned with appropriate cleaning agents.

## 1.3 Limits of connection types

All connections have to be realised free of tensions. Tensions caused by temperature should be minimised by using appropriate measures.

The longitudinally force-locked joints are available in following dimensions (table C.2):

connection type	OD					
	20 - 63	75 - 110	125 - 225	250 - 500	560 - 1400	1400 - 3500
heated tool butt welding	✓	✓	✓	✓	✓	✓
heated tool socket welding	✓	✓				
electro-socket welding	✓	✓	✓	✓	✓	
flange connection	✓	✓	✓	✓	✓	✓
screw connection	✓					

Table C.2: Permitted longitudinally force-locked joints

## 2 Heated tool butt welding (HS)

(acc. to DVS 2207-1)

With the heated tool butt welding process, the joining zones of the components to be welded are aligned under pressure on the heated tool (alignment),

heated up to the welding temperature with reduced pressure (heating up) and joined under pressure (joining) after removal of the heated tool (change-over).

Heated tool butt welding is usually conducted at temperatures  $220\text{ °C} \pm 10\text{ °C}$ .

Nominal wall thickness $s$ [mm]	Bead height [mm] pressure = $0.15\text{ N/mm}^2$	Heating-up time $t_{AW}$ [s] pressure $\leq 0.01\text{ N/mm}^2$	Max. changeover time $t_U$ [s]	Max. joining pressure build-up time $t_F$ [s]
up to 4,5	0.5	up to 45	5	5
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

Table C.3: Heated tool butt welding parameters (Source: DVS 2207-1)

Nominal wall thickness $s$ [mm]	Cooling time $t_{AK}$ (min. values) under joining pressure $p = 0.15 \pm 0,01\text{ N/mm}^2$ depending on the ambient temperature		
	up to $15\text{ °C}$ [min]	$15\text{ °C} - 25\text{ °C}$ [min]	$25\text{ °C} - 40\text{ °C}$ [min]
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 – 46	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

Table C.4: Cooling times for pipes and fittings made of PE depending on the ambient temperature (Source: DVS 2207-1)

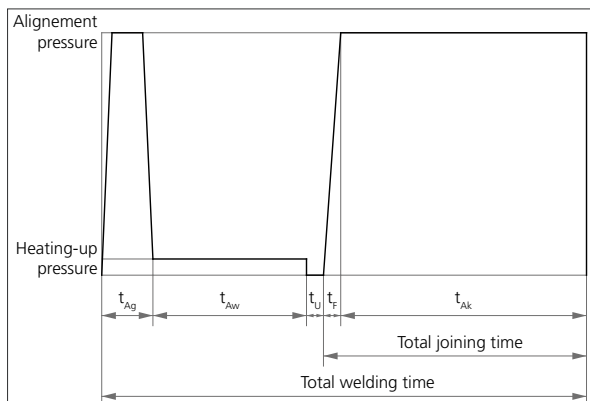


Figure C.2: Process steps of heated tool butt welding

## 2.1 Welding procedure heated tool butt welding:

### 2.1.1 Preparation of welding area

- Ensure a stable position of the welding machine and check the welding equipment.
- If necessary, set up the tent / shelter.

### 2.1.2 Preparation of pipes and fittings

- Align the pipes and fittings in the axial direction in the welding machine before clamping.
- The easy axial movement of the part to be welded-on can be ensured e.g. by means of dollies or swinging suspension.
- The joining areas have to be free of contamination (dirt, grease, silicone grease, etc.) and cannot be damaged
- The joining areas have to be planed and the shavings have to be removed from the welding area of the pipe/fitting (using brush, paper, pressurised air).
- If **pipes with protective PP-layer** are welded, the protective layer at the end of the pipe has to be removed before planing (20 mm). The pipe must not be damaged.

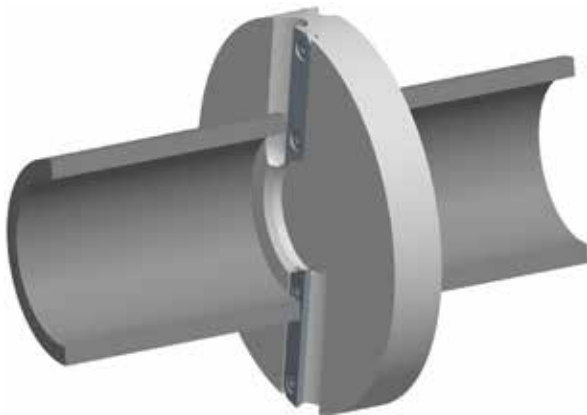


Figure C.3: Planing the pipe ends

- After removing the planing tool the gap width and the misalignment have to be controlled. The misalignment of the joining areas on the pipe outside may not exceed the permissible size of  $0,1 \times$  wall thickness. Also the nominal wall thickness of the pipes/fittings must match in the welding area.

### 2.1.3 Preparation welding procedure

- Prior to the start of the welding process, the welding temperature of the heated tool has to be checked. (start the welding procedure at least 10 minutes after reaching the welding temperature).
- To prevent the heating element from contamination or damage, it has to be stored under a protective cover before and after the welding.
- To ensure an optimum welding connection the heated tool has to be cleaned with clean lint-free cloth before every welding operation.

### 2.1.4 Welding

#### 2.1.4.1 Alignment

- The joining areas of the welding components are pressed to the heated tool until all areas are in contact with the heated tool. This fact is visible on the formation of beads. The alignment is finished when the bead heights have reached the required values (fig. C.4).

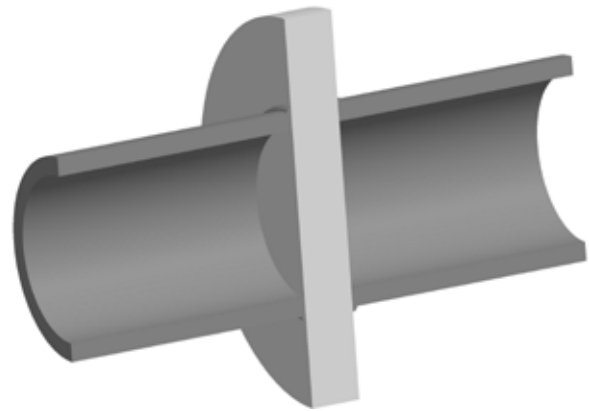


Figure C.4: Alignment of the joining areas (between the pipes: heating element)

## 2.1.4.2 Heating-up

- The alignment pressure is reduced to almost zero ( $<0.01 \text{ N/mm}^2$ ).
- Wait the required heating-up time.

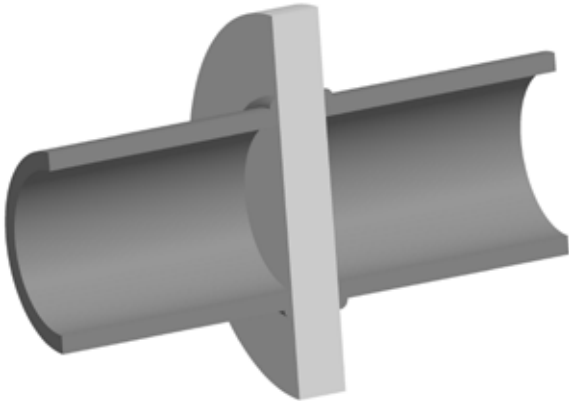


Figure C.5: Heating-up the pipe ends

## 2.1.4.3 Changeover

- The heated tool should be withdrawn within the max. changeover time (see table C.3). The changeover time should be as short as possible. Otherwise the plasticized areas will cool down and the welding joint quality will deteriorate.

## 2.1.4.4 Joining

- The areas to be welded should be brought together with a speed of almost zero. The pressure is then gradually increased to the recommended joining pressure.
- De-clamping is possible only after the required cooling time.
- Rough handling with full mechanical load of the joint (e.g. pressure test or operation) is allowed only after complete cooling down

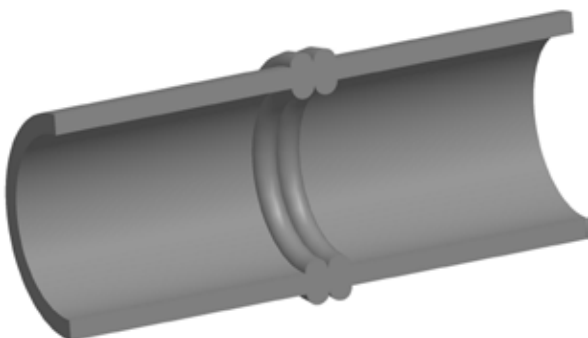


Figure C.6: Joining the pipe ends

## 2.1.5 Testing of welded joints

### 2.1.5.1 Visual test

Smooth welding joint on the complete circumference. The misalignment of the joining areas on the pipe outside may not exceed the permissible size of  $0.1 \times$  wall thickness.

### 2.1.5.2 Pressure test

A pressure test has to be conducted according to the standards (e.g. DVS 2210-1, supplement 2, DIN EN 805, DVGW 400-2 and chapter 7 respectively).

### 3 Heated tool socket welding

(acc. to DVS2207-1)

At heated tool socket welding (see figures D.8-D.10), pipe and pipeline components are welded in overlapped condition. Pipe end and fitting are heated up to welding temperature by a socket or spigot shaped heated tool and subsequently joined together.

Heated tools and fittings are dimensionally adapted so that on joining a joining pressure will be built-up.

Heated tool socket welding can be performed manually up to 50 mm pipe diameter. At diameters as from 63 mm, a welding device is required because of the higher joining force.

Heated tool socket welding of PE-HD is usually conducted at temperatures between 250 and 270 °C

Guidelines for the heated tool socket welding (PE-HD pipes and fittings, outside temperature: 20 °C, moderate air movement) are stated in the table C.6 below.

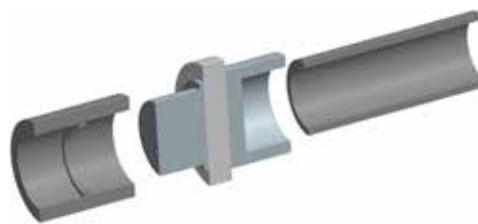


Figure C.7: Preparation heated tool socket welding



Figure C.8: Alignment and heating up

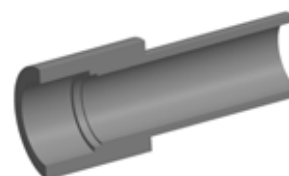


Figure C.9: Joining and cooling

#### 3.1 Welding procedure heated tool socket welding

##### 3.1.1 Preparation of welding area

OD [mm]	heating up		changeover	cooling down	
	heating time [s]			max. changeover time [s]	fastened [s]
	SDR11, SDR7.4, SDR 6	SDR17, SDR17.6			
16	5	Welding not recommended	4	6	2
20	5		4	6	2
25	7		4	10	2
32	8		6	10	4
40	12		6	20	4
50	18		6	20	4
63	24		8	30	6
75	30	18	8	30	6
90	40	26	8	40	6
110	50	36	10	50	8
125	60	46	10	60	8

Table C.6: Welding parameters heated tool socket welding (Source: DVS 2207-1)

- Ensure a stable position of the welding machine and check the welding equipment.
- If necessary, set up the tent / shelter.
- Clean the heating elements.

### 3.1.2 Preparation of pipes and fittings

- Cut the pipes and fittings rectangular and chamfer the inner edge with a knife.
- Chamfer the pipe end (table C.4) and remove the oxide layer by scraping the pipe end with a scraping tool. Keep scraping until the blades of the tool are flush with the pipe end.

pipe OD [mm]	pipe chamfer b [mm]	insert depth l [mm]
20	2	14
25		16
32		18
40		20
50		23
63	3	27
75		31
90		35
110		41

Table C.5: Required pipe chamfer and insert depth

### 3.1.3 Preparation welding procedure

- Prior to the start of the welding process, the welding temperature of the heated tool has to be checked. (start the welding procedure at least 10 minutes after reaching the welding temperature).
- To prevent the heating element from contamination or damage, it has to be stored under a protective cover before and after the welding.
- To ensure an optimum welding connection the heated tool has to be cleaned with clean lint-free cloth before every welding operation.

### 3.1.4 Welding

- For the purpose of heating, fitting and pipe are pushed swiftly and axially onto the devices fitted on the heated tool and held until the stop at machine welding or until the mark at manual welding. Under no circumstances must the end of the pipe be pushed against the heater block.
- The heating-up time starts according to the time values in table C.5.
- After the heating time has elapsed, the fitting and pipe should be withdrawn sharply from the heated tool and pushed together immediately without any twisting until the stop or mark is met.
- At manual welding the joined components have to be kept fixed until the cooling time (fixed) elapses.
- The connection may be pressurised or handled only after cooling time is over.

### 3.1.5 Testing of welded joints

#### 3.1.5.1 Visual test

Smooth welding joint on the complete circumference. The angular deviation of the pipe is not allowed.

#### 3.1.5.2 Pressure test

A pressure test has to be conducted according to the standards (e.g. DVS 2210-1, supplement 2, DIN EN 805, DVGW 400-2 and chapter 7 respectively).



## 4 Electro-fusion welding DIM 20-500 mm monofilar

(acc. to DVS 2207-1)

Electro-fusion (EF) fittings with monofilar welding system are used to weld the components using resistance wire (heating wire). The heating wire is completely embedded in the fitting.

This provides a smooth inner surface and allows an easy cleaning and insertion of the pipe ends/spigots. A (universal) welding machine provides the required power supply.

The required welding pressure results from the tensions caused by shrinkage of the fitting during the welding. This ensures an optimal welding result.

Special features of the process are a low voltage as well as a high automation level. Welding can be carried out on site even under difficult conditions (difficult access).

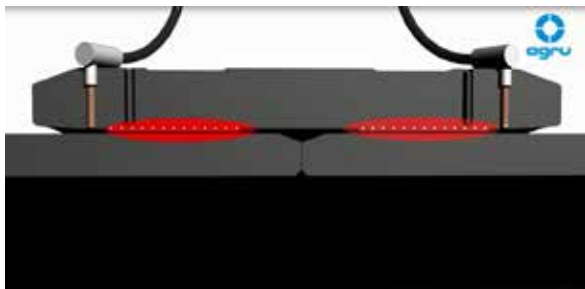


Figure C.10: Principle of the monofilar welding technique

A universal welding machine with a bar code reader and an automatic data logging should be used for the welding of the AGRU EF-fittings. Thus a simple handling and a traceability can be assured.

### 4.1 Bar code

A bar code contains all required welding parameters and can be read by all current welding machines. Agru ef-fittings have a label with a welding and a traceability codes attached.

The traceability code is used for the batch documentation. Both codes have different colors for better differentiation. (see fig. C.11):



Figure C.11: Agru bar code label

**welding code** white background, acc. to ISO 13950

position	description
1-2	fitting
3-6	manufacturer
7-8	cooling time
9-11	dimension
12	energy input
13-14	voltage level
15-17	resistance
18	resistance tolerance range
19-21	welding time
22-23	energy correction value
24	check digit

**traceability code** yellow background, acc. to ISO 12176-4

position	description
1-4	manufacturer
5-6	fitting
7-9	dimension
10-15	serial number
16-17	production plant
18	SDR
19-22	material code
23	material condition
24	MRS
25	MFR
26	check digit

## 4.2 General weldability

PE 80, PE 100 und PE 100-RC can generally be welded without any problems, as long as the pipes/ fittings to be welded have a melt flow rate (MFR 190/5) between 0.2 g/10' and 1.7 g/10'. A test welding has to be carried out.

**Attention:** The pipe / EF-fitting with the lowest PN rating determines the PN rating of the entire pipe-line (e.g. PN25 (SDR 7,4) pipes welded with PN16 (SDR11) EF-couper → pipeline: PN16).

The weldability of the ef-fittings is tested and approved with following SDR classes:

EF-fitting	OD [mm]	weldable pipes/fittings							
		SDR 33	SDR 26	SDR 17,6	SDR 17	SDR 13,6	SDR 11	SDR 9	SDR 7,4
Schweißbar mit Wanddicken von 2,5mm-3,5mm									
SDR 11 (EF-fitting)	20	x	x	x	x	x	✓	✓	✓
	25	x	x	x	x	x	✓	✓	✓
	32	x	x	x	x	x	✓	✓	✓
	40	x	x	✓	✓	✓	✓	✓	✓
	50	x	x	✓	✓	✓	✓	✓	✓
	63	x	x	✓	✓	✓	✓	✓	✓
	75	x	x	✓	✓	✓	✓	✓	✓
	90	x	x	✓	✓	✓	✓	✓	✓
	110	x	x	✓	✓	✓	✓	✓	✓
	125	x	x	✓	✓	✓	✓	✓	✓
	140	x	x	✓	✓	✓	✓	✓	✓
	160	x	x	✓	✓	✓	✓	✓	✓
	180	x	✓	✓	✓	✓	✓	✓	✓
	200	x	✓	✓	✓	✓	✓	✓	✓
	225	x	✓	✓	✓	✓	✓	✓	✓
	250	x	✓	✓	✓	✓	✓	✓	✓
	280	x	✓	✓	✓	✓	✓	✓	✓
	315	x	✓	✓	✓	✓	✓	✓	✓
355	x	✓	✓	✓	✓	✓	✓	✓	
400	x	✓	✓	✓	✓	✓	✓	✓	
450	x	x	✓	✓	✓	✓	✓	✓	
500	x	x	✓	✓	✓	✓	✓	✓	
SDR 17 (EF-fitting)	90	x	✓	✓	✓	x	x	x	x
	110	x	✓	✓	✓	x	x	x	x
	125	x	✓	✓	✓	x	x	x	x
	140	x	✓	✓	✓	x	x	x	x
	160	x	✓	✓	✓	x	x	x	x
	200	x	✓	✓	✓	x	x	x	x
	225	x	✓	✓	✓	x	x	x	x
	250	x	✓	✓	✓	x	x	x	x
	280	x	✓	✓	✓	x	x	x	x
	315	x	✓	✓	✓	x	x	x	x
	355	✓	✓	✓	✓	x	x	x	x
	400	✓	✓	✓	✓	x	x	x	x
	450	✓	✓	✓	✓	x	x	x	x
500	✓	✓	✓	✓	x	x	x	x	

\*thin-walled pipes must be welded using tubular stiffeners.

### 4.3 Welding procedure electro-socket welding Dim 20-500 mm monofilar



Installation animation  
electrofusion couplers Dim 20-500



Installation instructions B5116  
electrofusion couplers Dim 20-500

A universal welding machine with a bar code reader and an automatic data logging should be used for the welding of the AGRU EF-fittings. Thus a simple handling and a traceability without gaps can be assured.



Installation animation  
electrofusion couplers Dim 560-1400



Installation instructions B5127  
electrofusion couplers Dim 560-1400

## 5 Electro-fusion welding Dim 560-1400 SDR 11 - 17 bifilar

(acc. to DVS 2207-1)

Electro-fusion (EF) fittings with bifilar welding system are used to weld the components with two separate welding zones using resistance wire (heating wire). The heating wire is completely embedded in the fitting. That provides a smooth inner surface and allows an easy cleaning and insertion of the pipe ends/spigots.

Both sides of the EF-coupler can be welded separately. After the first welding is complete the pipe with the welded EF-coupler can be connected to the existing pipeline on site.

A pre-heating function is available to close bigger gaps between the pipe and the EF-fitting and to compensate high ovalities. A (universal) welding machine provides the required power supply.

Tension belts are required to provide the welding pressure. This ensures an optimal welding result.

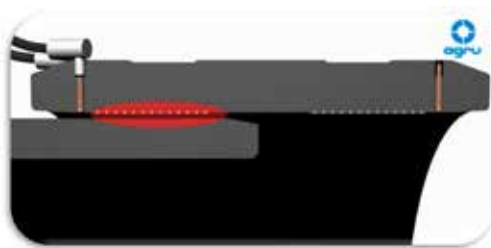


Figure C.12: Principle of the bifilar welding

## 6 Electro-fusion welding Dim 560-1600 SDR 26 bifilar - without pre-heating

(acc. to DVS 2207-1)



Installation instructions B5141  
electrofusion couplers Dim 560-1600

### 6.1 Testing of welding joints

- Conduct the pressure test acc. to relevant standards (e.g. DVS 2210-1, suppl. 2, DIN EN 805, DVGW-worksheet 400-2). Pressure test is only possible, after the welding connection is cooled down completely.
- Provide a welding protocol (handwritten or automatic logging of the welding machine).
- After the cooling time is reached, the tension belts can be removed.

## 7 Saddles

(acc. to DVS 2207-1)

Saddles are used for creating branches on existing pipelines. They are fastened with the lower part on the main line and connected to it via electro-fusion welding.

AGRU offers 3 different types of saddles:

### 7.1 Spigot saddle

Spigot saddles are used for **pressureless** creation of branches on existing lines. For the tapping of the main line an additional tapping tool is necessary. A tapping under pressure is possible with a special equipment.



Figure C.13: Example of a spigot saddle



Installation animation  
Spigot saddle



Installation instructions B5105-1  
Spigot saddle

### 7.2 Tapping saddle

Tapping saddles are used for creating branches in existing lines **under pressure**. The patented telescope tapping unit ensures a leak-tight tapping of an operating main line.



Figure C.14: Example of a tapping saddle



Installation animation  
Tapping saddle



Installation instructions B5101-1  
Tapping saddle

After the tapping the opening for the operating tool is closed with a screw or a weldable cap.

### 7.3 Pressure tapping valve

Pressure tapping valves are used for creating branches in existing lines **under pressure**. Compared to the tapping saddle, a multiple opening and leak-tight closing of the pressure tapping valve is possible.



Figure C.15: Example of a pressure tapping valve



Installation animation  
Pressure tapping valve



Installation instructions B5111-1  
Pressure tapping valve

## 7.4 Installation of saddles

(detailed and up-to-date installation manual available on request)

The mounting of all three saddle types is based on the same principle:

First the saddle is fastened on the main line and connected to it via electro-fusion welding.

All weldings have to be conducted with machines and equipment acc. to DVS 2208-1.

Depending on the saddle type, after reaching the cooling time, firstly the branch is connected and then the main line is tapped or vice-versa.

## 7.5 Detachable joints

- It is recommended to coat the bolts for the flange connection with molybdenum sulfide grease to ensure a smooth operation, even during a long operation period.
- When choosing a seal material, consider its thermal and chemical suitability.
- The bolts shouldn't protrude further than two to three thread lengths after the nut.
- Washers have to be placed at the bolt head and also at the nut.
- Before applying the bolt initial prestress, the sealing faces have to be aligned parallel to each other and fit tight to the sealing.
- Adjusting the position of the sealing faces by means of bolt pretensioning using a spanner is not permissible
- The required bolt-tightening torque depends on the shape and the selected material of the seal (Shore A hardness) as well as on the friction in the screw thread and on the nut contact face (average friction coefficient of 0.15 can be expected).
- The connecting bolts have to be screwed diagonally by means of a torque key (torque values see table C.8).
- The bolting torque must induce a certain amount of compressive stress on the elastomeric seal ( $\geq 0,5 \text{ N/mm}^2$ ). Below this minimum compressive stress a leak may occur. Otherwise, an excessive compressive stress may cause damage and deformation of the seal area (seal, stub end, backing ring, etc.).

- Flange connections which are exposed to alternating stresses and heavy impacts, have to be checked within prescribed maintenance intervals and retightened if necessary.

shape of the seal	recommended operational limits		flange- /stub end design
	pressure [bar]	temp. [°C]	
flat ring	up to 10*	bis 40	with sealing grooves
profiled flat ring	up to 16	no limits	with / w/o sealing grooves
*up to max. DN>150, max. 6bar			

Table C.7: Flat seal selection criteria (Source: DVS 2210-1 suppl. 3)

Nominal width	Thickness s [mm]
Up to d90 mm / DN 80	min. 2
$\geq d110 \text{ mm} / \text{DN } 100$	min. 3

Table C.8: Minimal thickness of flat seals (Source: DVS 2210-1 suppl. 3)

DN	Bolting torque [Nm]	
	flat ring up to 10 bar	profiled ring up to 16 bar
15	15	15
20	15	15
25	15	15
32	20	15
40	30	15
50	35	20
65	40	25
80	40	25
100	40	30
125	50	35
150	60	40
200	70*	50
250	80*	55
300	100*	60
350	100*	70
400	120*	80
500	190*	90
600	220*	100

Table C.9: Guidelines bolting torque (Shore-Hardness 80° acc. to DVS 2210-1 suppl. 3)

\* allowable operating pressure  $\leq 6 \text{ bar}$

## 8 Pressure test

The following chapter describes three pressure test methods, derived from valid standards. The test methods are divided into pressure tests for exposed pipeline or a buried pipeline for water or gas transport. The pressure tests based on national requirements may vary from the pressure test methods mentioned below.

The internal pressure test is to be made at pipelines out of any material which are ready for use with the medium water. The conditions at the test are higher than the operating conditions and confirm the reliability of the piping system.

**Attention:** Before the test pressure is calculated, the maximum permissible pressure of each component in the piping system has to be specified. It has to be ensured that the test pressure does not exceed this pressure!

### 8.1 Pressure test of exposed pipelines

(acc. to DVS 2210-1 suppl. 2)

In general there are three kinds of internal pressure tests:

- pre-test
- main-test
- short-test

The results of the tests have to be recorded. A continuous pressure and temperature record have to be conducted.

#### 8.1.1 Pre-test

The pre-test is to prepare the piping system for the main-test. Within the pre-test the pipeline adjusts to the stress-strain balance through the applied pressure, due to that the volume in the pipe increases. This will cause a decrease of the pressure which has to be adjusted to the test pressure. The bolts at the flanges have to be retightened as well.

#### 8.1.2 Main-test

With constant wall temperatures at the pipe, less decrease in pressure can be expected compared to the pre-test.

The focus at this test is:

- changes in length
- tightness of the flange connections

#### 8.1.3 Short-test

This kind of test is a special case because there is too short time that the pipe adjusts to the stress-strain balance.

Inadequacies can not be identified.

Topic and explanation		Pre-test	Main-test	Short-test
Test pressure $p_p$	depends on the wall temperature and on the max. pressure of components	$\leq p_{P(zul)}$	$\leq 0.85 \cdot p_{P(zul)}$	$\leq 1.1 \cdot p_{P(zul)}$
Test period	Pipes with or without branches and a total length of $L \leq 100 \text{ m}^1)$	$\geq 3 \text{ h}$	$\geq 3 \text{ h}$	$\geq 1 \text{ h}$
	Pipes with or without branches and a total length of $100 \text{ m} < \text{ges } L \leq 500 \text{ m}$	$\geq 6 \text{ h}$	$\geq 6 \text{ h}$	$\geq 3 \text{ h}$
	Pipes with or without branches and a total length of $\text{ges } L > 500 \text{ m}$	The respective piping system has to be tested in sections, the testing length of $L_p \leq 500 \text{ m}$ must be strictly adhered to <sup>1)</sup>		
Checks during the test	The test pressure and the temperature profile have to be recorded	$\geq 3$ checks (adjusting (increase) the pressure to the testing pressure again)	$\geq 2$ checks (no adjusting (increase) to the testing pressure)	$\geq 1$ check (keep the testing pressure constant)

Topic and explanation		Pre-test	Main-test	Short-test
Material specific decrease in pressure	Depends on the creep modul of the specific plastics material	PE ≤ 1.0 bar/h	PE ≤ 0.5 bar/h	For short term forces, no data regarding a decrease in pressure is available
		Usually used		Special case (acceptance of the operator or the principal is necessary)

#### Advice

<sup>1)</sup> In case the total length exceeds limit length more than 10% the described test conditions can be kept. Further advices please see <sup>2)</sup>

<sup>2)</sup> Limitation of test length is due to the reactions caused by change of test pressure and temperature. The bigger the test length is, the more difficult is classification and pressure tolerances. Testtemperature of 20 °C ± 5 °C can provide realizable results up to test length of > 500 m. Decision has to be made by the responsible person in charge.

### 8.1.4 Guidelines for pressure test of unburied piping systems

Prior to the pre-test, the air inside the pipe has to be removed. Therefore de-aeration points have to be set on the highest point of the pipe which have to be in open position when filling the pipe.

#### Filling of the pipe

The medium for filling is water.

The origin of the filling has to be the lowest point of the pipe. When setting the fill quantity per time unit it has to be considered that the air can escape safely at the de-aeration points.

If the pipeline has more than one lowest point, it may be necessary to fill the pipe in sections.

The time between filling and testing the pipe has to be long enough for the de-aeration (approximate time > 6 ... 12h; it depends on the dimension of the pipe).

At pipelines bigger than DN 150 which do not have a peak or just have a very low gradient it may be necessary to use a pipeline pig to remove the remaining air in the pipe.

Reference values for the filling rate are given in Table C.10

DN	V [l/s]
≤80	0.15
100	0.3
150	0.7
200	1.5
250	2.0
300	3.0
400	6.0
500	9.0

Table C.10: Reference values for filling the line

Applying the testing pressure

When applying the test pressure it has to be considered that the increase of the pressure does not causes any water hammers.

At pipelines which contain components with a smaller maximum operating pressure compared to the pipe, the maximum applicable test pressure has to be in accordance with the manufacturer.

Figure C.16 contains guide values Advice:

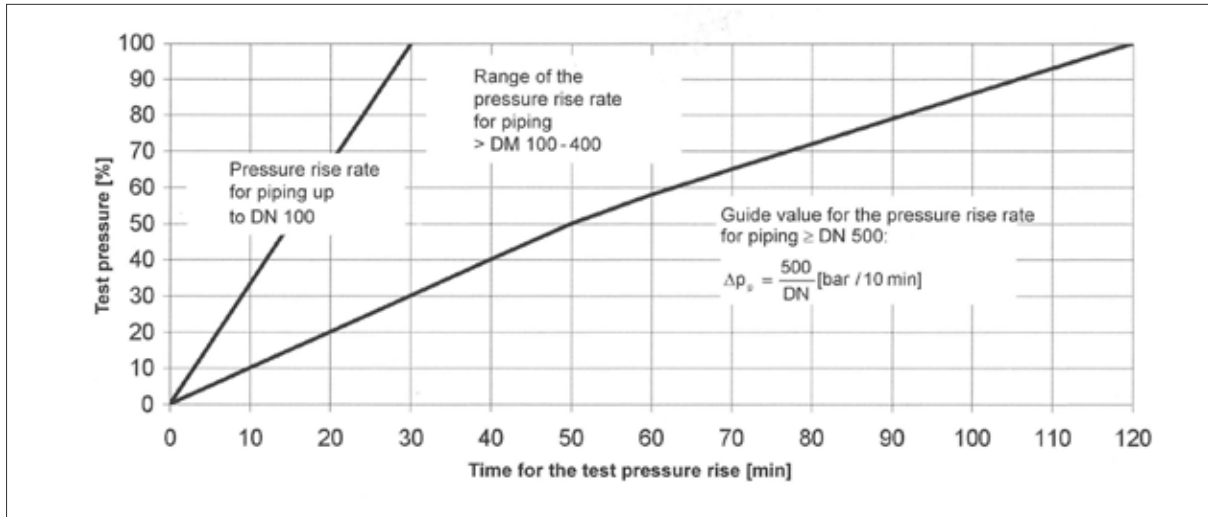


Figure C.16: Pressure increase time

## 8.1.5 Testing pressure and temperature

Evaluation of the testing pressure

The allowable testing pressure  $p_{P(zul)}$  is calculated according to the following formula:

$$p_{P(zul)} = \frac{1}{\frac{OD}{s}} \cdot \frac{20 \cdot \sigma_{v(T, 100h)}}{S_p \cdot A_G}$$

Od [mm] Outside Diameter

s [mm] wall thickness

$\sigma_{v(T, 100h)}$  [N/mm<sup>2</sup>] Reference stress for a wall temperature  $T_r$  at  $t = 100$  h

$S_p$  [1] Minimum safety distance to the creep strength

$A_G$  [1] Manufacturing and design specific factor which reduces the allowable

test pressure ( $AG \geq 1.0$ ).

For PE = 1 sufficient

da / s ~ SDR

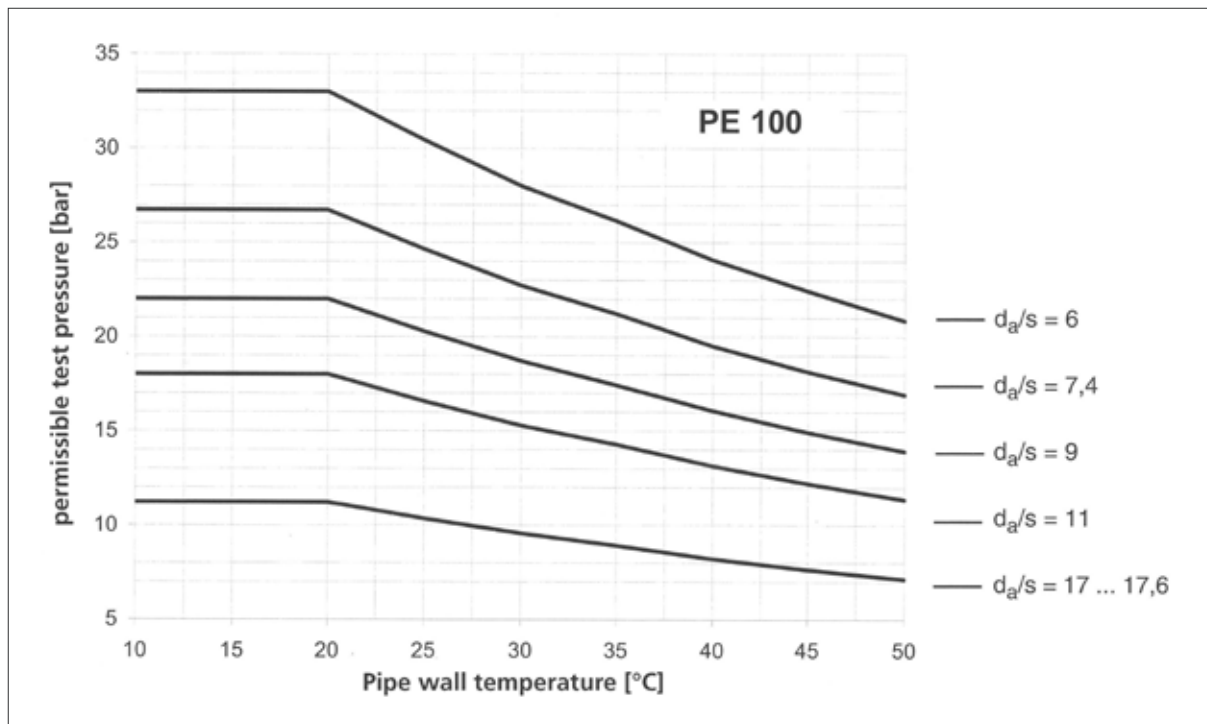
$p_B$  [bar] Operating pressure

Determining a bigger safety distance as stated in the following table is possible and depends on the user.

Material	PE
$S_p$	1,25

The allowable test pressure  $P_{P(zul)}$  depending on the wall temperature can be extracted from the following chart:





### 8.1.6 Test temperature

If it is assumed that the wall temperature changes within the test period the test pressure has to be adjusted according to the maximum expected temperature.

If the temperature check measurement on the pipe surface shows a higher temperature than expected the test pressure has to be adjusted immediately according to the chart or the calculation.

The wall temperature can be assumed as the arithmetic mean of  $T_i$  and  $T_{Ra}$ .

$$T_R = \frac{T_i + T_{Ra}}{2}$$

$T_i$	[°C]	Temperature of the medium inside the pipe
$T_{Ra}$	[°C]	Temperature on the surface of the pipe
$T_R$	[°C]	Average wall temperature

Beside the influence of the temperature on the test pressure especially for inside pressure test following the contraction method high attention has to be paid on constant pipe wall temperature, when testing open air installed pipelines it is difficult to keep the wall temperature constant which can influence the testing method. To keep the informational value of the test it is absolutely necessary to record the temperatures.

Is the average wall temperature supposed higher than calculated (or extracted from the table) due to direct sun radiation the test pressure has to be adjusted.

The measuring respectively the recording of the temperature in the inside of the pipeline (temperature of the test medium) demands the assembly of a gauge connection at the most disadvantageous point of the piping system. In case that it is ensured by proper arrangements, that the temperature of the pipe wall is never exceeding a pre-defined maximum value, it is not necessary to make the measurement of the medium temperature.

## 8.2 Guidelines for pressure test of buried water piping systems

Pressure test on the basis of EN 805 + ÖVGW W 101.

Each installed water pipeline has to be tested with a water pressure test to ensure the leak tightness of the pipeline and its components. As a test medium potable water should be used.

### 8.2.1 Filling and checking

The filling of the pipeline with clean water should be conducted with open air valves and adequate venting. Calibration of the testing equipment should be carried out, before the equipment is connected to the pipe and the pressure test is started. During the test all venting devices should be closed.

### 8.2.2 Preparation pressure test

To prevent the pipeline from moving, it should be covered with enough back-fill material before the pressure test. The joints may be left uncovered. The anchors and the bearings must verifiably withstand the forces caused by the test pressure. The test should be conducted either on the complete pipeline or in sections. When the pipeline is filled, the system test pressure (STP) must be reached at the lowest part of the pipeline. At the same time the system working pressure (MDP) must be reached at least at the highest point of each testing section. Before the pressure test the pipe has to be cleaned from any kind of contamination and has to be ventilated.

### 8.2.3 Minimising the temperature influence

High temperatures (or temperature fluctuation) on the pipe surface can lead to shorter lifetime or to false pressure test results.

To reduce the temperature influence following measures are recommended during the pressure test:

- The water for the pressure test should be as cold as possible
- The exposed areas of the pipeline should be covered (shaded) during the test to prevent the pipe from heating up

- Keep the pipe wall temperatures between 2 and 20 °C and control the temperature regularly. The pressure test should be performed during moderate outside temperatures (in summer e.g. early in the morning).
- If the temperature values cannot be kept below 20 °C, the test pressure STP can be lowered as an exception to the maximum operating pressure MDP after a consultation with the planning engineer. The test section of the pipe should be continuously horizontal.

### 8.2.4 Test pressure

The system test pressure (STP) can be calculated with following formula by taking the highest system working pressure MDP into account:

By considering the pressure surge:

$$STP = MDP_c + 100 \text{ kPa}$$

By not considering the pressure surge:

$$STP = MDP_a \cdot 1,5$$

or

$$STP = MDP_a + 500 \text{ kPa}$$

The lower of the two values is valid.

STP System testing pressure

MDP<sub>c</sub> Highest designed pressure by the planner/consultant including pressure surges

MDP<sub>a</sub> System pressure (DP) + minimum 200 kPa for pressure surge

The pressure surge should be calculated with appropriate basic equations and assumptions of the engineer (worst case).

The testing equipment should be connected to the pipeline at its the lowest part.

For the calculation of short pipe sections and branch lines ≤ DN 80 and shorter than 100 m, the operating pressure can be assumed as system working pressure, if not otherwise specified.

## 8.2.5 Types of pressure tests

The type of pressure test is determined depending on the type of the pipe and the material. The pressure test can consist of up to three parts:

- Pressure pre-test
- Integrated pressure loss test
- Main pressure test

## 8.2.6 Pressure pre-test

The pressure pre-test is carried out to avoid incorrect test results during the main pressure test. During the pre-test following steps are carried out:

- Relaxation phase (min. 1h) after the purging and venting of the pipeline. In the process the air must not get into the test sections.
- Continuous pressure increase (within 10 min) to the system test pressure (STP) and subsequent holding of the pressure by re-pumping (30 min). During that period the pipeline should be inspected for leakages.
- Wait the rest period (1h) without re-pressurising and measure the residual pressure. If the pressure drop is higher than 30% of the STP, then the pressure test has to be stopped to search for the cause of the failure. The rerun of the test is only possible 1h after relaxation phase at the earliest.
- When the pre-test is completed successfully, the main pressure test can be started.

## 8.2.7 Integrated pressure loss test

The pressure loss test is used to determine the residual air volume in the pipeline. It allows to improve the precision of the main pressure test. During the pressure loss test the following steps are performed:

- Rapid pressure reduction ( $\Delta p$ : 10 – 15% of STP) by draining the water
- Measuring the volume of the drained water
- Calculating the allowable loss of water  $\Delta V_{\max}$  according to the following equation:

$$\Delta V_{\max} = 1,2 \cdot V \cdot \Delta p \cdot \left( \frac{1}{E_w} + \frac{D}{e \cdot E_r} \right)$$

$\Delta V_{\max}$  allowable loss of water [l]

V volume test section [l]

$\Delta p$  measured pressure drop [kPa]

$E_w$  compressive modulus water [kPa]

D inner diameter of the pipe [m]

e wall thickness of the pipe [m]

$E_r$  E-modulus pipe wall in circumferential direction = 770 000 kPa

1,2 factor: allowable amount of air before the main pressure test

- Checking if  $\Delta V > \Delta V_{\max}$ . If  $\Delta V$  is higher, the pressure test has to be stopped and repeated after the relaxation phase.

## 8.2.8 Main pressure test

The integrated pressure loss test interrupts the viscoelastic expansion of the pipe and leads to a contraction of the pipeline.

The resulting pressure rise is monitored and recorded in the period of 30 minutes. If the pressure curve doesn't drop during the monitoring period, the main pressure test is considered as passed.

A drop of the pressure curve indicates a leakage in the pipeline.

When uncertainty exists, the test duration can be extended to 90 minutes. In doing so the pressure drop cannot exceed 25 kPa, otherwise the main pressure test is considered as failed.

The repeat of the main pressure test is only possible if the complete test process (+1h relaxation phase) is repeated.

## 8.3 Guidelines for pressure test of buried gas piping systems

Pressure tests on the basis of german DVGW G469 and austrian ÖVGW GE101 guidelines.

### 8.3.1 Pressure test conditions

The pressure test can be started only after the cooling time after the welding is reached. After the test pressure is applied the temperature of the test medium has to reach the temperature of the ground (setting time). To minimize the temperature influence of the environment on the pressure the pipes have to be buried. The connections between the pipes and the branch connections may not be buried, but must be covered during the pressure test.

The pressure medium is pressurised air. The test air temperature must not exceed >40 °C, otherwise the air has to be cooled down (e.g. air-conditioned room). The pressurised air comes from a compressor with a dryer and oil- and air-water separators

During the pressure test proper safety precautions have to be taken (danger signs, barriers).

### 8.3.2 Settling time

According to the ÖVGW GE101 / DVGW G469 guidelines the condition of stability is achieved after 1 – 2 hours per 1 bar test pressure (e.g. 9 bar test pressure: min. 9 – 18 hours settling time).

By experience the settling time is reached after:

Condition	Setting time
6 bar	min. 24 hours
15 bar	min. 3 days

Table C.11: Experience values for settling time.

The shown values are guide values and may vary, depending on the actual conditions (e.g. temperature) on site.

### 8.3.3 Test pressure

The test pressure should be minimum 1.5 x MOP, but at least 2 bar higher than the MOP (e.g. 6bar MOP: 9 bar test pressure, 1 bar MOP: 3 bar test pressure).

The pressure drop  $\Delta p$  is the difference between the pressure at the beginning and at the end of the pressure test. The pressure drop  $\Delta p$  must be smaller than the calculated allowable pressure drop  $\Delta p_{allow}$  ( $\Delta p \leq \Delta p_{allow}$ ). The maximum allowable pressure drop is calculated with the following formula.

$$\Delta p_{allow} = \frac{(\Delta V_{allow} \cdot t \cdot L) \cdot p_0}{V}$$

$\Delta p_{allow}$  allowable pressure drop [bar]

$p_0$  atmospheric pressure (1,013 bar)

$V$  tested pipeline volume [dm<sup>3</sup>]

$\Delta V_{allow}$  allowable volume change [dm<sup>3</sup>/km\*h]  
(acc. to ÖVWG GE 110: 10 dm<sup>3</sup>/(km\*h))

$t$  test duration [h]

$L$  pipeline length [km]

The pressure profile is measured by means of recording precision manometer in the pipeline.

### 8.3.4 Minimum test duration

The test duration depends on the pipe volume, the minimum values are mentioned in the table below.

Pipe volume V [dm <sup>3</sup> ]	Min. test duration [h]
≤ 1000	2
≤ 3000	4
≤ 6000	8
≤ 9000	12
≤ 12000	16
> 12000	24

Table C.12: Minimum test duration.

For the detection of the pressure change during the test, the length of the test sections must not exceed 18 km (OD pipe: ≤ 120 mm) or 11 km (OD pipe: > 120 mm).

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## 1 Transport / Handling / Storage

### 1.1 Pipes

During the transport of AGRU PE100 / PE 100-RC pipes, the cargo area of the vehicle should be clean and free from sharp objects such as nails, screws etc.

It is recommended to support the pipes along their entire length. The height of the pipe crates should not exceed 1 m (pipes > 1000 mm diameter have to be stored in bulk). Pipe coils should be stored in horizontal position if possible.

Pipe ends should not overhang for extended periods. When several pipe dimensions are transported on one vehicle, the smaller and lighter pipes should be placed on top.

Impacts on pipes should be avoided as much as possible. Contact with oils, greases, colours, petroleum etc. should be avoided. At temperatures around the freezing point the pipes must be handled carefully.

Pipes used for potable water should be protected from contamination during storage by capping the pipe ends.



During the unloading, care should be taken of not to drag the pipes over sharp edges. During the storage on site the pipes shouldn't be placed onto stones or sharp-edged objects.

For the PE-Xa pipes basically the same transport, handling and storage conditions are applied

According to the current ÖVGW and DVGW regulations, pipes and pipeline parts need to be checked for transport and storage damages before the positioning in the trench.

Pipes with grooves, scratches or areal abrasion of more than 10 % of the wall thickness cannot be installed.

Non-black PE pipes have a maximum UV-resistance of 2 years if exposed to direct sun irradiation (Central Europe).

### 1.2 Fittings

AGRU PE-fittings should be transported and stored only in the original packaging (protection against external influences).

When the fittings are palletised, the overhang should be avoided.



On site AGRU PE-fittings should be stored in a tent or a construction trailer. If the fittings are protected from moisture and stored in their original packaging (cartons with additional flexible package) an unlimited storage life can be expected.

Fittings are to be kept in original package until directly before the welding process to prevent contamination and damaging.

Seamless (sweep) bends have to be stored in a cool place without solar radiation. Otherwise a deviation in the angular dimension of the sweep bends is possible.

On request, sweep bends can be offered with angle fixations.



## 2 Installation

Installation methods	Standard	PE 100	Sureline® (PE 100-RC)	SurePEX (PE-Xa)	SureFIT® (PE 100)
Open laying with sandbed		x	x	x	
Open laying without sandbed			x	x	
Ploughing			x	x	
Milling			x	x	
Relining	EN ISO 11295	x	x	x	x
Burst lining			x <sup>1</sup>	x	
Horizontal directional drilling			x	x	
Soil displacement hammer			x	x	

Table D.1: Overview installation methods.

<sup>1</sup>For stony grounds Sureline® with protective layer is recommended

### 2.1 Bending radius

The flexibility of the pipe ensures that minor deviations due to structural conditions can be absorbed by the pipe without the use of fittings. Reference values for the minimum bending radius of SDR 11 and SDR 17 pipes are as follows:

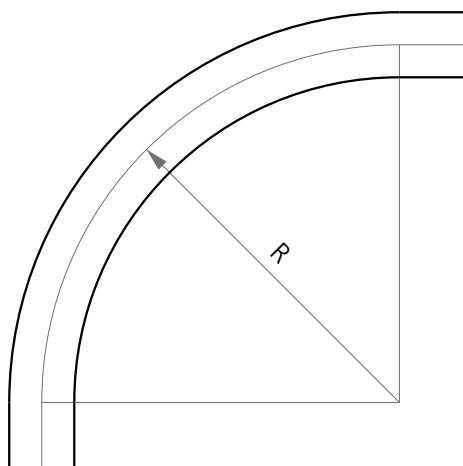


Figure D.1: Bending radius.

$$R = OD \cdot x$$

Formula D.1: Bending radius.

- R Bending radius [mm]
- OD Outer diameter of the pipe [mm]
- x Multiplication factor [1]

Installation temperature [°C]	Multiplication factor [x] Sureline I + Sureline II pipe		
	SDR 7,4-17	SDR 21-26	SDR 33-41
+30	20	30	50
+20	20	30	50
+10	35	52,5	87,5
0	50	75	125

Table D.2: Multiplication factor bending radius.

Installation temperature [°C]	Multiplication factor [x] Sureline III pipe with protective layer
	SDR 7,4-17
+30	30
+20	30
+10	50
0	75

Table D.3: Multiplication factor bending radius.

**Attention:** if fittings or flanges are installed in the bending area, a minimum bending radius of  $da \cdot x$  100 must not be exceeded.

## 2.2 Open trench installation

For the construction of pipe trenches and the installation of the pipes, corresponding national and regional regulations have to be taken into account.

Generally changes in direction are realised by means of fittings (e.g.: bends, elbows and tees) whereas the fittings and pipes are welded together (see chapter D). For big pipe dimensions the welding outside the trench has to be aimed in order to make work easier. For butt welding of big dimensions it is recommended to install the welding machine stationary and continue to pull the welded pipe sections after the welding.

For smaller pipes, which are laid along the trench or when using electrofusion welding, the welding machine can be transported to the welding spot. For cross-country installations a detection cable should be installed with the pipe in order to detect the pipeline easier in the future.

The following influencing factors on the installation technique and -depth have to be considered:

- Depth of frost or heat penetration (local conditions)
- Flow rate, pressure and temperature of the media in the pipeline
- Insulation of the pipeline
- Traffic and soil loads
- Soil type, soil moisture and the surface condition
- Crossing lines

**A structural analysis considering all influencing factors should be performed before each installation.**

**For this purpose acknowledged calculation guidelines (ATV-DVWK-A 127, AWWA M55) have to be used.**

### 2.2.1 Open trench installation with sand bed

The most established installation technique is currently the open trench installation with sand bed. For the installation the trench should be at least 40 cm wider than the pipe diameter. The trench depth should be excavated considering national standards. In doing so the crown of the pipe should be located underneath the depth of frost (especially important for water application). The trench bottom should be planar, stable and free of stones. A bedding layer of at least 10 cm (rocky ground: 15 cm) should be placed on the trench bottom. The pipeline should be lowered into the trench carefully. Additionally an all-side cover have to be created (at least 10 cm) to avoid scratches and point-loads.

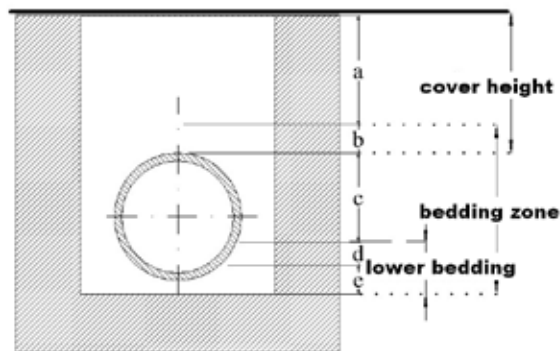


Figure D.2: Diagram of a trench

a. Backfill	excavated material may be reused
b. Cover	min. 10 cm around the pipe
c. Side bedding layer	
d. Upper bedding layer	
e. Lower bedding layer	

Table D.3: Guidelines bedding/backfill

### 2.2.1.1 Trench width

The trench width must be sufficiently wide to ensure a safe work and a professional installation of the pipeline. Trenches wider than 0.80 m have to be provided with covers (e.g. footbridge or walkway surface).

Guidelines for minimum trench width [mm] depending on the outside diameter (OD)			
OD[mm]	obstructed trench	unobstructed trench	
		$\beta^1 > 60^\circ$	$\beta^1 \leq 60^\circ$
$\leq 225$	OD + 400	OD + 400	
$> 225$ bis $\leq 355$	OD + 500	OD + 500	OD + 400
$> 355$ bis $\leq 710$	OD + 700	OD + 700	
depending on the trench depth			
depth [mm]		width [mm]	
$< 1000$		not specified	
$\geq 1000$ to $\leq 1750$		800	
$> 1750$ to $\leq 4000$		900	
$> 4000$		1000	

Table D.4: Guidelines for trench width (source: DIN EN 1610).

<sup>1)</sup> slope angle

### 2.2.1.2 Bedding material

The bedding material should be suitable for the particular pipeline, i.e. it must not cause corrosion, chemical or mechanical damage. A material is suitable for the bedding if it has sufficient compressibility (e.g. sand-gravel mixture). The bedding ensures that the surrounding soil absorbs the forces caused by internal pressure and external loads.

	DN	grain size [mm]	
		round	crushed
PE 100 pipe	$\leq 200$	0-22	0-11
	$> 200$	0-40	0-11
PE 100-RC pipe	$\leq 63$	0-22	
	$> 63$	0-100	

Table D.5: Guidelines for the mean grain size in the embedment (acc. to DVGW W 400-2 and ÖVGW/GRIS QS-W 405/1)

The cover should be at least 1 m higher than the crown of the pipe. The trench has to be back-filled directly after the installation to prevent damage on the pipeline. Unless specified otherwise (e.g. road-works) the excavated material can be reused as backfill.

Type of pipe	Depth of cover [m]
Water line	0.9 <sup>1)</sup> - 1.8 m
Gas line	0.6 <sup>1)</sup> - 1.3 m
Sewerage line	min. 2.0 m

Table D.6: Guidelines for the depth of cover (acc. to DVGW W 400-1)

<sup>1)</sup> In the agricultural areas a minimum depth of cover of 1.2 m is recommended.

## 2.2.2 Installation without sand bed

Soil characteristics as well as the pipe material are essential for the selection of the appropriate installation method.

In addition to the installation with a sand bed PE 100-RC pipes and fittings can be used for alternative installation techniques such as installation without sand bed or trenchless installation.

Installation without sand bed means that the excavated soil can be reused to refill the trench as long as the soil is compressible acc. to the current standards (e.g. ÖNORM B2538 and ÖNORM B5016). The requirements for the grain sizes in a sandbed-free installation are stated in the ÖNORM B 2538



Figure D.3: Diagram of a trench after a sandbed-free installation.

DN/OD $< 63$	up to 22 mm
DN/OD $\geq 63$	up to 100 mm

Table D.7: Guidelines for the grain size of the bedding material (acc. to ÖVGW/GRIS QS-W 405/1)

## 2.2.3 Calculation of buried piping systems

A stress and deformation proof according to ATV-DVWK-A 127, AWWA M55, has to be furnished for buried piping systems (e. g. drainage channels). But there can also serve other basis for calculation, or results of research projects.

There is a software program for the surcharge calculation according to ATV-DVWK-A 127 at disposal in our technical engineering department in order to furnish the demanded proof. Please fill in the following questionnaire as completely as possible. We will promptly prepare a corresponding statics after receipt of the questionnaire.

Comments to some points of the questionnaire.

- Generally:  
These general statements are necessary to enable an assignment of the different projects.
- Details for pipe:  
Pipe material (polyethylene or polypropylene) and pipe dimensions must be specified here.
- Soil / Installation:  
There are four different groups of soil.

Group		Specific gravity $\gamma_B$ [kN/m <sup>3</sup> ]	gravity of internal friction $\phi'$	Deformation modulus $E_B$ in [N/mm <sup>2</sup> ] at degree of compaction $D_{Pr}$ in %					
				$D_{Pr}$					
				85	90	92	95	97	100
G1	non-cohesive soils (e.g. sand, gravel-/sand-mixtures)	20	35	2,0	6	9	16	23	40
G2	slightly cohesive soils (e.g. silts / silty sand and gravel mixtures)	20	30	1,2	3	4	8	11	20
G3	cohesive mixed soils, coarse clay (e.g. silty sand and gravel, cohesive stony residual soil)	20	25	0,8	2	3	5	8	13
G4	cohesive soils (e.g. clay)	20	20	0,6	1,5	2	4	6	10

Table D.8: Information soil types.

The at the calculation applied deformation modulus of the soil has to be distinguished by the following zones:

- $E_1$  Surcharge above pipe summit
- $E_2$  Pipe (embedding) zone around the pipe (min. 10 cm)
- $E_3$  Native soil beside the pipe zone
- $E_4$  Native soil below the pipe

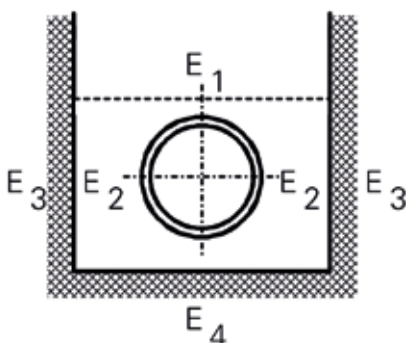


Figure D.4: Trench embedding condition

- Surcharge:  
The surcharge height is at the trench embedding condition the installation depth of the pipe (referring to the pipe summit) and at the dam embedding condition the waste surcharge.
- Operating conditions of the pipe:  
You only have to fill in the corresponding operating parameter for each application.

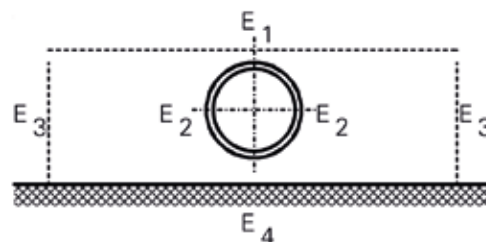


Figure D.5: Dam embedding condition

<b>1. Generally</b>	Project:	<input type="text"/>				
	Site:	<input type="text"/>				
	Principal:	<input type="text"/>				
<b>2. Details for pipe</b>	Pipe material:	<input type="text"/>	Pipe inside diameter:	<input type="text"/>	mm	
	Pipe outside diameter:	<input type="text"/>	mm	Wall thickness:	<input type="text"/>	mm
	Nominal width:	<input type="text"/>	mm			
<b>3. Soil</b>	Zone	E1	E2	E3	E4	
	Group	G (1,2,3,4)	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
	Specific gravity	[kN/m <sup>3</sup> ]	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
	Proctor density	[%]	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
	E-Modulus of the soil $E_b$	[N/mm <sup>2</sup> ]	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
<b>4. Installation</b>	Method of laying: Trench <input type="checkbox"/> Dam <input type="checkbox"/>					
	Cover height (installation depth) from pipe crown to finished floor	h= <input type="text"/>	mm	Trench width in pipe crown height	b= <input type="text"/>	[m]
				Gradient of slope	$\beta$ = <input type="text"/>	[°]
<b>5. Surcharge</b>	Traffic load: without <input type="checkbox"/> LKW12 <input type="checkbox"/> SLW30 <input type="checkbox"/> SLW60 <input type="checkbox"/>					
	Additional weight on surface	F= <input type="text"/>	[kN/m <sup>2</sup> ]			
	Minimum ground water level above pipe sole	<input type="text"/>	m			
	Maximum ground water level above pipe sole (m)	<input type="text"/>	m			
<b>6. Operating conditions of the pipe</b>	Operating temperature	T= <input type="text"/>	[°C]			
	Operating pressure short time (24h)	p= <input type="text"/>	[bar]			
	Operating pressure long time (50 years)	p= <input type="text"/>	[bar]			

## 2.3 Trenchless installation

### 2.3.1 Ploughing

Ploughing is very dependent on the given soil conditions. At the ploughing process, a pipe with a maximum diameter of OD 225 mm, is inserted into the ground by a plough or a ram. Due to the displacement of the soil the new pipe can be inserted in the same process. Depending on the outer diameter several pipelines can be installed at the same time.

The created hollow is closed again. This installation method can be used up to a maximum installation depth of ca. 2 m.

### 2.3.2 Milling

With this installation method, a milling machine digs a trench and installs the pipeline in one step. In general the filling of the trench is done right after the laying with the displaced earth. This installation technique can also be used for grounds which are hard to process.

The different soil conditions during the installation along the piping section have to be considered. Therefore the piping section should be inspected prior the installation and the choice of the material should be based on the findings.

### 2.3.3 Horizontal directional drilling

Horizontal directional drilling is a trenchless installation method where streets, rails, waters etc. are crossed underground. The installation of pipelines by means of horizontal directional drilling has 3 steps:

- **Primary drilling:**  
Beginning at the start pit, the driller is - under constant detection of the drilling head - drilling to the target pit. Due to the special geometry of the head as well as the drilling fluid at the drilling head it is possible to change direction.
- **Enlarging the drill hole:**  
For the enlarging of the drill hole the drilling head is replaced from the leverage in the target pit by a special widening-tool (back reamer). In reverse and rotating the back reamer is drawn back to the start pit.  
Depending on the pipe's dimension the process is repeated till the required drill hole diameter is reached.
- **Feeding the pipe:**  
The feeding in is done from the target to the start pit when widened the last time. An insertion head is mounted to the pipe. A transition piece prevents a rotation of the pipe. If requested, several pipes can be drawn in at once.

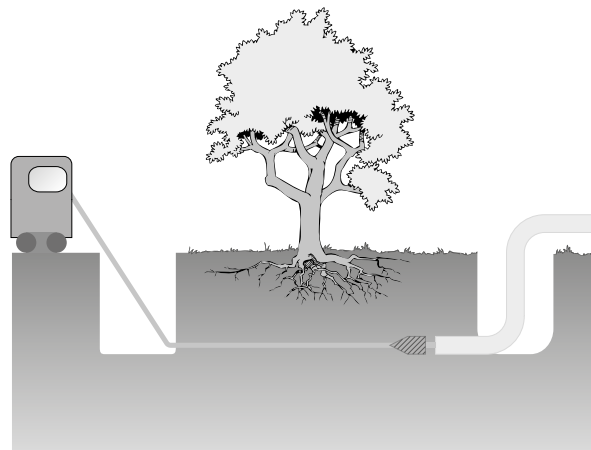


Figure D.6: Horizontal directional drilling.

### 2.3.4 Pipe bursting

With the burst lining method defect pipes can be replaced. With a bursting head the existing old pipe is demolished and displaced into the surrounding soil. The drill hole is enlarged till a new pipe with the same or a larger diameter fits into it. It is installed in the same work step.

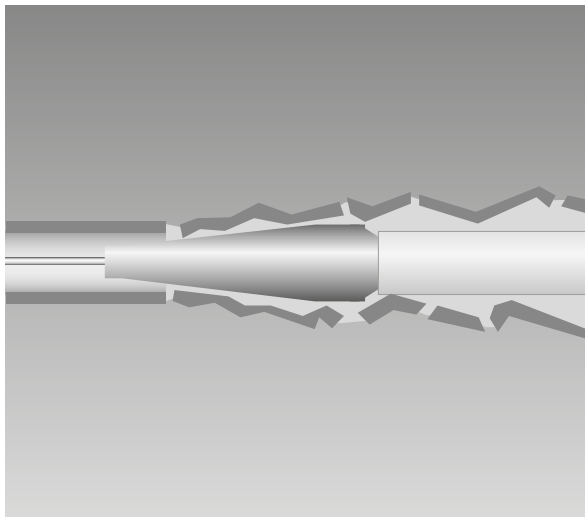


Figure D.7: Burst lining.

## 2.4 Above ground installation

Pipes and pipelines made of thermoplastic polymers have changes in length due to temperature fluctuation. The following requirements for the installation of pipelines have to be considered.

### 2.4.1 Pipe support, mounting

Mountings or pipe clips for PE pipeline systems made out of different materials are available. Steel pipe clips should be equipped with bands made of PE or elastomers in order to protect the plastic pipe at length expansions.

Make sure that the pipe clips supporting area is as wide as possible to avoid punctual loads. The diameter should be adjusted to the pipe's outer diameter.

AGRU plastic pipe clips and pipe supports are especially suitable for installation due to the aligned tolerances of mountings and pipes. These pipe clips also work as e.g. slide bearings or guide bearings at horizontally installed pipelines, take vertically directed forces and hinder the pipeline from buckling. Stick to the support distances and the maximum guiding distance to prevent buckling. The support distances can be enlarged for pipes smaller OD 63 mm if the pipeline is supported with steel half-shells.

### 2.4.2 Anchoring

Expansions and contractions in radial and axial direction must not be hindered when installed above ground; i.e. building radial slackness, creating compensation loops, controlled length expansion due to reasonable positioning of anchors.

In general valves (for certain applications tees too) should be used as anchors within the pipeline. Advantageous are valve constructions, where the mounting mechanism is integrated in the valve. Electro fusion couplers in pipelines can also be used as anchors.

## 2.5 Relining

There are two ways of relining:

- Relining with annular space (Slip-lining)
- Relining without annular space (Close-fit-lining)

### 2.5.1 Slip-lining

Standard PE pipes used for rehabilitation need to be smaller in diameter than the old pipe. On the one hand pipes with a length of several hundred metres can be used, e.g. coiled pipes. On the other hand singular pipes can be welded incrementally in the construction pit and afterwards be inserted into the old pipe.

Slip-lining leads to a reduction of the cross-section due to the annular space between new and old pipe. The reduced flow capacity can partially be compensated due to the good surface properties of PE. Nevertheless a capacity reduction has to be taken into account. The entire available dimension range of PE pipes (20 mm up to 2500 mm) can be used for slip-lining.

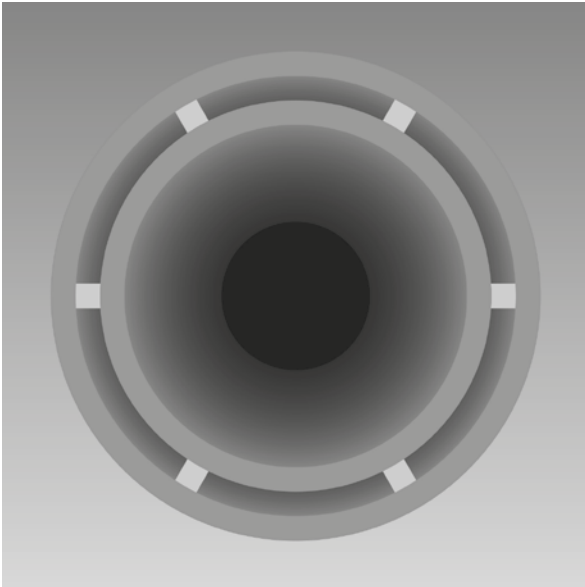


Figure D.8: Slip-lining.

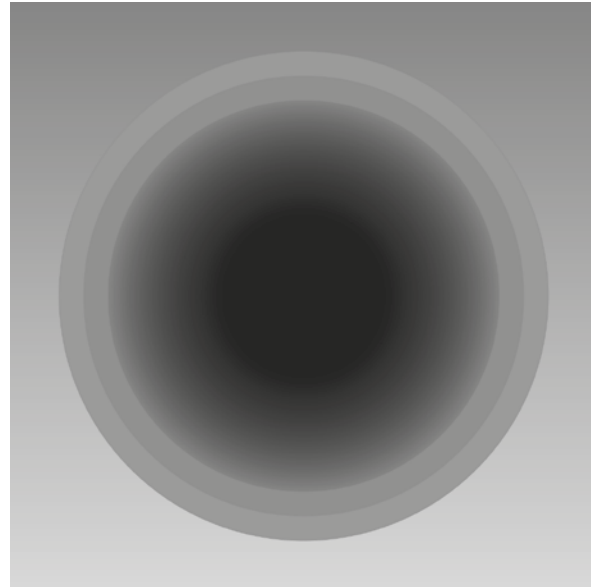


Figure D.10: SureFIT® after installation.

## 2.5.2 Close-fit-lining

During close-fit-lining - relining without annular space - a PE pipeline with reduced cross-section is inserted into the old pipe.



Figure D.9: SureFIT® during installation.

Once the pipe has been inserted into the existing old pipe, both ends are sealed. Then the pipe is heated up by using steam (water) and / or pressure.

This activates the memory effect. The treatment is continued until the pipe regains its original round shape and fits closely to the old pipe.

In the range of factory-preformed pipes AGRU offers the SureFIT® / r.tec® close-fit-liner - a tailor-made solution for diameters ranging between 150 mm and 400 mm. If bigger diameters are required, PE 100 pipes are used of which the cross-section will be reduced on site.

## 2.6 Soil displacement hammer

Soil displacement hammers are driven by pneumatics.

Conditions for the application are a start pit and a target pit or target spot. The hammer is adjusted in the start pit. Then the target is aimed at. After that the hammer is driven to the target by compressed air.

Basically there are two installation systems available:

- One-step-system:  
The complete soil displacement hammer with the attached pipe is driven to the target.
- Two-steps-system:  
The first step is to drive a multi-cutter-cone to the target. In a second and final step the pipe is then drawn in.  
This system is the more precise one.

In general there are two kinds of soil displacement hammers:

- uncontrolled hammers
- controlled hammers



## 2.6.1 Uncontrolled soil displacement hammer

Installation lengths: up to 40 m

Maximum dimension: DN 200

Maximum speed: 15 m/h

Location: target pit

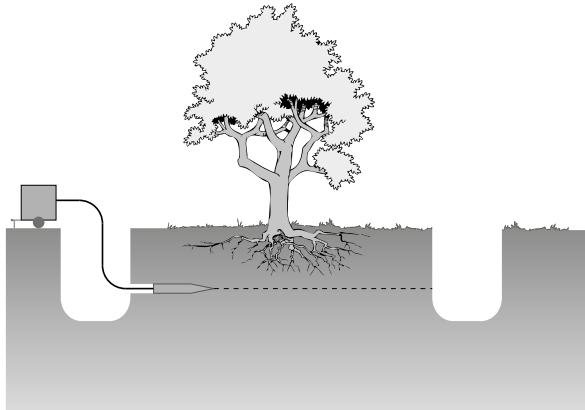


Figure D.11: Uncontrolled soil displacement hammer.

## 2.6.2 Controlled soil displacement hammer

Installation lengths: up to 70 m

Maximum dimension: DN 65

Maximum speed: 10 m/h

Minimum radius R: 27 m

Location: target pit or target spot

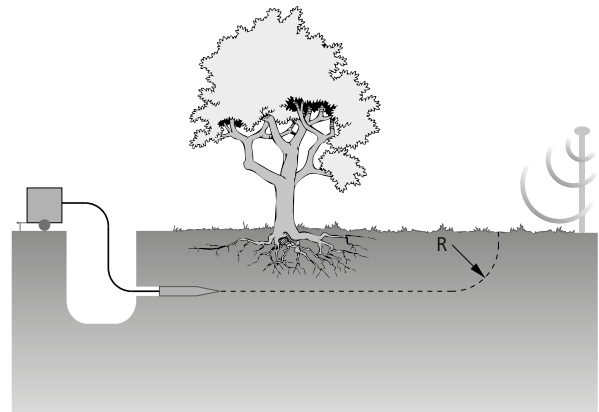


Figure D.12: Controlled soil displacement hammer.

Besides course corrections, the controlled soil displacement hammer holds another advantage. It can record the data of its course (pitches, side motions and depths information). These data can be transferred to a computer and be stored as a path-diagram.

## 3 Product-specific characteristics for relining

### 3.1 Specifics of PE 100

Slip-lining: suitable

### 3.2 Specifics of Sureline® (PE 100-RC)

Slip-lining: suitable

Close-fit-lining: suitable

Uncontrolled soil displacement hammer: suitable up to DN 200 mm

Controlled soil displacement hammer: not suitable

For trenchless installations certain tractive forces must not be exceeded. The following table is an indication of permissible forces for a duration of 30 min.

OD [mm]	Maximum permissible tractive forces [kN]			
	SDR 17		SDR 11	
	20 °C	40 °C	20 °C	40 °C
63	-	-	10	7,2
75	9,5	6,6	15	10
90	14	9,5	21	15
110	20	14	31	22
125	26	18	41	28
140	33	23	51	36
160	43	30	66	47
180	55	38	84	59
200	67	47	104	73
225	85	60	131	92
250	105	74	162	114
280	132	92	204	142
315	167	117	258	180
355	212	149	327	229
400	269	189	415	291
450	341	239	526	368
500	421	295	648	454
560	528	370	814	570
630	668	468	1030	721
710	849	594	1309	916

Table D.9: Tractive forces for Sureline®-pipes (Source: DVGW GW 320-1).

For drawing-in periods >30 min the values have to be reduced by 10 %.

For drawing-in periods >20 h the values have to be reduced by 25 %.

Due to the high elasticity and flexibility of the Sureline® pipe, changes in direction during the installation can be realised without the used of fittings. Nevertheless the minimum bending radii have to be considered (see chapter 2.1).

### 3.3 Specifics of SureFIT® (PE 100)

Slip-lining: not suitable

Close-fit-lining: suitable (from DN 150 mm to DN 400 mm)

### 3.4 Specifics of SurePEX (PE-Xa)

Slip-lining: suitable

Close-fit-lining: not suitable

Uncontrolled soil displacement hammer: suitable

Controlled soil displacement hammer: suitable

Due to the low creep modulus of PE-Xa, these pipes can be processed easier than PE 100 pipes. Low temperatures around the freezing point result in a decreased flexibility of the pipe material. Based on this fact it is recommended to store the coiled bundle in a heated hall or heated tent till the installation, in order to guarantee an easier decoiling of the bundle and an easier installation. Alternatively pipes can be warmed up by hot water or steam flowing through.

According to ÖVGW and DVGW regulations the squeezing off of PE-Xa pressure piping systems is acceptable. The squeezed area must have a minimum distance of  $5 \times OD$  to the next pipe connection / connector.

## 4 Machining

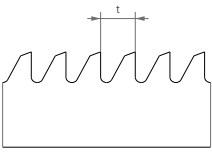
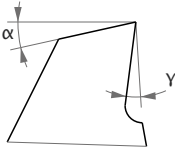
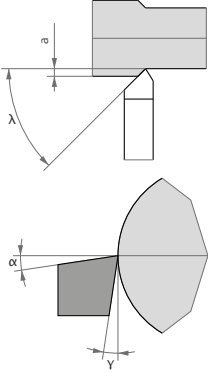
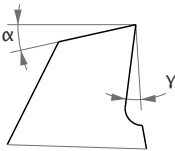
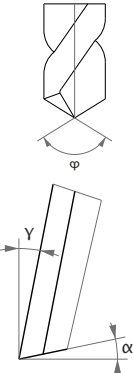
Cutting				
	Clearance angle $\alpha$ Rake angle $\gamma$ Pitch $t$ Cutting speed $v$	[°] [°] [mm] [m/min]	20 - 30 2 - 5 3 - 8 500	Band saws are appropriate for the cutting of pipes, blocks, thick sheets and round bars.
Cutting				
	Clearance angle $\alpha$ Rake angle $\gamma$ Pitch $t$ Cutting speed $v$	[°] [°] [mm] [m/min]	20 - 30 6 - 10 3 - 8 2000	Circular saws can be used for the cutting of pipes, blocks and sheets. Carbide tipped saws have a considerably longer working life.
Turning				
	Clearance angle $\alpha$ Rake angle $\gamma$ Tool angle $\lambda$ Cutting speed $v$ Feed $f$ Cutting depth $a$	[°] [°] [°] [m/min] [mm/min <sup>-1</sup> ] [mm]	6 - 10 0 - 5 45 - 60 250 - 500 0.1 - 0.5 > 0.5	The peak radius ( $r$ ) should be at least 0.5 mm. High surface quality is obtained by means of a cutting tool with a wide finishing blade. Cut-off: Sharpen turning tool like a knife.
Milling				
	Clearance angle $\alpha$ Rake angle $\gamma$ Cutting speed $v$ Feed $f$	[°] [°] [m/min] [mm/min <sup>-1</sup> ]	10 - 20 5 - 15 250 - 500 0.5	High surface quality is obtained by means of a milling machine with fewer blades - this increases cutting capacity.
Drilling				
	Clearance angle $\alpha$ Rake angle $\gamma$ Centre angle $\varphi$ Cutting speed $v$ Feed $f$ Spiral angle $\gamma_x$	[°] [°] [°] [m/min] [mm/min <sup>-1</sup> ] [°]	5 - 15 10 - 20 60 - 90 50 - 150 0.1 - 0.3 12 - 16	For holes with diameters of 40 mm - 150 mm, hollow drills should be used; for holes <40 mm diameter, use a normal high-speed-steel drill.

Table D.10: Parameter guidelines for machining processes.

The cutting speed, the conveying and the cutting geometry should be designed in a way that any subsequent heat can mainly be removed through the shavings (too much pre-heating can lead to melting and/or discolouration of the processed surface).

All usual metal and wood processing machines may be applied.

**Caution:** the usage of silicone grease or other lubricants, which can negatively affect the welding result is not permitted.

<b>1</b>	<b>Standards</b>	161
<b>2</b>	<b>Approvals / External quality control</b>	161



## 1 Standards

AGRU pipes and fittings are manufactured out of standardised moulding materials and produced according to relevant international standards.

A summary of the most important standards for PE is listed below.

- ÖNORM B 5014-1: Sensory and chemical requirements and testing of materials in contact with drinking water - Part 1: Organic materials.
- DIN 8074: Polyethylene (PE) - Pipes PE 63, PE 80, PE 100, HDPE - Dimensions.
- DIN 8075: Polyethylene (PE) pipes - PE 63, PE 80, PE 100, HDPE - General quality requirements, testing.
- DIN 16963 (part 1 - part 15): Pipe Joints and Elements for High Density Polyethylene (HDPE) Pressure Pipelines, Types 1 and 2.
- EN 1555 (part 1 - part 7): Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE).
- EN 12201 (part 1 - part 7): Plastics piping systems for water supply - Polyethylene (PE).
- ISO 1872-1: Plastics - Polyethylene (PE) moulding and extrusion materials.
- ISO 4065: Thermoplastics pipes - Universal wall thickness table.
- ISO 4427: Plastics piping systems - Polyethylene (PE) pipes and fittings for water supply.
- ISO 4437: Buried polyethylene (PE) pipes for the supply of gaseous fuels - Metric series - Specifications.
- ÖVGW QS-W 405 Part2 Polyethylene pipings systems PE 100-RC for the supply of drinking water - Part 2 - pipes
- ÖVGW QS-G 392 (Part1-4): Polyethylene pipings systems PE 80, PE 100 and PE 100-RC for the supply of gaseous fuels
- ÖVGW QS-W 406 (Part1-3): Polyethylene (PE 40, PE 80 und PE 100) pipesystems for the supply of drinking water - Part 1 - pipes
- GRIS GV 19: Spezielle Gütevorschrift für Kanalrohre und Formstücke aus Polyethylen (PE) für den Siedlungswasserbau
- GRIS GV 20: Spezielle Gütevorschrift für Kanal-Druckrohre und Formstücke aus Polyethylen  
PE 100-RC für nicht konventionelle Verlegungstechniken im Siedlungswasserbau

- PAS 1075: Pipes made from Polyethylene for alternative installation techniques
- DVGW W 400/1: Technische Regel Wasserverteilungsanlagen (TRWV) - Teil 1: Planung
- ASTM D2513: Standard Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings
- ASTM D3261: Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing
- ASTM F1055: Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing

## 2 Approvals / External quality control

Additionally to the internal controls, regular tests on products and internal procedures are performed by independently accredited test institutes.

External control is one element of product approvals in several application ranges and countries, where the modalities of the external control are regulated in registration and approval certificates.

Currently the following institutes are commissioned for production control:

- IIP Milano (Italy)
- TGM Vienna (Austria)
- TÜV Süd (Southern Germany)
- Certigaz

The high quality standard of our products is documented by a series of approvals and certification for gas and water supply in following countries:

Country	Approval	Natural gas	Potable water	Sewage
Algeria	Sonelgaz	×		
Australia	Watermark		×	
Austria	ÖVGW	×	×	
	GRIS			×
Belgium	BELGAQUA		×	
	Electrabel	×		
Europe	EN 12201		×	×
	EN 1555	×		
France	Gaz de France	×		
Germany	DVGW	×	×	
	Dibt		×	×
Great Britain & Northern Ireland	WRAS		×	
Italy	IIP - UNI	×	×	
New Zealand	Watermark		×	
Poland	Install	×	×	
Russia	DIN Gost TÜV	×	×	
	GasCert	×		
Switzerland	SVGW	×	×	

Table E.1: Overview approvals.

**FM approved 218 psi and 250 psi** PE pipes and fittings (OD 63 - 630 mm) according to FM class 1613 "Plastic pipes and fittings for underground fire protection service".



**DNV approval** for the use of pipes/fittings made of PE 100 / PE 100-RC in systems for water and sea water.



## Piping Systems

AGRULINE | INDUSTRIE | PURAD



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## Concrete Protection

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