General properties of PE

As result of continuous development of PE molding materials, the efficiency of PE pipes and fittings have been improved considerably. This fact has been taken into account by the introduction of new international standards (ISO 9080, EN1555, EN12201), which lead to higher permissible operating pressures.

Polyethylene (PE) is no longer classified by its density (for example PE-LD, PE-MD, PE-HD) as it is now divided into MRS-strength classes (MRS = **M**inimum **R**equired **S**trength).

In comparison to other thermoplastics PE shows an excellent diffusion resistance and has therefore been applied for the safe transport of gases for many years.

Other essential advantages of this material are the UV-stability (if is black coloured), and the flexibility of the molding material ("flexible piping system").

Physiological non-toxic

With respect to its composition polyethylene complies with the relevant food stuff regulations (according to OENORM B 5014, Part 1, BGA, KTW guidelines).
PE pipes and fittings are verified and registered regarding potable water suitability according DVGW guideline W270.

Behaviour at radiation strain

Pipes out of polyethylene may be applied across the range of high energy radiation. Pipes out of PE are well established for drainage of radioactive sewage water from laboratories and as cooling water piping systems for the nuclear energy industry.
The usual radioactive sewage waters contain beta and gamma rays. PE piping systems do not become radioactive, even after many years of use.
Also in environment of higher radio activity, pipes out of PE are not damaged if they are not exposed during their complete operation time to a larger, regularly spread radiation dose of $< 10^4$ Gray.

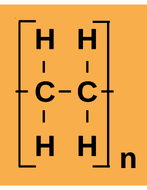
Advantages of PE

- UV-resistance
- flexibility
- low specific weight of 0,95g/cm^3
- favourable transportation (e. g. coils)
- very good chemical resistance
- weathering resistance
- radiation resistance
- good weldability
- very good abrasion resistance
- no deposits and no overgrowth possible
  due to less frictional resistance less pressure
- losses in comparison with e. g. metals
- freeze resistance
- resistant to rodents
- resistant to all kinds of microbic corrosion

Polyethylene type PE 100

These materials can also be described as polyethylene types of the third generation (PE-3) resp. also as MRS 10 materials.
This is a further development of the PE materials which shows by a modified polymerisation process an amended mol mass distribution. Therefore PE 100 types have a higher density and by this improved mechanical properties comes a raised stiffness and hardness. Also the creep pressure and the resistance against rapid crack propagation are also increased.
Consequently, this material is suitable for the production of pressure pipes with larger diameters. In comparison to usual pressure pipes out of PE with less wall thicknesses the corresponding pressure rating will be achieved.

Chemical structure of polyethylene



General properties of PE-Xa:

SurePEX-pipes have following properties:

- high resistance against scratches and grooves
- high resistance against puncture loads
- high resistance against slow crack growth
- no rapid crack propagation
- high resistance against abrasion
- high notched impact strength at extreme low temperatures
- high flexibility at low temperatures
- useable up to 95 °C working temperature
- high memory effect

Due to this special material properties we have following practical advantages during installation:

SurePex pipes are suitable for trenchless installation and renovation e.g.

ploughing
milling
horizontal drilling
relining
burstlining

and also for application with coild pipes.

- installation without sandbedding possible
- special for areas with high ground settlements
- very high operating safety

Because of this SurePEX pipes can be installed in areas where a very high safety is required for underground installation of gas and water pipelines.

Material:
The resin PE-Xa occurs through the peroxide crosslinking from polyethylene at high pressure. At this the individual molecules of the polyethylene are connecting to a three-dimensional network. This crosslinking process ensures that also thick-walled pipes have a constant crosslinking over the whole circumference.
After the crosslinking the SurePEX-PE-Xa pipes are no more a thermoplastic material.
The resin is now not fusible and connect the good properties of thermoplastic materials together with elastomer materials. Due to this properties this material would also referred as thermoelastic.

Material properties of PE-Xa:

High resistance against slow crack growth
At pipes out of non crosslinked thermoplastic material it is possible that puncture loads from outside e.g. stones, stress concentration and elongation at the pipe inside occurs.
Because of this tensile stress at the inside of the pipe, the outer fiber starts to elongate and a stress crack starts from the inside to the outside - the stress crack went through the complete wall thickness till the medium discharge and pipes are damaged. So called stress corrosion cracking.

Through to the crosslinking of the molecular chain PE-Xa has a much better resistance against the generation of stress cracks in comparison to pipes out of PE 80 and PE 100.
This property enables the sandbeedfree installation of SurePEX PE-Xa pipes.

Resistance against scratches and grooves
During the installation of pipes underground and possibly during the later operation of the system, notches could occur on the pipe surface.
In the course of the operating time of the pipes, these notches could grow under mechanical loading, maybe by internal pressure or earth loading. The depth and grow speed of the notches are decisive for the life expectancy of the piping system.

Resistance against slow crack growth
PE-Xa has an essential higher resistance against scratches and slow crack growth than pipes out of standard HDPE.
Via long term pressure tests it is proved that a notch in the nominal wall thickness up to 20% the minimum test duration according to DIN 16892 will be fulfilled by the SurePEX pipes.

In the FNCT (Full Notch Creep Test), a Tensile Creep Test with notched specimens in a watersolution with 2% agent at a temperature of 95 °C and a constant load of 4 N/mm² the SurePEX pipes reach test durations of >6000 hours.
Pipes out of crosslinked polyethylene are special suitable for trenchless installation methods where damages at the surface can not be avoided during the installation process.

Rapid crack propagation
As rapid crack propagation (RCP) is designated the incline of plastics pipes under certain conditions of temperature and pressure, a brittle crack can propagate in the pipe wall at a high speed and grow to a long length.

Resistance at low temperature
A pipe out of PE-Xa shows also at temperatures down to -50°C and pressure up to 16bar no indication for rapid crack propagation.
It is not possible that air in a not fully deaerated piping system out of SurePEX create a rapid crack propagation.
Pipes out of SurePEX are designed specially for pipe networks with high operating pressure.

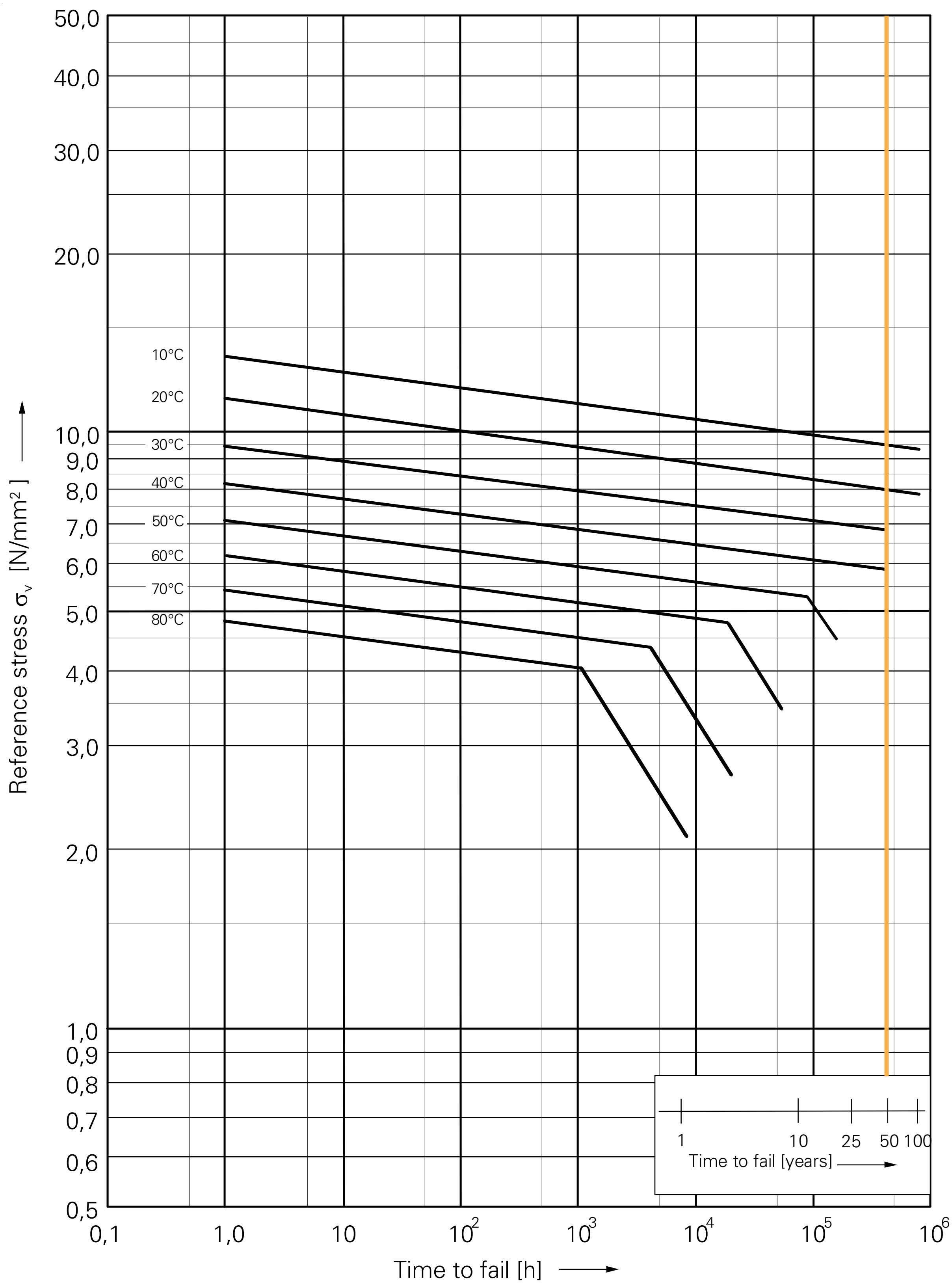
Memory effect
Pipes out of SurePEX PE-Xa have an excellent behaviour for reset.
This property is called Memory-Effect and has a positiv effect for mechanical joints.

Specific material properties PE

	Property	Standard	Unit	PE80 (MD)	PE80 (HD)	PE100	PE-Xa
	Specific density at 23°C	ISO 1183	g/cm^3	0,94	0,95	0,95	0,94
	Melt flow index	ISO 1133	g/10min				n. a.
	MFR 190/5			0,9	0,50	0,3	
	MFR 190/2,16					<0,1	
	MFR 230/5						
	MFI range	ISO1872/1873		T012	T006	T003	
Mechanical Properties	Tensile stress at yield	ISO 527	MPa	20	22	25	19-26
Mechanical Properties	Elongation at yield	ISO 527	%	10	9	9	16-20
Mechanical Properties	Elongation at break	ISO 527	%	>600	>600	>600	350-550
Mechanical Properties	Impact strength unnotched at +23°C	ISO 179	kJ/m^2	no break	no break	no break	no break
Mechanical Properties	Impact strength unnotched at -30°C	ISO 179	kJ/m^2	no break	no break	no break	no break
Mechanical Properties	Impact strength notched at +23°C	ISO 179	kJ/m^2	12	12	16	
Mechanical Properties	Impact strength notched at 0°C	ISO 179	kJ/m^2				
Mechanical Properties	Impact strength notched at -30°C	ISO 179	kJ/m^2	4,5	4,5	6	k.A.
Mechanical Properties	Ball indentation hardness acc. Rockwell	ISO 2039-1	MPa	36	42	46	k.A.
Mechanical Properties	Flexural strength (3,5% flexural stress)	ISO 178	MPa	18	21	24	20
Mechanical Properties	Modulus of elasticity	ISO 527	MPa	750	950	1100	600
Thermal Properties	Vicat-Softening point VST/B/50	ISO 306	°C	63	72	77	133
Thermal Properties	Heat deflection temperature HDT/B	ISO 75	°C	60	70	75	k.A.
Thermal Properties	Linear coefficient of thermal expansion	DIN 53752	$K^{-1} \times 10^{-4}$	1,8	1,8	1,8	1,4
Thermal Properties	Thermal conductivity at 20 °C	DIN 52612	W/(mxK)	0,4	0,4	0,4	0,35
Thermal Properties	Flammability	UL94 DIN 4102	--	94-HB B2	94-HB B2	94-HB B2	94-HB B2
Electrical Properties	Specific volume resistance	VDE 0303	OHM cm	$>10^{16}$	$>10^{16}$	$>10^{16}$	$>10^{15}$
Electrical Properties	Specific surface resistance	VDE 0303	OHM	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{12}$
Electrical Properties	relative dielectric constant at 1 MHz	DIN 53483	--	2,3	2,3	2,3	2,3
Electrical Properties	Dielectric strength	VDE 0303	kV/mm	70	70	70	60-90
	Physiologically non-toxic	EEC 90/128	--	Yes	Yes	Yes	n. a.
	FDA	--	--	Yes	Yes	Yes	n. a.
	UV stabilized	--	--	carbon black	carbon black	carbon black	yes
	Colour	--	--	black	black	black	yellow / blue
	MRS - Classification	ISO 9080	N/mm²	8	8	10	8 (9,5)

Note: The mentioned values are recommended values for the particular material.

Pressure curve for pipes out of PE80



Permissible component operating pressures (p_B) for PE 80 depending on temperature and operation period

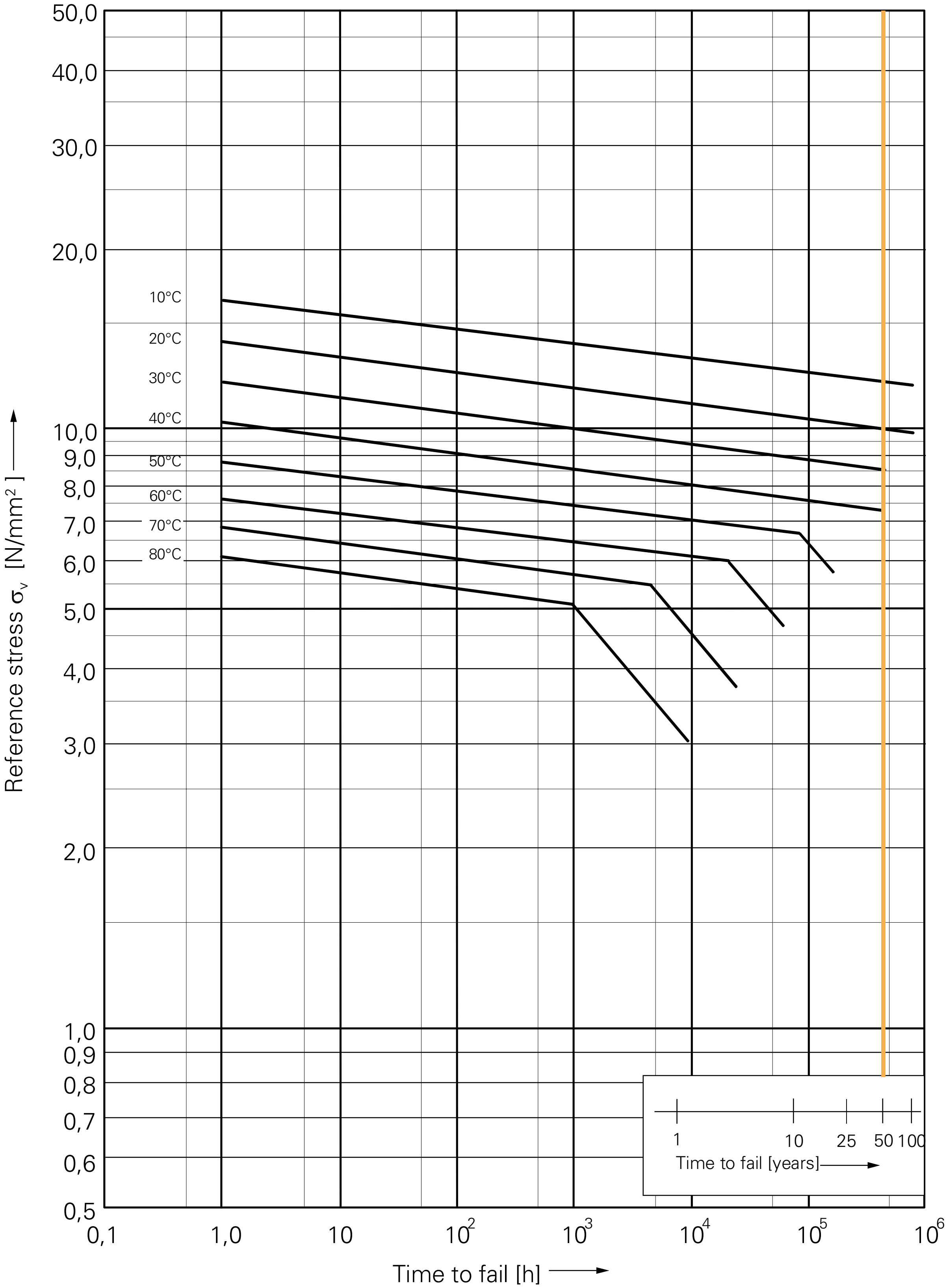
The table states the data apply to water*. They were determined from the creep curve taking into account a safety coefficient of C=1,25.

Temperature [°C]	Operating period [years]	Diameter-wall thickness relation SDR 17,6	17	11	7,4
		Pipe series S 8,3	8	5	3,2
		permissible component operating pressure PFA [1] [bar]			
10	5	9,4	10,1	15,8	25,3
	10	9,3	9,9	15,5	24,8
	25	9,0	9,7	15,1	24,2
	50	8,9	9,5	14,8	23,8
	100	8,7	9,3	14,6	23,3
20	5	7,9	8,5	13,2	21,2
	10	7,8	8,3	13,0	20,8
	25	7,6	8,1	12,7	20,3
	50	7,5	8,0	12,5	20,0
	100	7,3	7,8	12,2	19,6
30	5	6,7	7,2	11,2	18,0
	10	6,6	7,0	11,0	17,7
	25	6,4	6,9	10,8	17,3
	50	6,3	6,7	10,6	16,9
40	5	5,8	6,2	9,6	15,5
	10	5,7	6,0	9,5	15,2
	25	5,5	5,9	9,2	14,8
	50	5,4	5,8	9,1	14,5
50	5	5,0	5,3	8,4	13,4
	10	4,8	5,1	8,1	12,9
	15	4,3	4,5	7,1	11,4
60	5	3,3	3,6	5,6	9,0
70	2	2,6	2,7	4,3	6,9

[1] We recommend for the calculation of the operating pressure in piping systems to multiply the in the table contained operating pressure with a system reduction coefficient fs = 0,8 (This value contains installation-technical influences such as welding joint, flange or also bending loads).

* The table with the working pressure for the media gas you will find in the ON EN 1555 part 1.

Pressure curve for pipes out of PE100



Permissible component operating pressures (p_B) for PE 100 depending on temperature and operation period

The tables state the data apply to water. They were determined from the creep curve taking into account a safety coefficient of C =1,25.

Temperature [°C]	Operating period [years]	Diameter-wall thickness relation SDR 17	11	7,4
		Pipe series S 8	5	3,2
		PN 10	16	25
		permissible component operating pressure (PFA) [1] [bar]		
10	5	12,6	20,2	31,5
	10	12,4	19,8	31,0
	25	12,1	19,3	30,2
	50	11,9	19,0	29,7
	100	11,6	18,7	29,2
20	5	10,6	16,9	26,5
	10	10,4	16,6	26,0
	25	10,1	16,2	25,4
	50	10,0	16,0	25,0
	100	9,8	15,7	24,5
30	5	9,0	14,4	22,5
	10	8,8	14,1	22,1
	25	8,6	13,8	21,6
	50	8,4	13,5	21,2
40	5	7,7	12,3	19,3
	10	7,6	12,1	19,0
	25	7,4	11,8	18,5
	50	7,2	11,6	18,2
50	5	6,7	10,7	16,7
	10	6,5	10,4	16,2
	15	5,9	9,5	14,8
60	5	4,8	7,7	12,1
70	2	3,9	6,2	9,8

[1] We recommend for the calculation of the operating pressure in piping systems to multiply the in the table contained operating pressure with a system reduction coefficient fs=0,8 (This value contains installation-technical influences such as welding joint, flange or also bending loads.).

* The table with the working pressure for the media gas you will find in the ON EN 1555 part 1.

According to the EN 12201 part 1 there are following reduction factors for the nominal pressure rate depending on the operating temperature.

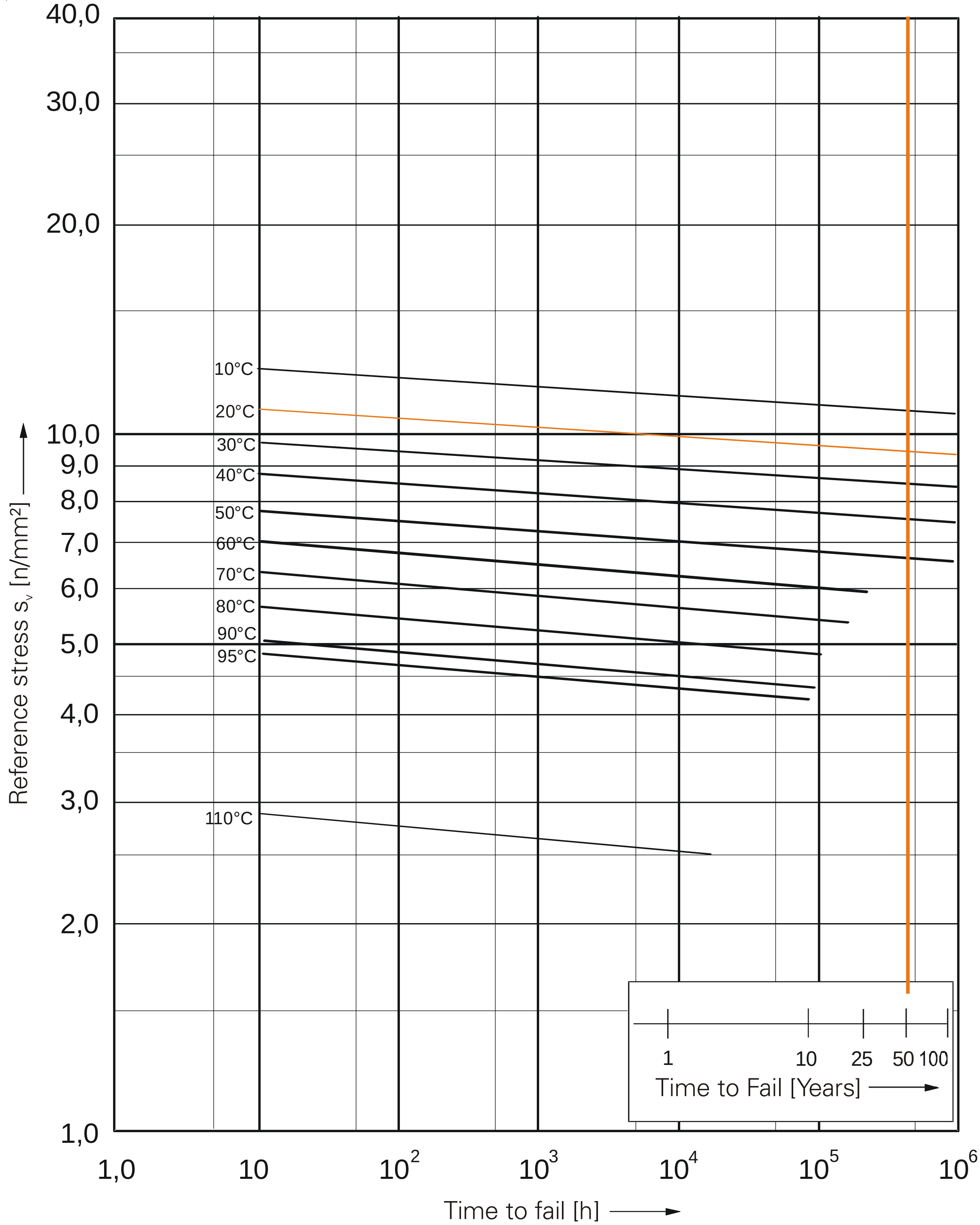
Operating temperature	Reduction coefficient
20°C	1,00
30°C	0,87
40°C	0,74

For pipes and fittings out of PE 100, a smaller wall thickness than for standard PE results due to the higher calculation stress. They can therefore be applied for higher operating pressures at the same wall thickness. Please find the comparison of the SDR-serie, S-serie and PN-pressure ratings in the below listed table.

SDR	S	PN-pressure rate PE80	PE100
41	20	3,2	4
33	16	4	5
26	12,5	5	6,3
17,6	8,3	7,5	9,6
17	8	8	10
11	5	12,5	16
7,4	3,2	20	25

Valid for 20°C and 50 years life time C=1,25

Pressure curve for pipes out of PE-Xa DIN 16892



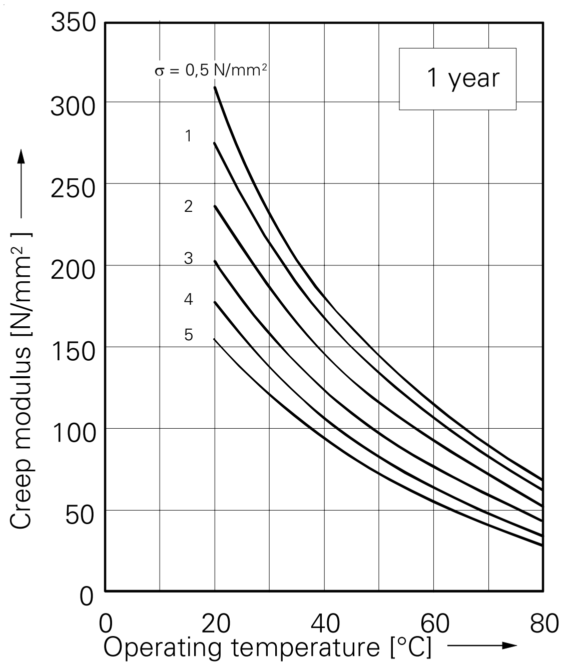
Permissible component operating pressures (p_B) for PE-Xa depending on temperature and operation period according DIN 16892

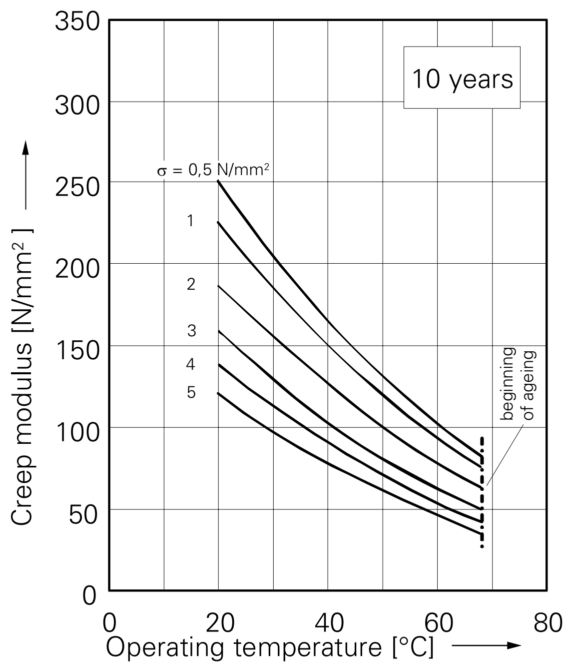
The tables state the data apply to water. They were determined from the creep curve taking into account a safety coefficient of C =1,25.

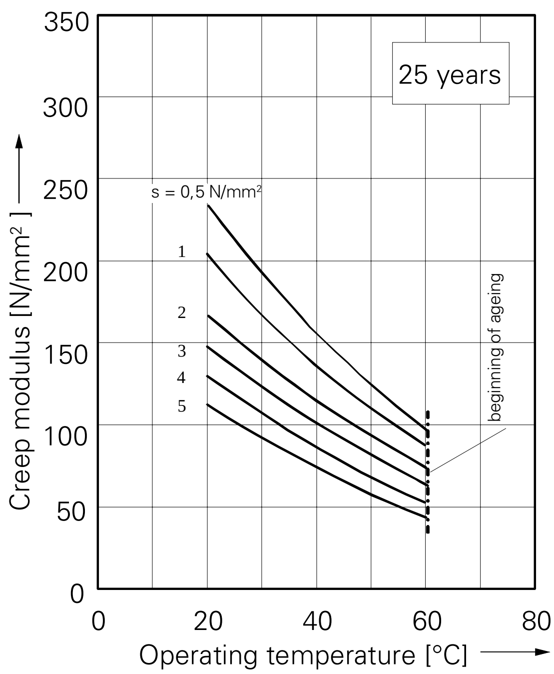
Temperature [°C]	Operating period [years]	Diameter-wall thickness relation SDR 11 / Pipe series S 5 / permissible component operating pressure [bar] [2]
10	1	17,9
	5	17,5
	10	17,5
	25	17,2
	50	17,1
	100	17,0
20	1	15,8
	5	15,5
	10	15,4
	25	15,2
	50	15,1
	100	15,0
30	1	14,0
	5	13,8
	10	13,7
	25	13,5
	50	13,4
	100	13,3
40	1	12,5
	5	12,2
	10	12,1
	25	12,0
	50	11,9
	100	11,8
50	1	11,1
	5	10,9
	10	10,8
	25	10,7
	50	10,6
	100	10,5
60	1	9,9
	5	9,7
	10	9,7
	25	9,5
	50	9,5
70	1	8,9
	5	8,7
	10	8,6
	25	8,5
	50	8,5
80	1	8,0
	5	7,8
	10	7,7
	25	7,6
90	1	7,2
	5	7,0
	10	6,9
	(15) [1]	(6,9) [1]
95	1	6,8
	5	6,6
	(10) [1]	(6,6) [1]

[1] The values in the bracket aim as confirmation from long term tests for 1 year at 110°C
[2] The calculation is done to the second decimal place, the second place is not rounded but cancelled

Creep modulus curves for PE 80 (acc.to DVS 2205, part 1)







Reducing of the creep modulus

In the stated diagrams the calculated creep modulus still has to be reduced by a safety coefficient of ≥ 2 for stability calculations.
Influences by chemical attack or by eccentricity and unroundness have to be taken into account separately.

Creep modulus curve for PE 100

As no valid creep modulus curves are availabel for PE 100 at the moment, we recommend to raise the from the diagrams for PE 80 determined creep modulus values by 10 %.

Permissible buckling pressures for PE 80 and PE 100

In the table stated the data apply to water. They were determined taken into account a safety coefficient of 2,0 (minimum safety coefficient for stability calculations).

Temperature [°C]	Operation period [years]	SDR-series 17.6 / S-series 8.3 / PN 6 — Permissible buckling pressure 1) [bar] PE80	SDR-series 11 / S-series 5 / PN 10 — Permissible buckling pressure 1) [bar] PE80
20	1	0,60	2,75
	10	0,47	2,20
	25	0,43	1,95
30	1	0,47	2,20
	10	0,39	1,80
	25	0,35	1,65
40	1	0,37	1,70
	10	0,32	1,50
	25	0,29	1,35
50	1	0,29	1,35
	10	0,25	1,15
	25	0,23	1,10
60	1	0,23	1,05
	10	-	-
	25	-	-
70	1	0,18	0,80

1) ...This buckling pressures have been calculated according to formula on page 23. These buckling pressures have to be decreased by the corresponding reducing factors due to chemical influence or unroundness for any application.

Material Properties
Installation Guidelines
Calculation Guidelines
Connection Systems
Applications and References
Approvals and Standards

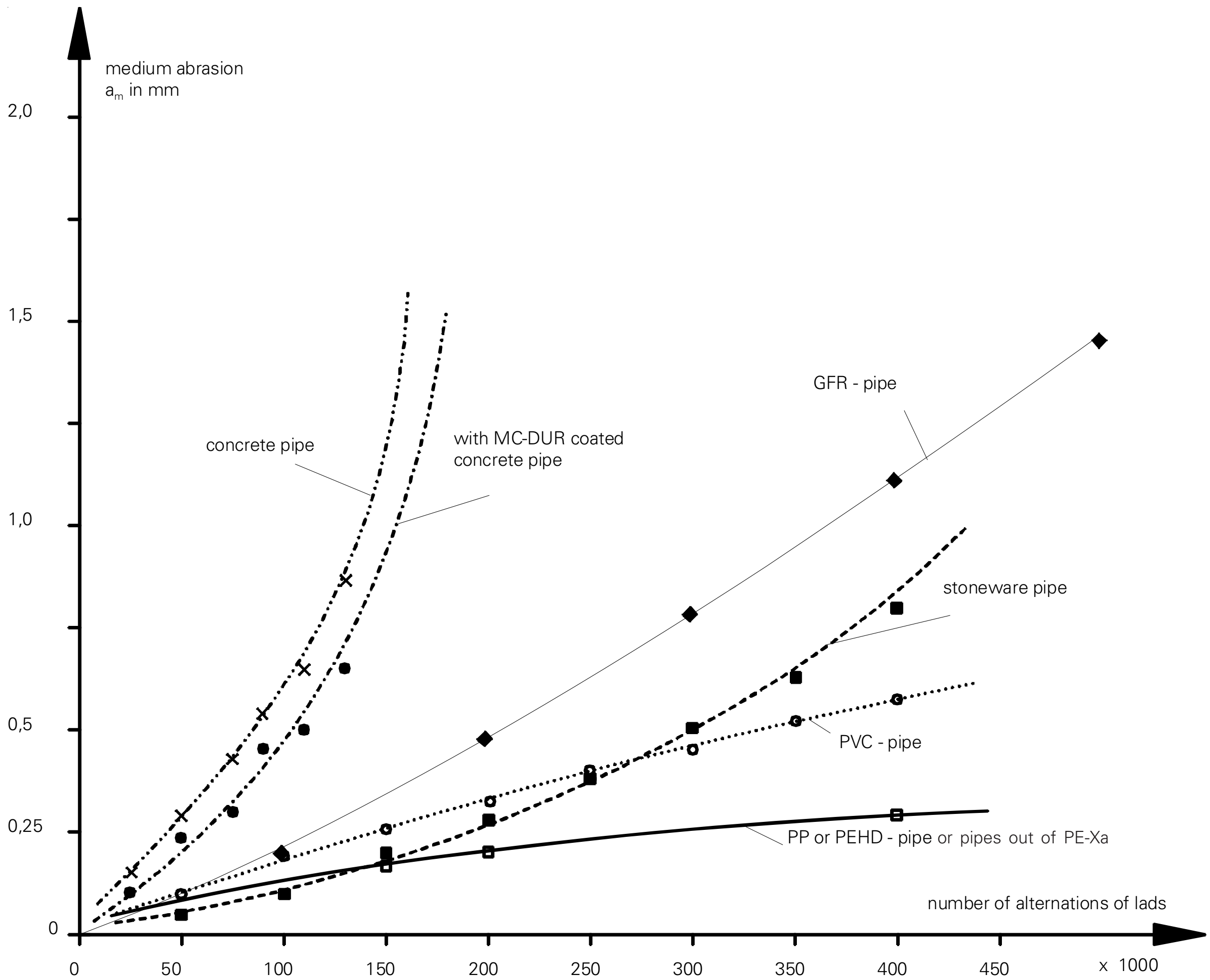
Behaviour at abrasive fluids

In principle, thermoplastic pipes are better suited for the conveying of fluid-solid-mixtures than e. g. concrete pipes or also steel pipes. We have already resulted positive experiences of different applications.
At the developed method of the Technical University Darmstadt a 1 m long half-pipe is tilted with a frequency of 0,18 Hz. The local deduction of the wall thickness after a certain loading time is regarded as measure for the abrasion.
The advantage of thermoplastic pipes for the transportation of solids in open channels can clearly be seen from the test result.

The fittings are not recommended for use in installations where water velocities could exceed >15 ft/s (4,6m/sec.)

Abrasion behavior according to method Darmstadt

Medium: silica sand-gravel-water-mixture 46 Vol.-% silica sand/gravel, grain size up to 30 mm



Source: Technical University of Darmstadt

General chemical properties of PE

In comparison to metals where an attack of chemicals leads to an irreversible chemical change of the material, it's mostly physical processes at plastics which reduce the utility value. Such physical changes are e.g. swelling and solution processes at which the composition of the plastics can be changed in this way that the mechanical properties are affected. There have to be taken reducing factors into consideration at the design of facilities and parts of those in such cases.

PE is resistant against diluted solutions of salts, acids and alkalis if these are not strong oxidizing agents. Good resistance is also given against many solvents, such as alcohols, esters and ketones.
At contact with solvents, as aliphatic and aromatic compound, chlorinated hydroxycarbon, you have to reckon upon a strong swelling, especially at raised temperatures. But a destruction commences only rarely.
The resistance can be strongly reduced by stress cracking corrosion due to ampholytiocs (chromic acid, concentrated sulphuric acid).

Lyes

Alkalis

Diluted alkali solutions (e. g. caustic lye), even at higher temperature and with higher concentrations do not react with PE and can therefore be applied without problems.

Bleaching lye

As these lyes contain active chlorine, only a conditional resistance is given at room temperature.
At higher temperatures and concentrations of the active chlorine,
PE are rather only suitable for pressureless piping systems.

Hydrocarbons

PE is resistant against hydrocarbons (benzine as well as other fuels) already at ambient temperature (swelling > 3 %) for the conveying up to temperatures of 40°C and for the storage of these media up to temperatures of 60°C.
Only at temperatures > 60°C PE is conditonally resistant as the swelling is > 3 %.

Acids

Sulphuric Acid

Concentrations up to approximately 70% change the properties of PE only slightly. Concentrations higher than 80 % cause already at room temperature oxidation.

Hydrochloric acid, hydrofluoric acid

Against concentrated hydrochloric acid and hydrofluoric acid, PE is chemically resistant.
But there appears a diffusion of HCl (concentrations > 20 %) and of HF (concentrations > 40 %), which does not damage the material, but causes secondary damages on the surrounding steel constructions.
Double containment piping systems have proven for such applications.

Nitric acid

Higher concentrated nitric acid has an oxidizing effect on the materials. The mechanical strength properties are reduced at higher concentrations.

Phosphoric acid

Against this medium, PE is also resistant at higher concentrations and at raised temperatures.

However the fittings should not be used in location where there is constant spillage or, by soil analysis, presence of aromatic hydrocarbons, including gasoline.

For more detailed information regarding the chemical resistance of our products, our application engineering department will be at your disposal at any time.

Transport

During transport of AGRU-PE pipes, care must be taken to support the pipes over their full length. At sub zero temperatures the pipes must be handled carefully and any sudden impact should be avoided. Contact with oils, greases, colours, petroleum etc. should be avoided.

All transport vehicles should ensure that floors are free of sharp objects such as nails, screws etc.

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

Handling

During offloading care should be taken not to drag pipes over sharp edges and they should not be placed onto rough ground.

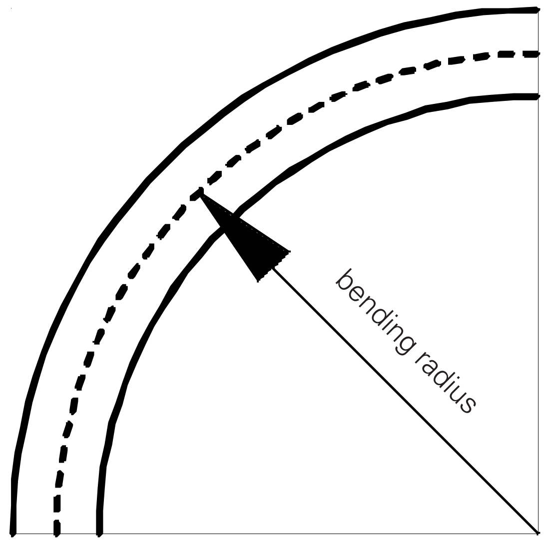
The maximum recommended storage height is 1,0 m and the pipes should be secured to avoid bundles splitting open. Coils should be stored in the horizontal position if possible.

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

Installation guidelines - Piping systems below ground

For trench excavation and pipe installation the local regulations should be adhered to. On rocky or stony ground the pipe should be placed on a 15 cm minimum sand bed.

The flexibility of the pipe ensures that minor devitations in the excavated trench can be taken up by the pipe without the use of fittings. Reference values for the minimum bending radius are as follows:



Installation temperature +20°C: minimum bending radius 20 x outside diameter

Installation temperature +10°C: minimum bending radius 35 x outside diameter

Installation temperature + 5°C: minimum bending radius 50 x outside diameter

Generally bends, elbows and tees are used for changes in direction; the fittings and pipes are welded together (see welding instructions).

It is recommended when welding large diameter pipes, that a stationary welding unit be set up at the top of the trench.The pipe should then be pulled forward after each welding process. For small diameter pipes the welding machine can be moved to each joint.

In the open field, a detection cable should be installed so that the pipeline can easily be detected at a later date.

For final static verification proven calculation processes (OENORM B 5012, ATV 127, prEN 1295) have to be adhered to.

The following guidelines are valid for installation:
Water DIN 2000
Gas G 260 / I / II - PN 4

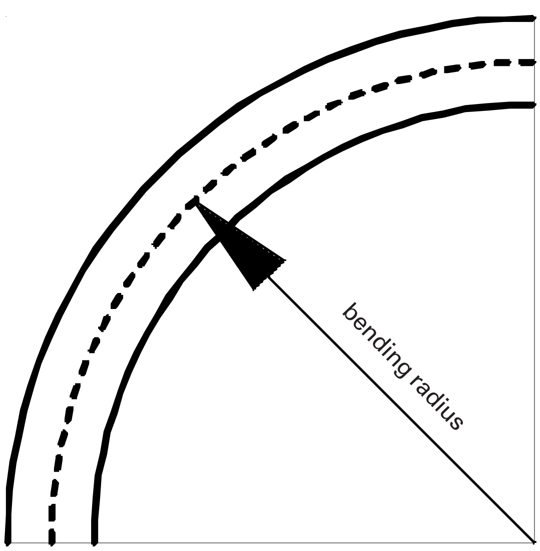
Installation guidelines for SurePEX-pipes

Coloured marking
Depending on the intended use the pipes out of PE-Xa are coloured blue for drinking water and yellow for gas.

Transport, handling and storage
For SurePEX piping systems the same transport, handling and storage conditions as for standard PE 80 or PE 100 piping systems are valid.
According to valid OVGW or DVGW regulations all pipes and fittings must be controlled onto visual damages before installation into the trench.
It is not allowed to install pipes with crooves or scratches or other extensive abrasion of greater then 20% of the nominal wall thickness.

Flexibility
Although pipes from PE-Xa can be processed due to the smaller E-module more easily than pipes from PE 80 or PE 100 the reduction of the flexibility at low temperatures entails that the pipes cannot be handled or installed at shifting temperatures around the freezing point any longer so easily. Before installation a temporary storage of the bundled coil in a heated facility or a heated tent during for some hours is recommended. Alternatively also a heating up of the pipes can take place by conveying warm air or steam.

Bending radius
The high flexibility of the pipes whether rods or bundled coils enables a simple and fast installation. So smaller obstacles can be gone around by bending the pipes and changes of direction in the ditch are possible, without insertion of fittings. With pipes from SUREPEX PE-Xa smaller bending radius are possible compared to pipes out of PE-HD. Here the minimum bending radius dependent on the pipe temperature to be considered according to the following table:



Bending radius

Installation temperature +20°C:
min. bending radius 10 x outside diameter

Installation temperature +10°C:
min. bending radius 15 x outside diameter

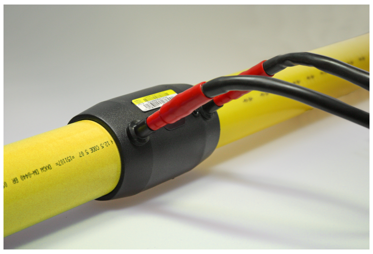
Installation temperature +0°C:
min. bending radius 20 x outside diameter

Squeeze off method
According to the valid OVGW or DVGW regulations it is possible to use the squeeze off method for the repair and / or connection of PE-Xa pressure pipes.

Squeezed zones should be 5 x OD away from joints and 6 x OD away from other squeezed zones.

Installation
The basic requirements according to OVGW or DVGW should be considered before installation. During the trench installation of drinking water or gas pipes out of SUREPEX a special bedding is not necessary.

Connection method
SurePex pipes are weldable with AGRU electro fusion fittings according to the AGRU installation guidelines. A connection by means of heating element butt welding is not allowed.



Also mechanical connection with all standard clamp connection, screw joint and push fit fittings are possible.

For the installation with other connection methods take notice of the guidelines of the fitting producer.

Installation guidelines for Sureline®II-pipes

Allowed tensile force

With the trenchless installation (e.g. horizontal hydraulic boring method) certain tensile forces need not be exceeded. The table below contains a survey of the allowed tensile forces (calculated with 10 N/mm²).

Outside diameter	maximum allowed tensile force [kN] for Sureline®II-pipes at wall thickness temperature of 20 °C ***(40 °C)***			
da /OD [mm]	SDR 17 [kN]		SDR 11 [kN]	
110	–	**–**	31	***22***
125	–	**–**	41	***29***
140	–	**–**	51	***36***
160	44	***31***	66	***46***
180	56	***39***	83	***59***
200	69	***48***	103	***73***
225	88	***62***	131	***92***
250	109	***76***	162	***114***
280	136	***95***	203	***143***
315	173	***121***	257	***180***
355	219	***153***	327	***229***
400	279	***195***	415	***291***

If the introduction time is >10 h [>20 h] these values have to be reduced by 10 % [25 %].

Installation method

Bending radius

Due to the high elasticity and flexibility of Sureline®II-pipes changes of direction can be taken. The minimum bending radius have to be considered as listed in the table below.

With the use of the flexibility of Sureline®II-pipes essential economic advantages could be achieved with the reduction of necessary fittings in comparison to piping systems out of traditional materials. The chart below shows a survey of minimum bending radius.

bending radius r [m]			
da / OD	bei + 20 °C	bei + 10 °C	bei 0 °C
	20 x da	35 x da	50 x da
110	2,2	3,9	5,5
125	2,5	4,4	6,3
140	2,8	4,9	7,0
160	3,2	5,6	8,0
180	3,6	6,3	9,0
200	4,0	7,0	10,0
225	4,5	7,9	11,3
250	5,0	8,8	12,5
280	5,6	9,8	14,0
315	6,3	11,0	15,8
355	7,1	12,4	17,8
400	8,0	14,0	20,0

The installation technology

Sureline®II-pipes can be connected together by means of E-socket fusion res. heating element butt fusion or with other PE pipes res. fittings as far as these correspond to the requirements acc. to DVS, WIS and also JIS. The weldability with all E-fusion fittings out of PE 100 and PE 80 available on the market is given.

The fusion of Sureline®II-pipes is performed acc. to DVS, WIS and also JIS. Generally at all pipes out of PE 100 we would recommend the use of rotation peeling devices for the fusion preparation.
Extensive works for additional isolation because of corrosion protection are not necessary because pipe and fitting are out of the same material. A homogeneous tight connection is the result and no additional sliding protection is needed. The colored signal layer of the Sureline®II-pipe is an integrated element which need not be removed before welding.

Electro fusion welding

Heating element Butt welding

The exact welding regulation you will find in the section "Connection Systems" page 34 - 58.

Piping systems above ground

Installation guidelines

Due to the lower stiffness and rigidity as well as to the enormous length expansions (caused by changes in temperature) of thermoplastics in comparison with metallic materials the following requirements for the fixing of piping components should be met.

Fixing by means of pipe clips

Supports made of steel or of thermoplastics are available for PE piping systems. Steel clips have at any rate to be lined with tapes made of PE or elastomers, otherwise the surface of the plastic pipe may be damaged.

AGRU plastics pipe clips as well as pipe holders are very suitable for installation. These may be commonly applied and have been especially adjusted to the tolerances of the plastics pipes.

Therefore they serve as a sliding bearing for horizontal installed piping systems in order to take up vertical stresses. A further application range of the AGRU pipe clip is the function of a guiding bearing which should hinder a lateral buckling of the piping system as it can also absorb tranversal stresses.

It is recommended for smaller pipe diameters (< OD 63mm), to use steel half-round pipes as support of the piping system in order to enlarge the support distances.

Installation temperature

A minimum installation temperatur of >0°C is to observe.

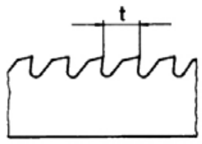
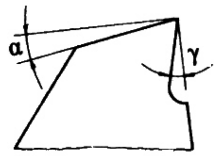
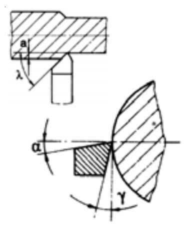
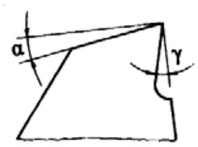
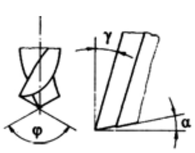
- On laying of pipes above ground expansion and contractions of pipes in both radial and axial directions must not be hindered - that means, installation with radial clearance, precision of compensation facilities, control of changes in length by reasonable arrangement of fixed points.

- Attachments have to be calculated so as to avoid pin-point stresses, that means the bearing areas have to be as wide as possible and adapted to the outside diameter (if possible, the enclosing angle has to be chosen > 90°).

- The quality of the surfaces of the attachments should help avoid mechanical damage to the pipe surface.

- Valves (in certain cases also tees) should basically be installed on a piping system as fixed points Valve constructions with the attachment devices being integrated within the valve body are most advantageous.

Machining of PE
(valid for cutting, turning, milling and drilling)

	**Cutting** Clearance angle α Rake angle γ Pitch t Cutting speed	 [°] [°] [mm] [m/min]	 30 ÷ 40 0 ÷ 5 3 ÷ 5 upto 3000	Band saws are appropriate for the cutting of pipes, blocks, thick sheets and for round bars
	**Cutting** Clearance angle α Rake angle γ Pitch t Cutting speed	 [°] [°] [mm] [m/min]	 10 ÷ 15 0 ÷ 15 3 ÷ 5 upto 3000	Circular saws can be used for the cutting of pipes, blocks and sheets. HM saws have a considerably longer working life
	**Turning** Clearance angle α Rake angle γ Tool angle λ Cutting speed Feed Cutting depth a	 [°] [°] [°] [m/min] [mm/rotation] [mm]	 5 ÷ 15 0 ÷ 15 45 ÷ 60 200 ÷ 500 0,1 ÷ 0,5 upto 8	The peak radius (r) should be at least 0,5mm. 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 α Rake angle γ Cutting speed Feed	 [°] [°] [m/min] [mm/rotation]	 5 ÷ 15 upto 10 upto 1000 0,2 ÷ 0,5	High surface quality is obtained by means of a milling machine with fewer blade - this increases cutting capacity.
	**Drilling** Clearance angle α Rake angle γ Centre angle φ Cutting speed Feed	 [°] [°] [°] [m/min] [mm/rotation.]	 12 ÷ 16 3 ÷ 5 approx. 100 50 ÷ 100 0,1 ÷ 0,3	Spiral angles 12 - 15°. For holes with diameters of 40 - 150mm, hollow drills should be used; for holes < 40mm diameter, use a normal SS-twist drill.

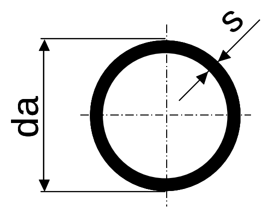
The cutting speed, conveying and cutting geometry should be designed in a way that any subsequent heat can mainly be removed through the shavings (too much pre-heating can lead to melting resp. discolouration of the processed surface).

All usual metal and wood processing machines may be applied.

System of units

Size	Technical system of units	SI - unit (MKS-system) Legal unit	ASTM - unit
Length	m	m 1m = 10dm = 100cm = 1000mm 1000m = 1km	ft 1,609km(statute) = 1Meile = 1,852km (naut.) = 1Mile 0,9144m = 1yd = 3ft 25,4mm = 1 inch
Area	m^2	m^2 $1m^2 = 100dm^2 = 10000cm^2$	yd^2 $0m836m^2 = 1yd$ $1yd^2 = 9ft^2$
Volume	m^3	m^3 $1m^3 = 10^3 dm^3 = 10^6 cm^3$	yd^3 $0,765m^3 = 1yd^3$ $1yd^3 = 27ft^3$
Force	kp 1N = 0,102kp 1kp = 9,81N	N $1N = 1kgm/s^2 = 10^5$ dyn	lb 1lbf = 4,447N = 32poundals
Pressure	kp/m^2 $1N/cm^2 = 0,102kp/cm^2$ 0,1bar = 1mWS 1bar = 750Torr 1bar = 750 mmHg 1bar = 0,99atm	bar $1bar = 10^5 Pa = 0,1N/mm^2$ $10^6 Pa = 1MPa = 1N/mm^2$	psi 1bar = 14,5psi = 14,5lb/sq in
Mechanical stress	kp/mm^2 $1N/mm^2 = 0,102kp/mm^2$	N/mm^2	psi $1N/mm^2 = 145,04psi$ = 145,04lb/sq in
Velocity	m/s	m/s	ft/sec. 1m/s = 3,2808ft/sec.
Density	g/cm^3	g/cm^3	psi $1g/cm^3 = 14,22x10^{-3}psi$
Volume	m^3	m^3	cu ft $1m^3 = 35,3147$ cu ft = 1,3080 cu yd $1cm^3 = 0,061$ cu in
Temperature	°C	°C 1°C = 1K	°F °F = 1,8 x °C + 32

SDR - Standard Dimension Ratio



Example:
da = 110 mm
s = 10 mm

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

$$SDR = \frac{da}{s} = \frac{110}{10} = 11$$

SDR ... Diameter - wall thickness relation
da ... outside diameter [mm]
s ... wall thickness

S - series

Example:
SDR11

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

$$S = \frac{SDR - 1}{2} = \frac{11 - 1}{2} = 5$$

SDR ...Diameter - wall thickness relation

Component operating pressure

Example:
PE 100, 20°C, 50 years, wather (d.h. σ_V=10)
SDR11
Cmin=1,25

$$p_B = \frac{20 \cdot \sigma_v}{(SDR - 1) \cdot C_{min}}$$

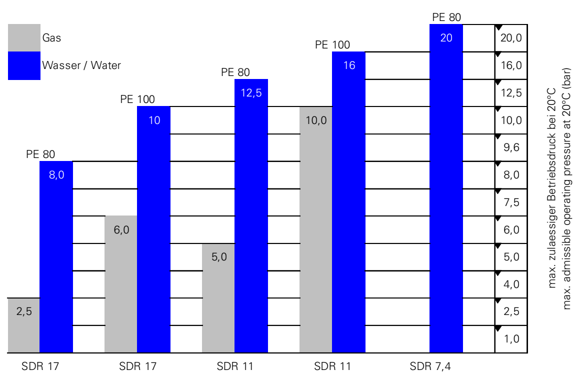
$$p_B = \frac{20 \cdot \sigma_v}{(SDR - 1) \cdot C_{min}} = \frac{20 \cdot 10}{(11 - 1) \cdot 1{,}25} = 16$$

p_B ... Component operating pressure [bar]
σ_v ... Reference strength [N/mm²]
(see the pressure curve for each material)
SDR ... Standard Dimension Ratio
C_{min} ... Minimum safety factor
(see following table)

Material	Temperature		
	10 to 40°C	40 to 60°C	over 60°C
PE 80	1,25 for water / 2,0 for gas		
PE 100	1,25 for water / 2,0 for gas		

Operating pressure depending on the media

On the accompanying chart the interrelationship between SDR-value, medium (gas or water) and nominal pressure is shown.



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Calculation of the permissible wall thickness s_{min}

The vessel formula is applied for the calculation of the pipe wall thickness. The permissible tension for the calculation of the pipe wall thickness for water and non-dangerous fluids at a temperature of 20°C and 50 years lifetime is 8 N/mm^2 for pipes and fittings made of PE 80 and 10 N/mm^2 for PE 100.
For dangerous fluids, the permissble tension has to be decreased by the corresponding reducing factors.

$$s_{\min} = \frac{p \cdot da}{20 \cdot \sigma_{zul} + p}$$

$$\sigma_{zul} = \frac{\sigma_v}{C_{\min}}$$

$s_{\min}$	....	Minimum wall thickness	[mm]
p	....	Operating pressure	[bar]
da	....	Pipe outside diameter	[mm]
σ_{zul}	...	Reference stress	[N/mm^2]
σ_v	...	Reference stress	[N/mm^2]
$C_{\min}$	...	Minimum safety factor (see page 21)	

If necessary, the reference stress σ_v and. the operating pressure p can also be calculted from this formula.

$$\sigma_{zul} = \frac{p \cdot (da - s_{\min})}{20 \cdot s_{\min}}$$

$$p = \frac{20 \cdot \sigma_{zul} \cdot s_{\min}}{da - s_{\min}}$$

Example:
PE 100, 20°C, 50 years, water (d.h. σ_v=10 N/mm²)
Operating pressure 16bar
Outside diameter da=110mm

$$\sigma_{zul} = \frac{\sigma_v}{C_{\min}} = \frac{10}{1{,}25} = 8$$

$$s_{\min} = \frac{p \cdot da}{20 \cdot \sigma_{zul} + p} = \frac{16 \cdot 110}{20 \cdot 8 + 16} = 10$$

$$\sigma_{zul} = \frac{p \cdot (da - s_{\min})}{20 \cdot s_{\min}} = \frac{16 \cdot (110 - 10)}{20 \cdot 10} = 8$$

$$\sigma_v = \sigma_{zul} \cdot c_{\min} = 8 \cdot 1{,}25 = 10$$

Load by external pressure (buckling pressure)

In certain cases, piping systems are exposed to external pressure:
-Installation in water or buried below groundwater table
-Systems for vacuum. e.g. suction pipes

$$p_k = \frac{10 \cdot E_c}{4 \cdot (1-\mu^2)} \cdot \left(\frac{s}{r_m}\right)^3$$

p_k	...Critical buckling pressure	[bar]
E_c	...Creep modulus (see tables page 10) [N/mm^2] for t=25a	
μ	...Transversal contraction factor (for thermoplastics generally 0,4)	
s	...Wall thickness	[mm]
r_m	...Medium pipe radius	[mm]

The buckling tension can then be calculated directly:

$$\sigma_k = p_k \cdot \frac{r_m}{s}$$

Example
PE 80 pipe SDR17
40°C, 25 years
E_C=120N/mm² (creep modulus curve - page 10)
outside diameter da=110
Wall thickness =6,3mm
Additional safety factor 2,0 (Minimum security factor for stability calculation).

$$p_k = \frac{10 \cdot E_c}{4 \cdot (1-\mu^2)} \left(\frac{s}{r_m}\right)^3 =$$

$$= \frac{10 \cdot 120}{4 \cdot (1-0{,}4^2)} \left(\frac{6{,}3}{53{,}3}\right)^3 = 0{,}58$$

$$p_k = \frac{0{,}58}{2{,}0} = 0{,}29$$

$$\sigma_k = p_k \cdot \frac{r_m}{s} = 0{,}58 \cdot \frac{53{,}3}{6{,}3} = 4{,}90$$

Determination of the pipe cross section

Flowing processes are calculated by means of the continuity equation. For fluids with constant volume flow, the equation is:

$$\dot{V} = 0{,}0036 \cdot A \cdot v$$

$\dot{V}$	...	Volume flow	[m³/h]
A	...	Free pipe cross section	[mm²]
v	...	Flow velocity	[m/s]

For gases and vapours, the material flow remains constant. There, the following equation results:

$$\dot{m} = 0{,}0036 \cdot A \cdot v \cdot \rho$$

$\dot{m}$	...	Material flow	[kg/h]
ρ	...	Density of the medium depending on presure and temperature	[kg/m³]

If in these equations the constant values are summarized, the formulas used in practice for the calculation of the required pipe cross section result there of:

$$d_i = 18{,}8 \cdot \sqrt{\frac{Q'}{v}}$$

$$d_i = 35{,}7 \cdot \sqrt{\frac{Q''}{v}}$$

d_i	...	Inside diameter of pipe	[mm]
Q'	...	Conveyed quantity	[m³/h]
Q''	...	Conveyed quantity	[l/s]
v	...	Flow velocity	[m/s]

Reference values for the calculation of flow velocities may be for fluids:

v ~ 0,5 ÷ 1,0 m/s (suction side)
v ~ 1,0 ÷ 3,0 m/s (pressure side)
Reference values for the calculation of flow velocities may be for gases
v ~ 10 ÷ 30 m/s

Determination of the hydraulic pressure losses

Flowing media in pipes cause pressure losses and consequently energy losses within the conveying system.

Important factors for the extent of the losses:
- 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 flowing medium

Calculation of the several pressure losses

Pressure loss in straight pipes Δp_R

The pressure loss in an straight pipe length is reversed proportional to the pipe cross section.

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

λ	...	Pipe frictional index (in most cases 0,02 is sufficient)	
L	...	Lenght of piping system	[m]
d_i	...	Inside diameter of pipe	[mm]
ρ	...	Medium density	[kg/m³]
v	...	Flow velocity	[m/s]

Pressure loss in fittings Δp_{RF}

There appear considerable losses regarding friction, reversion and detachment.
The for the calculation necessary resistance coefficients can been seen in the DVS 2210, table 9 (extract see page 45) or special technical literature.

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

ζ	...	Resistance coefficient for fittings	[-]
ρ	...	Density of medium	[kg/m³]
v	...	Flow velocity	[m/s]

The whole pressure loss Δp_{ges} results from the sum of the following individual losses:

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

Pressure loss in mountings Δp_{RA}

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

ζ	...	Resistance coefficient for mountings	[-]
ρ	...	Density of medium	[kg/m³]
v	...	Flow velocity	[m/s]

The for the calculation necessary resistance coefficients can be seen in DVS 2210, table 10 (extract see page 26) or special technical literature.

Pressure loss of finished joints or couplings Δp_{RV}

It is impossible to give exact information, because types and qualities of joints (welding joints, unions, flange joints) vary.
It is recommended to calculate a resistance coefficient of each

$$\zeta_{RV} = 0,1$$

for joints in a thermoplastic piping system, such as butt and socket welding as well as flanges.

REMARK

For the design of piping systems out of PE-HD (OD 110 - 1200 mm) also the AGRU tabular compilation for the hydraulic design of PE-HD piping systems can be looked up.

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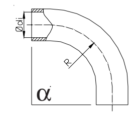
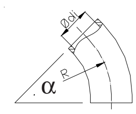
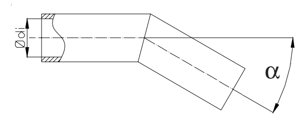
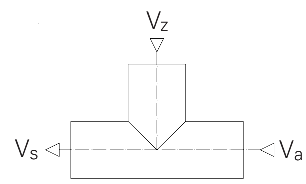
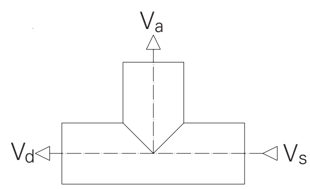
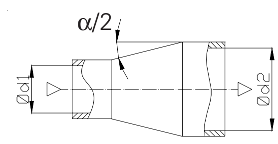
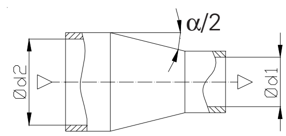
Determination of the hydraulic pressure losses

Hydraulic resistance coefficients of fittings (acc. DVS® 2210 part 1, table 9)

Kind of Fitting	Parameter	Resistance coefficient ζ			Drawing ⇄ =Flow direction
bend α=90°	R = 1,0 x da	0,51			
	= 1,5 x da	0,41			
	= 2,0 x da	0,34			
	= 4,0 x da	0,23			
bend α=45°	R = 1,0 x da	0,34			
	= 1,5 x da	0,27			
	= 2,0 x da	0,20			
	= 4,0 x da	0,15			
ellbow	α=45°	0,30			
	30°	0,14			
	20°	0,05			
	15°	0,05			
	10°	0,04			
tee 90° (flow collection)		ζz	ζs		
	V_Z/V_S=0,0	-1,20	0,06		
	0,2	-0,4	0,20		
	0,4	0,10	0,30		
	0,6	0,50	0,40		
	0,8	0,70	0,50		
	1	0,90	0,60		
tee 90° (flow separation)		ζa	ζd		
	V_A/V_S=0,0	0,97	0,10		
	0,2	0,90	-0,10		
	0,4	0,90	-0,05		
	0,6	0,97	0,10		
	0,8	1,10	0,20		
	1,0	1,30	0,35		
reducers concentric (pipe extension)	Angle α	4 ... 8°	16°	24°	
	d_2/d_1=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	
reducers concentric (pipe throat)	Angle α	4°	8°	20°	
	d_2/d_1=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	

positive ζ-values: pressure drop
negative ζ-values: pressure increase
Va: outgoing volume flow
Vd: continuous volume flow
Vs: total volume flow
Vz: additional volume flow

Determination of the hydraulic pressure losses

Hydraulic resistance coefficients of mountings
(acc. DVS® 2210 part 1, table 10)

Nominal width Ø	MV	GSV	SSV	S	KH	K	RV	RK
	Resistance coefficient (ζ)							
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

Annotation: The hydraulic resistance coefficients mentioned are reference values and are suitable for rough calculation of pressure loss. For material-related calculations use the values of the particular manufacturer.

Criteria for choice of gate valves
(acc. DVS® 2210 part 1, table 11)

Selection criteria	MV/GSV/SSV	S	KH	K	RV	RK
	Assessment					
Flow resistance	big	low	low	moderate	big	moderate
Aperture- and Closing time	medium	long	short	short	short	
Operation moment	low	low	big	moderate		
Wear	moderate	low	low	moderate	moderate	
Flow regulation	suitable	less suitable				
Face-to-face length acc. row F	medium	big	big	big	mittel	big
Face-to-face length acc. row K			low	low		low

(grey field) no criteria

Legend for tables above:
MV diaphragm valve
SSV angle seat valve
GSV straight valve
S gate valve
KH ball valve
K butterfly valve
RV check valve
RK swing type check valve

Dog bone load

Dog bones should prevent a sliding or moving of the piping system in each direction. They serve furthermore for compensation of the reaction forces of compensators such as sliding sockets and push-fit fittings. The dog bone has to be dimensioned for all appearing forces:

- Force by hindered thermal length expansion
- Weight of vertical piping systems
- Specific weight of the flow medium
- Operating pressure
- Inherent resistance of the compensators

Dog bones which have not been determined should be chosen in a way so as to make use of direction alterations in the course of the piping system for the absorption of the length alterations. As dog bones, edges of fittings sockets or special dog bone fittings are suitable.
Swinging clips are not appropriate to be used as dog bones or the clamping of the pipes.

Rigid system

If the length alteration of a piping system is hindered, a fixed system is developed.
The rigid or fixed piping length has no compensation elements and has to be considered concering the dimensioning as special application.

The following system sizes have to be determined therefore by calculation:

- Dog bone load
- Permissible guiding element distance under consideration of the critical buckling length
- Appearing tensile and pressure stresses

Dog bone load at fixed systems

The largest dog bone load appears at the straight, fixed piping. It is in general kind:

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

F_{FP}	...	Dog bone force	[N]
A_R	...	Pipe wall ring area	[mm²]
E_c	...	Creep modulus [N/mm²] for t=100min	
ε	...	Prevented length expansion by heat expansion, internal pressure or swelling	[-]

Under consideration of the possible loads, ε has to be determined as follows:

Load by heat expansion

$$\varepsilon = \alpha \cdot \Delta T$$

α	..	Linear heat expansion coefficient	[1/°K]
ΔT	...	Max. temperature difference	[°K]

Load by internal pressure

$$\varepsilon = \frac{0{,}1 \cdot p \cdot (1 - 2\mu)}{E_c \cdot \left(\frac{da^2}{di^2} - 1 \right)}$$

p	...	Operating pressure	[bar]
μ	...	Transversal contraction coefficient	[-]
E_c	...	Creep modulus [N/mm²] for t=100min	
da	...	Pipe outside diameter	[mm]
d_i	...	Pipe inside diameter	[mm]

Calculation of support distances for pipes

The support distances from the thermoplastic piping systems should be determined under consideration of the licensed bending stress and the limited deflection of the pipe line. On calculating of the support distances, a maximum deflection of $L_A/500$ to $L_A/750$ has been taken as basis. Under consideration of the previous deflection of a pipe line between the centers of tire impact results a permissible support distance of the pipe system.

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

L_A	...	Permissible support distance	[mm]
f_{LA}	...	Factor for the deflection (0,80 ... 0,92)	[-]
E_c	...	Creep modulus for t=25a	[N/mm²]
J_R	...	Pipe inactivity moment	[mm^4]
q	...	Line load out of Pipe-, filling- and additional weight	[N/mm]

Remark: The factor fLA is determined depending on the pipe outside diameter. There is the following relation valid:

$$\min \leftarrow da \rightarrow \max$$
$$0{,}92 \leftarrow f_{LA} \rightarrow 0{,}80$$

The support distances in the table may be changed for other pressure ratings, SDR-rows or materials as follows:

SDR 17	**- 8%**
SDR 7,4	**+ 7%**

For the transportation of **gases** with a density of < 0,01 g/cm³, the support distances can be increased as stated below:

SDR 17	**+45 %**
SDR 11	**+30 %**
SDR 7,4	**+21 %**

Usual Support distances can be taken from the following tables.

PE80, SDR11 (acc. DVS® 2210 part 1, Tab.13)

da	Support distance L_A in [mm] at				
[mm]	20°C	30°C	40°C	50°C	60°C
16	500	450	450	400	350
20	575	550	500	450	400
25	650	600	550	550	500
32	750	750	650	650	550
40	900	850	750	750	650
50	1050	1000	900	850	750
63	1200	1150	1050	1000	900
75	1350	1300	1200	1100	1000
90	1500	1450	1350	1250	1150
110	1650	1600	1500	1450	1300
125	1750	1700	1600	1550	1400
140	1900	1850	1750	1650	1500
160	2050	1950	1850	1750	1600
180	2150	2050	1950	1850	1750
200	2300	2200	2100	2000	1900
225	2450	2350	2250	2150	2050
250	2600	2500	2400	2300	2100
280	2750	2650	2550	2400	2200
315	2900	2800	2700	2550	2350
355	3100	3000	2900	2750	2550
400	3300	3150	3050	2900	2700

Support distances for PE 100

As there are no valid creep modulus curves available for PE 100 at the moment, we recommend you to raise the values in the table for PE 80 contained support distances after eventually necessary conversion (f_1- and f_2-factor) by 10%.

Calculation of the change in length

Changes in length of a plastic piping systems are caused by changes in the operating or test process. There are the following differences:

- Change in length by temperature change
- Change in length by internal pressure load
- Change in length by chemical influence

Change in length by temperature change

If the piping system is exposed to different temperatures (operating temperature or ambient temperature) the situation will change corresponding to the moving possibilities of each pipe line. A pipe line is the distance between two dog bones.

For the calculation of the change in length use the following formula:

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

ΔL_T .... Change in length due to temperature change [mm]

α .... Linear expansion coefficient [mm/m·°K]

L .... Pipe length [m]

ΔT .... Difference in temperature [°K]

The lowest and hightest pipe wall temperature T_R by installation, operation or standstill of the system is basis at the determination of ΔT.

α-average value	mm/(m.K)	1/K
PE	0,18	1,8x10-4

Change in length by internal pressure load

The by internal pressure caused length expansion of a closed and frictionless layed piping system is:

$$\Delta L_P = \frac{0{,}1 \cdot p \cdot (1-2\mu)}{E_c \cdot \left(\frac{da^2}{di^2} - 1\right)} \cdot L$$

ΔL_P ... Change in length by internal pressure load [mm]

L ... Length of piping system [mm]

p ... Operating pressure [bar]

μ ... Transversal contraction coefficient [-]

E_c ... Creep modulus [N/mm²]

da ... Pipe outside diameter [mm]

d_i ... Pipe inside diameter [mm]

Calculation of the minimum straight length

Changes in length are caused by changes in operating or ambient temperatures. On installation of piping systems above ground, attention must be paid to the fact that the axial movements are sufficiently compensated.
In most cases, changes in direction in the run of the piping may be used for the absorption of the changes in length with the help of the minimum straight lengths. Otherwise, compenstion loops have to be applied.

The minimum straight length is expressed by:

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

L_s	....	Minimum straight length	[mm]
ΔL	....	Change in length	[mm]
da	....	Pipe outside diameter	[mm]
k	....	Material specific proportionality factor (exact values see table)	

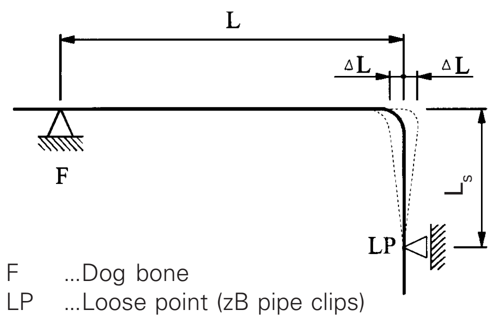
If this cannot be realised, use compensators of possibly low internal resistance. Depending on the construction, they may be applied as axial, lateral or angular compensators.
Between two dog bones, a compensator has to be installed. Take care of appropriate guiding of the piping at loose points whereby the resulting reaction forces should be taken into account.

Material specific proportionality factors k

	0°C	10°C	30°C	40°C	60°C
	at change in temperature				
PE	16	17	23	28	-
	one-time change in temperature				
PE	12	12	16	17	-

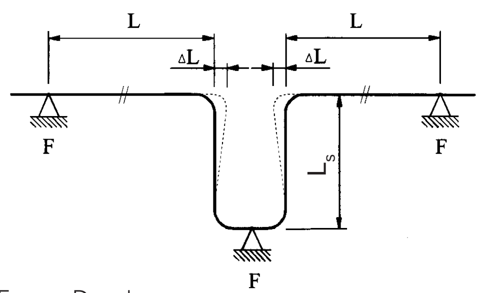
Note: An installation temperature of 20°C is basis at the calculation of the k-values. At low temperatures, the impact strength of the material has to be taken into account.
The k-values can be reduced by 30% for pressureless pipes (e.g. ventilation).

Principle drawing L-compensation elbow



F ...Dog bone
LP ...Loose point (zB pipe clips)

Principle drawing U-compensation elbow



F ...Dog bone

Calculation of straight lengths

Straight lengths in [mm] for pipes out of polyethylene [1] depending on the change in length ΔL

da	Change in length ΔL [mm]								
[mm]	50	100	150	200	250	300	350	400	500
16	850	1200	1500	1700	1900	2100	2250	2400	2700
20	950	1350	1650	1900	2150	2350	2500	2700	3000
25	1100	1500	1850	2150	2400	2600	2800	3000	3350
32	1200	1700	2100	2400	2700	2950	3200	3400	3800
40	1350	1900	2350	2700	3000	3300	3550	3800	4250
50	1500	2150	2600	3000	3350	3700	4000	4250	4750
63	1700	2400	2950	3400	3800	4150	4450	4800	5350
75	1850	2600	3200	3700	4150	4500	4900	5200	5800
90	2050	2850	3500	4050	4500	4950	5350	5700	6400
110	2250	3150	3900	4450	5000	5450	5900	6300	7050
125	2400	3350	4100	4750	5300	5800	6300	6700	7500
140	2500	3550	4350	5050	5650	6150	6650	7100	7950
160	2700	3800	4650	5400	6000	6600	7100	7600	8500
180	2850	4050	4950	5700	6400	7000	7550	8050	9000
200	3000	4250	5200	6000	6700	7350	7950	8500	9500
225	3200	4500	5550	6400	7150	7800	8450	9000	10100
250	3350	4750	5800	6700	7500	8250	8900	9500	10600
280	3550	5000	6150	7100	7950	8700	9400	10000	11250
315	3800	5350	6550	7550	8450	9250	10000	10650	11900
355	4000	5650	6950	8000	8950	9800	10600	11350	12650
400	4250	6000	7350	8500	9500	10400	11250	12000	13450
450	4500	6400	7800	9000	10100	11050	11950	12750	14250
500	4750	6750	8250	9500	10650	11650	12550	13450	15000
560	5050	7100	8700	10050	11250	12300	13300	14200	15900
630	5350	7550	9250	10650	11950	13050	14100	15100	16850

[1] The minimum straight length have been increased by a safety factor of appr.10%

Comparison of stiffnesses

Comparison between SN and SDR - ISO-S rating according to EN 12666.

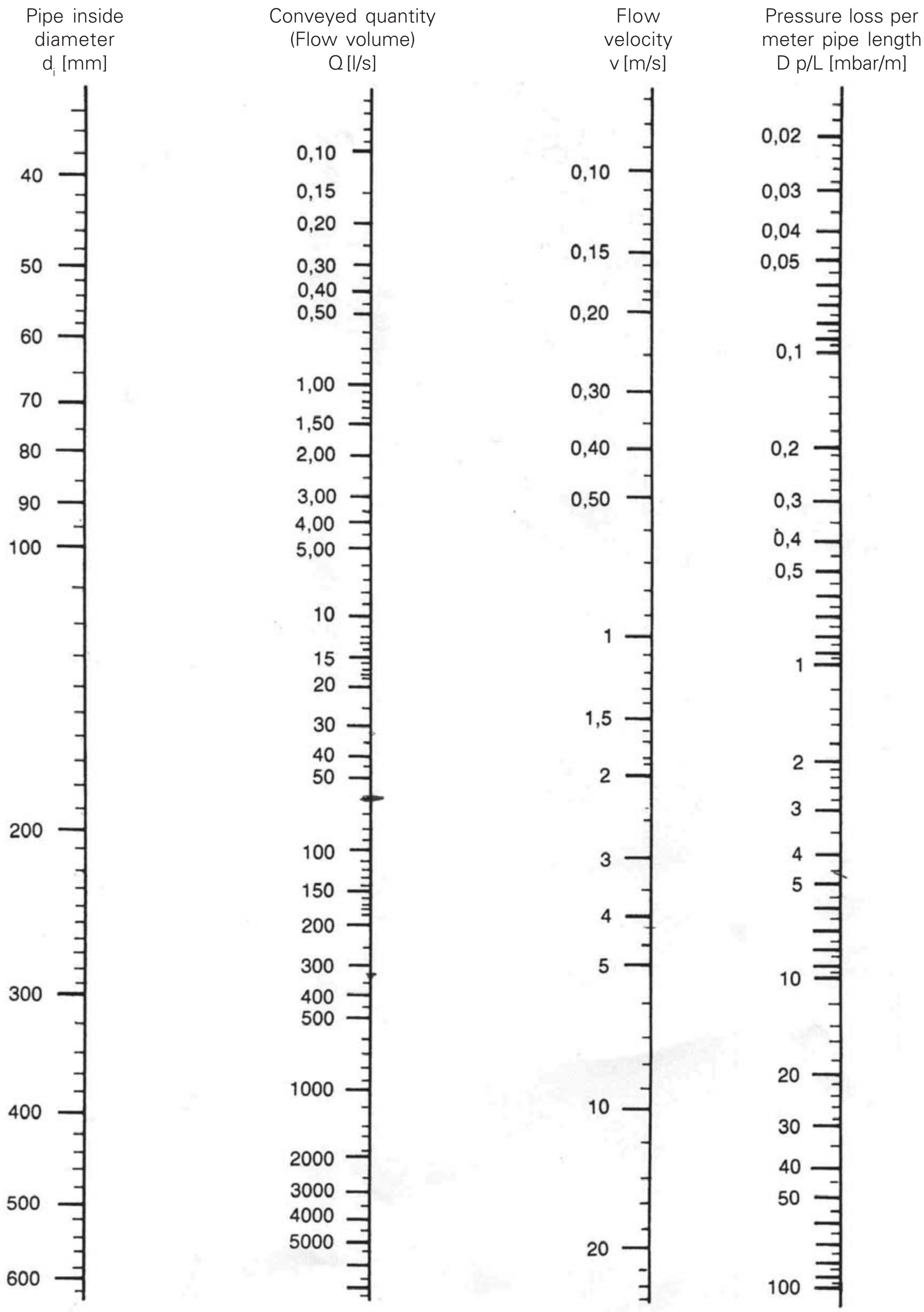
SN	SDR / ISO - S
2	SDR 33 - ISO - S 16
4	SDR 26 - ISO - S 12,5
8	SDR 21 - ISO - S 10

SN = nominal stiffness

The influence of the rigidity at flexible piping systems out of plastic is overrated. The pipe must have a sufficient rigidity during installation to take up the load from the compression. With a good compression work within the area of the line the soil carries the arising loads, the pipe itself escapes from the loads by deformation (usually 2 to 3 %) and lies after a period of approx. 2 years (relaxation) stress-less in the soil. A rigidity of 8 kN/m2 is optimal and sufficient.

Flow nomogramm

For rough determination of flow velocity, pressure loss and conveying quantity serves the following flow nomogram. At an average flow velocity 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 x d.



General standard

The quality of the welded joints depends on the qualification of the welder, the suitability of the machines and appliances as well as the compliance of the welding guidelines. The welding joint can be checked through non destructive and / or destructive methods.

The welding process should be supervised. Method and size of the supervision must be agreed from the parties. It is recommended to document the method datas in welding protocols or on data medium.

Each welder must be qualified and must have a valid proof of qualification. The intended field of application can be determined for a type of qualification. For the heating element butt welding from sheets as well as for the industrial piping system construction DVS® 2212 part 1 valids. For pipes >225mm outside diameter is an additional proof of qualification necessary.

The used machines and appliances must correspond to the standards of the DVS® 2208 part 1.

Measures before the welding operation

The welding area has to be protected from unfavourable weather conditions (e. g. moisture, wind, intensive UV-radiation, temperatures < 5°C). If appropriate measures (e. g. preheating, tent-covering, heating) secure that the required pipe wall temperature will be maintained, welding operations may be performed at any outside temperatures, provided, that it does not interfere with the welder's manual skill.
If necessary, the weldability has to be proved by performing sample welding seams under the given conditions.

If the semi finished product should be disproportionately warmed up as a consequence of intensive UV-radiation, it is necessary to take care for the equalization of temperature by covering the welding area in good time. A cooling during the welding process throught draft should be avoided.

PE pipes from coils are immediately after the rolling action oval. Before welding the pipe ends have to be adjusted for example by heating with a hot-air blower and usage of a suitable cut pressure or round pressure installation.

The joining areas of the parts to be welded must not be damaged or contaminated.
Immediately before starting the welding process, the joining areas have to be cleaned and must be free from e.g. dirt, oil, shavings.

On applying any of these methods, keep the welding area clear of flexural stresses (e. g. careful storage, use of dollies).

The AGRU welding instructions apply to the welding of pipes and fittings out of the in the table (according to DVS® 2207 part 1) contained thermoplastics.

Material designation	Weldability
Polyethylene PE 80, PE 100	MFR (190/5) = 0,3 - 1,7 [g/10min]

Application limits for different kinds of joints

If possible, all joints have to executed so as to avoid any kind of stresses. Stresses which may arise from differences in temperature between laying and operating conditions must be kept as low as possible by taking appropriate measures.
The in the table contained axial conclusive joints are permissible.

Welding method	da 20 ÷ 63		da 63 ÷ 110		da 110 ÷ 225		da 225 ÷ 400	
Heating element butt welding (HS)	●[1)]	●[1)]	●	●	●	●	●	●
Heating element socket welding	●[1)]	●[1)]	●[1)]	●[1)]	●	●	●	●
Electric socket welding (hot wedge welding)	●	●	●	●	●	●	●	●
Flange joint	●[1)]	●[1)]	●[1)]	●[1)]	●[1)]	●[1)]	●[1)]	●[1)]
Union (only for dring water pipelines)	●	●	●	●	●	●	●	●

●[1)] - not recommended for gas supply systems
(the guidelines of the national standards have to be adhered to)

Electrofusion welding

(following to DVS® 2207, part 1 for PE-HD)

Welding method

On electric welding, pipes and fittings are welded by means of resistance wires which are located within the electro-fusion socket. A transformer for welding purposes supplies electric power.

The expansion of the plastified melt and the shrinking behaviour of the electro-fusion-fitting produce the necessary welding pressure which guarantees an opitmal welding result.

The method is characterized by an extra-low safety voltage and by a high automatization grade.

Welding systems

For the welding of AGRU-E-fittings an universal welding machine should be used.
This welding machine operates with bar code identification, it supervises all functions full automatically during the welding process and stores them.

After feeding the code for universal welding machines with magnetic code characteristic, the code is deleted which means that the card can be used once only.

Suitable welding machines

For the welding of electric weldable AGRU-fittings the following universal welding devices with bar code identification are suitable:

- Polymatic plus + top**
- Huerner junior+, print+**

**with fitting traceability acc. ISO 12176-4

General welding suitability

Only parts made of the same material may be joined with one another. The MFR-value of the E-fittings out of PE is in the range of 0,3 - 1,3 g/10min. They can be joined with pipes and fittings out of PE 80 and PE 100 with a MFR-value between 0,3 and 1,7 g/10min.

The weldable SDR-serie and the maximum ovality are listed in the following table.

The welding area has to be protected against unfavourable weather conditions (e. g. rain, snow, intensive UV-radiation or wind) The permissible temperature range for PE is from -10°C up to +50°C. The national guidelines must also be considered.

Welding parameters

The welding parameters are specified by the bar code, which is directly affixed on the fitting.

For AGRU electro fusion fittings is valid:

		SDR 33	SDR 26	SDR 17,6	SDR 17	SDR 13,6	SDR 11	SDR 9	SDR 7,4
SDR 11	20	no	no	no	no	no	yes*	yes*	yes*
	25	no	no	no	no	no	yes**	yes**	yes**
	32	no	no	no	no	no	yes	yes	yes
	40	no	no	yes	yes	yes	yes	yes	yes
	50	no	no	yes	yes	yes	yes	yes	yes
	63	no	no	yes	yes	yes	yes	yes	yes
	75	no	no	yes	yes	yes	yes	yes	yes
	90	no	no	yes	yes	yes	yes	yes	yes
	110	no	no	yes	yes	yes	yes	yes	yes
	125	no	no	yes	yes	yes	yes	yes	yes
	140	no	no	yes	yes	yes	yes	yes	yes
	160	no	no	yes	yes	yes	yes	yes	yes
	180	no	yes	yes	yes	yes	yes	yes	yes
	200	yes	yes	yes	yes	yes	yes	yes	yes
	225	yes	yes	yes	yes	yes	yes	yes	yes
	250	yes	yes	yes	yes	yes	yes	yes	yes
	280	yes	yes	yes	yes	yes	yes	yes	yes
	315	yes	yes	yes	yes	yes	yes	yes	yes
	355	yes	yes	yes	yes	yes	yes	no	no
	400	yes	yes	yes	yes	yes	yes	no	no
	450	no	no	yes	yes	yes	yes	no	no
	500	no	no	yes	yes	yes	yes	no	no
SDR 17	450	yes	yes	yes	yes	no	no	no	no
	500	yes	yes	yes	yes	no	no	no	no
	560	yes	yes	yes	yes	no	no	no	no
	630	yes	yes	yes	yes	no	no	no	no
	710	yes	yes	yes	yes	no	no	no	no

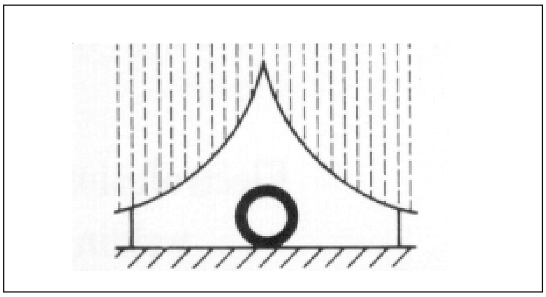
* weldable with wall thickness from 2,3 mm up to 3,5 mm

** weldable with wall thickness from 2,5 mm up to 3,8 mm

Pipes with thinner walls must be welded with support sleeves

Electrofusion welding

Preparation of welding place



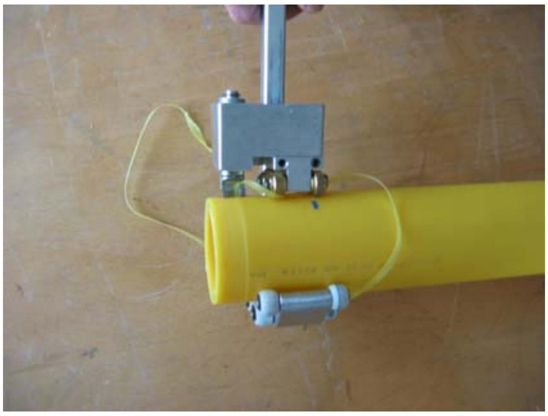
Processing guidelines

Assemble welding equipment (prepare tools and machinery), control welding devices.

Install welding tent or similar device.

Depending on the environmental conditions and the envirnmental temperature (see page 29)

Preparation of the welding seam
(immediately before starting the welding process)



Cut off pipe at right angles by means of a proper cutting tool and mark the insert length.

Insert length= socket length/2

Clean pipe of dirt with a dry cloth at insert length and carefull machine pipe by means of a peeling tool or scraper knife in axial direction (cuting depth min. 0,2mm). Remove flashes inside and outside of pipe ends.

If a fitting is welded instead of the pipe, the welding area of the fitting has to be cleaned and scrapped as the pipe.

Preparations before welding

Unpack the E- fitting immediately before welding.

Never touch the inside of the socket and the scrapped pipe end.

If a pollution cannot be excepted, clean the welding areas with PP- or PE-cleaner (or similar) and with fluffless paper.

The faces to be welded have to be dry before the socket is put over the pipe. At any rate, remove residues of clean-sing agents or condensation water with fluffless, absorbent paper.
Slide the socket into the prepared end of pipe right to its center stop until it reaches the marking.

Electrofusion welding

Preparations before welding

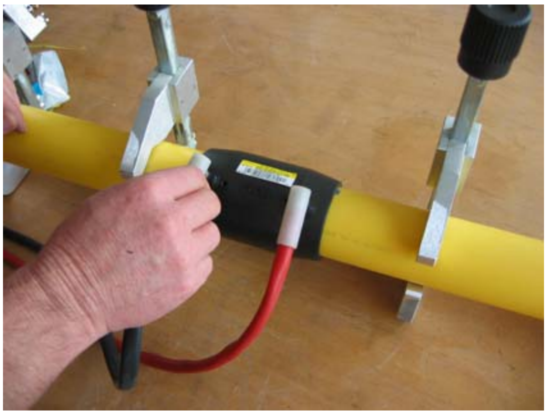
Processing guidelines

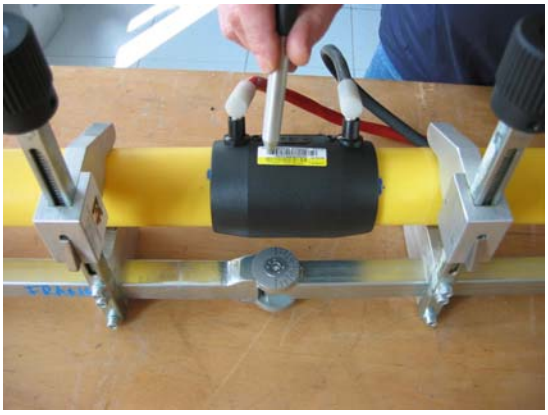
The second part which has to be welded with the socket (pipe or fitting) should be prepared too. Insert the second pipe end (or fitting) into the socket and clamp both pipes into the holding device, so that no forces can raise between welding area and the pipe (fitting) and that the socket can be turned smoothly.

Check:
If a marking does not flush with a socket end, the pipe has not been inserted right up to the center stop.

The clamping device has to be loosened and the pipe ends must be inserted until the markings are directly visible on the socket ends.

Performing the welding process





Observe the operating instructions for the welding device. Only the most significant steps of the welding procedure are described as follows.

Both plug-type socket connections should be turned upwards (however the axial position of the socket must not be changed) and connected with the welding cable. Position welding cable so as to prevent its weight from twisting the welding socket.

After the welding equipment has been properly connected, this is shown on the display.

The welding parameters are fed in by means of a reading pencil or a scanner. An audio signal will acknowledge the data input.

After the welding parameters have been fed in, the trademark, dimension and outside temperature are shown on the display. These values now have to be acknowledged. Then, for control purposes, you will be asked, whether the pipe has been worked.

Welding without clamping device:
It is possible to weld AGRU electro fusion fittings without using a clamping device.
The working instructions must correspond to DVS® 2207 part 1 and to the AGRU welding requirements.
Keep in mind that the installation situation must be stress free.
Is a stress free situation not possible a clamping device must be used.

Electrofusion welding

Performing the welding process

Visual control and documentation

Processing guidelines

Optional a traceability barcode is marked directly on the fitting. So it is easy to read the code into the welding machine. The using of the traceabilitycode is not forcing. That means, if you don´t need the code nothing changes at your working process. So you can use your standard welding machine.

The welding process is started by pressing the green start key. This time on the display also the desired welding time and the actual welding time are given as well as the welding voltage.

During the whole welding process (including cooling time) the clamping device shall remain installed. The end of the welding process is indicated by an audio signal.

After expiration of the cooling time, the clamping device may be removed. The recommended cooling time must be observed!
If a welding process is interrupted (e.g. in case of a power failure), it is possible to reweld the socket after cooling down to ambient temperature (<35°C).

minimum Cooling time:

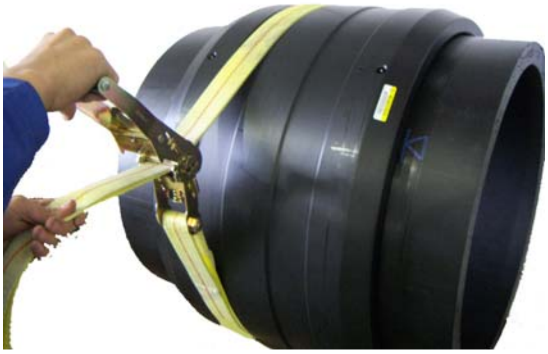
OD 20 mm	-	63 mm	6 min
OD 75 mm	-	125 mm	10 min
OD 140 mm			15 min
OD 160 mm	-	180 mm	20 min
OD 200 mm	-	280 mm	30 min
OD 315 mm	-	400 mm	45 min
OD 450 mm	-	500 mm	60 min
OD 560 mm	-	710 mm	90 min

Visual weld control is performed by the welding indicator on the socket. Moreover, all welding parameters are stored internally by the device and can be printed to receive a welding protocol.

Electrofusion welding - Big Couplers

welding of E-Couplers >500mm

mounting of the tension belts



Performing the welding process

Processing guidelines

For the preparation of the electro fusion couplers >500mm apply the same installations steps as descriped on page 37 and 38.

After the insertion of the pipes you have to consider following points.

After the insertion of the pipes both from AGRU delivered tension belts (50mm wide) must be inserted in the grooves and mounted.

Installation guidelines for the tension belts see page 41.

The belts must be mounted in the grooves and pulled tight by hand until the belts can not be displaced.
An additional tool is not allowed.

After the correct installation of the tension belts the welding process according to page 39 can be performed.

minimum cooling time:
da 560 mm - 630 mm 90 min.

Both tension belts must be inserted in the grooves and mounted as following.

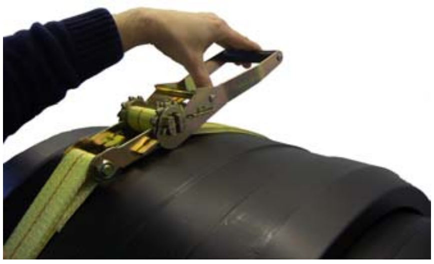
Open the ratchet lever

Mount the loose end through the slot spindle and pull it through

Clamp the tension belt

Tighten the belt with the ratchet lever till the belt is tight on the coupler and can not be removed by hand

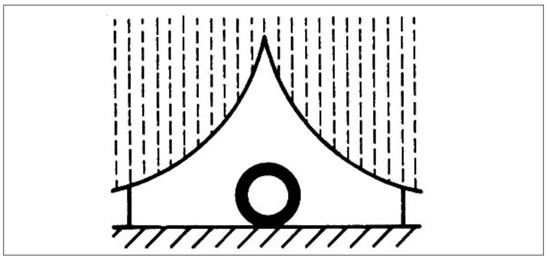
After tightening the belt bring the ratchet lever to the closure position



To open the belt pull the functional slider at the ratchet lever and turn them approx. 180° to the end position

Tapping saddle

Preparation of welding place



Preparation of welding seam
(at any rate immediately before starting the welding process)

Preparations before welding

Processing guidelines

The following processing guidlines are valid for tapping saddles.

Assemble welding equipment, prepare tools and machinery, control welding devices.

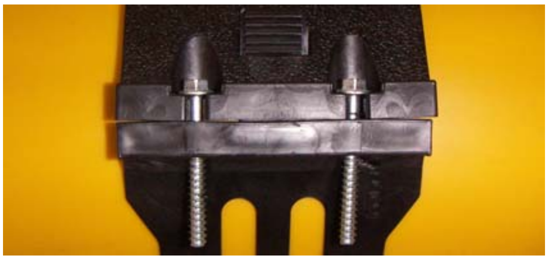
Install welding tent or similar device.

Depending on the environmental conditions and the environmental temperature (see page 34)

Machine pipe surface carefully in the welding area by means of a scraper knife.
The area of the pipe to be welded has to be cleaned with PE-cleaner (or similar) and fluffless paper.
At any rate remove residues of cleaning agents or condensation water with clean absorbent paper.

After this, the tapping saddle is opened, seated onto the pipe and fixed by snapping together the top and bottom parts.
To exert the necessary welding pressure the AGRU crimp or the screws has to be mounted on the tapping saddle.

The proper saddle prestress may be controlled by the red indicator, which shall be visible in such case (see picture).
Raise the prestress by means of the eccentric clamping device by one step, if the indicator does not become visible. A third step has been provided in case, if the stress is still insufficient.
Instead of the clamping device you can also use the screws. The gap between the top and bottom part must be closed (see picture).



Tapping saddle

Performing the welding process

Visual control and documentation

Processing guidelines

Before welding the right position of the tapping saddle should be checked.

After the welding equipment has been connected properly to the tapping saddle, this is shown on the display.
The welding parameters are fed in by means of a reading pencil or a scanner. An audio signal will acknowledge the data input.
After the welding parameters have been fed in, the trademark, dimension and outside temperature are shown on the display. These values now have to be acknowledged. Then, for control purposes, you will be asked, whether the pipe has been worked.

The welding process is started by pressing the green start key. This time on the display also the desired welding time and the actual welding time are given as well as the welding voltage.
During the whole welding process (including cooling time) the clamping device or screws shall remain installed. The end of the welding process is indicated by an audio signal.
The clamping device is removed after 20 minutes. This recommended cooling time must be observed!

The screws remain on the tapping saddle.

If a welding process is interrupted (e.g. in case of a power failure), it is possible to reweld the saddle after cooling down to ambient temperature (<35°C).

Visual weld control is performed by the welding indicator on the socket. Moreover, all welding parameters are stored internally by the device and can be printed to receive a welding protocol.

Tapping saddle

Tapping of the tapping saddle

Processing guidelines

Once the cooling time is up, under-pressure tapping may be started. For doing so, it is absolutely necessary to tension the clamp. The cutter, being an integrated part of the tapping saddle, is turned clockwise by the respective tapping device until the marking is not visible on the tapping device (see picture).
As soon as the pipe has been tapped this way, the cutter is turned back, now allowing the pipe to be connected.

The tapping saddle is closed by the sealing cap. Tighten the cap only manually; don´t make use of any instruments (e.g. tongs).
In case of a weldable sealing cap, the cap is mounted and welded separately.

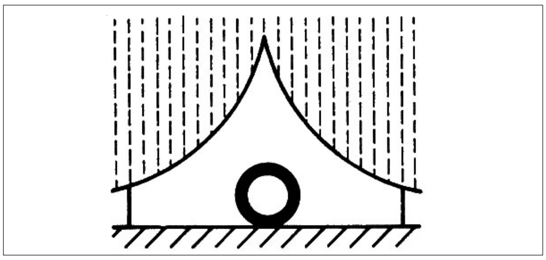
It is understood that for tapping the service line must have been provided in advance.

Following dimensions and SDR rows are weldable and to tap with AGRU tapping saddle.

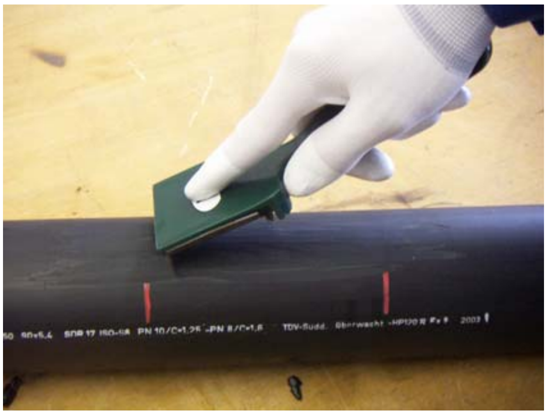
Dimension	SDR 17	SDR 11
32	no	**yes**
40	no	**yes**
50	no	**yes**
63	no	**yes**
90	**yes**	**yes**
110	**yes**	**yes**
125	**yes**	**yes**
160	**yes**	**yes**
180	**yes**	**yes**
200	**yes**	**yes**
225	**yes**	**yes**
250	**yes**	**yes**
280	**yes**	**yes**
315	**yes**	**yes**

Tapping valve

Preparation of welding place



Preparation of welding seam
(at any rate immediately before starting the welding process)



Preparations before welding

Processing guidelines

The following processing guidelines are valid for tapping valves.

Assemble welding equipment, prepare tools and machinery, control welding devices.

Install welding tent or similar device.

Depending on the environmental conditions and the envirnmental temperature (see page 34)

Machine pipe surface carefully in the welding area by means of a scraper knife.
The area of the pipe to be welded has to be cleaned with PE-cleaner (or similar) and fluffless paper.
At any rate remove residues of cleaning agents or condensation water with clean absorbent paper.

After this, the tapping valve is opened, seated onto the pipe and fixed by snapping together the top and bottom parts.
To exert the necessary welding pressure a clamp has to be mounted on the valve tapping saddle.

The proper saddle prestress may be controlled by the red indicator, which shall be visible in such case (see picture).
Raise the prestress by means of the eccentric clamping device by one step, if the indicator does not become visible. A third step has been provided in case, if the stress is still insufficient.

Tapping valve

Performing the welding process

Visual control and documentation

Processing guidelines

Before welding the right position of the tapping valve should be checked.

After the welding equipment has been connected properly to the valve tapping saddle, this is shown on the display.
The welding parameters are fed in by means of a reading pencil or a scanner. An audio signal will acknowledge the data input.
After the welding parameters have been fed in, the trademark, dimension and outside temperature are shown on the display. These values now have to be acknowledged. Then, for control purposes, you will be asked, whether the pipe has been worked.

The welding process is started by pressing the green start key. This time on the display also the desired welding time and the actual welding time are given as well as the welding voltage.
During the whole welding process (including cooling time) the clamping device shall remain installed. The end of the welding process is indicated by an audio signal.
The clamping device is removed after 20 minutes. This recommended cooling time must be observed!
If a welding process is interrupted (e.g. in case of a power failure), it is possible to reweld the saddle after cooling down to ambient temperature (<35°C).

Visual weld control is performed by the welding indicator on the socket. Moreover, all welding parameters are stored internally by the device and can be printed to receive a welding protocol.

Tapping valve

Tapping of the tapping valve

Processing guidelines

Once the cooling time is up, under-pressure tapping may be started. For doing so, it is absolutely necessary to tension the clamp. The cutter, being an integrated part of the tapping valve, is turned clockwise by the respective tapping attachment until it reaches the stop. As soon as the pipe has been tapped this way, the cutter is turned back, now allowing the pipe to be connected.

It is understood that for tapping the service line must have been provided in advance. If necessary, the tapping valve can be closed again from outside by means of the respective tapping attachment.

Following dimensions and SDR rows are weldable and to tap with AGRU tapping saddle with valve and universal tapping saddle.

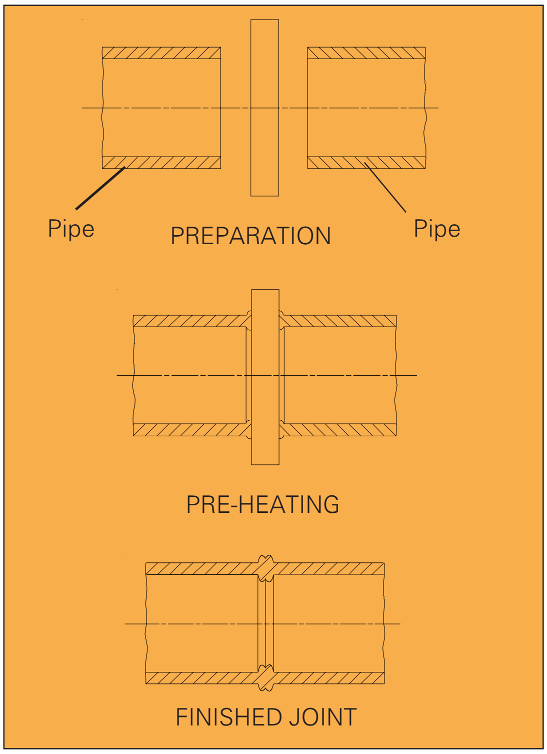
DIM	SDR 17	SDR 11	SDR 7,4	ovality
63	+	+	-	1,5%
75	+	+	-	1,5%
90	+	+	-	1,5%
110	+	+	-	1,5%
125	+	+	-	1,5%
140	+	+	-	1,5%
160	+	+	-	1,5%
180	+	+	-	1,5%
200	+	+	-	1,5%
225	+	+	-	1,5%

Heating element butt welding

(following to DVS® 2207, part 1 for PE-HD)

Welding method description

The welding faces of the parts to be joined are aligned under pressure onto the heating element (alignment). Then, the parts are heated up to the welding temperature under reduced pressure (pre-heating) and joined under pressure after the heating element has been removed (joining).



Principle of the heating element butt welding illustrated by a pipe.

All welding must be practised with machines and devices which correspond to the guidelines of the DVS® 2208 part 1.

Preparations before welding

Control the necessary heating element temperature before each welding process. That happens e.g. with a high speed thermometer for surface measurements. The control measurement must happen within the area of the heating element which corresponds to the semi finished product. That a thermal balance can be reached the heating element should be used not before 10 minutes after reaching the rated temperature.

For optimal welding clean the heating element with clean, fluffless paper before starting of each welding process. The non-stick coating of the heating element must be undamaged in the working area.

For the used machines the particular joining pressure or joining power must be given. They can refer to e.g. construction information, calculated or measured values. In addition during the pipe welding process by slow movement of the workpieces occurs a movement pressure or movement power which can be seen on the indicator of the welding machine and should be added to the first determined joining power or joining pressure.

The nominal wall thickness of the parts to be welded must correspond to the joining area.

Before clamping the Pipes and fittings in the welding machine they must be axial aligned, The ligh longitudinal movement of the parts to be welded is to ensure for exsample through adjustable dollies or swinging hangings.

The areas to be welded should be cleaned immediately before the welding process with a PE cleaner, so that they are plane parallel in this clamped position. Permissible gap width under adapting pressure see following table.

Pipe outside diameter [mm]	die gap width [mm]
≤ 355	0,5
400 ... < 630	1,0
630 ... < 800	1,3
800 ... ≤ 1000	1,5
>1000	2,0

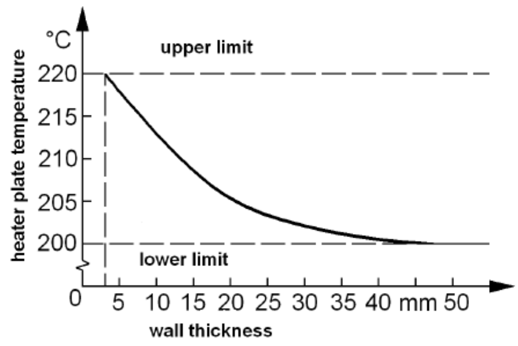
Together with the control of the gap width also the disalignment should be checked. The disalignment of the joining areas to one another should not overstep the permissible degree of 0,1 x wall thickness on the pipe outside or on the table respectively.
Not worked welding areas shouldn´t be dirty or touched by hands otherwise a renewed treatment is necessary. Shavings which are fallen in the pipe should be removed.

Heating element butt welding

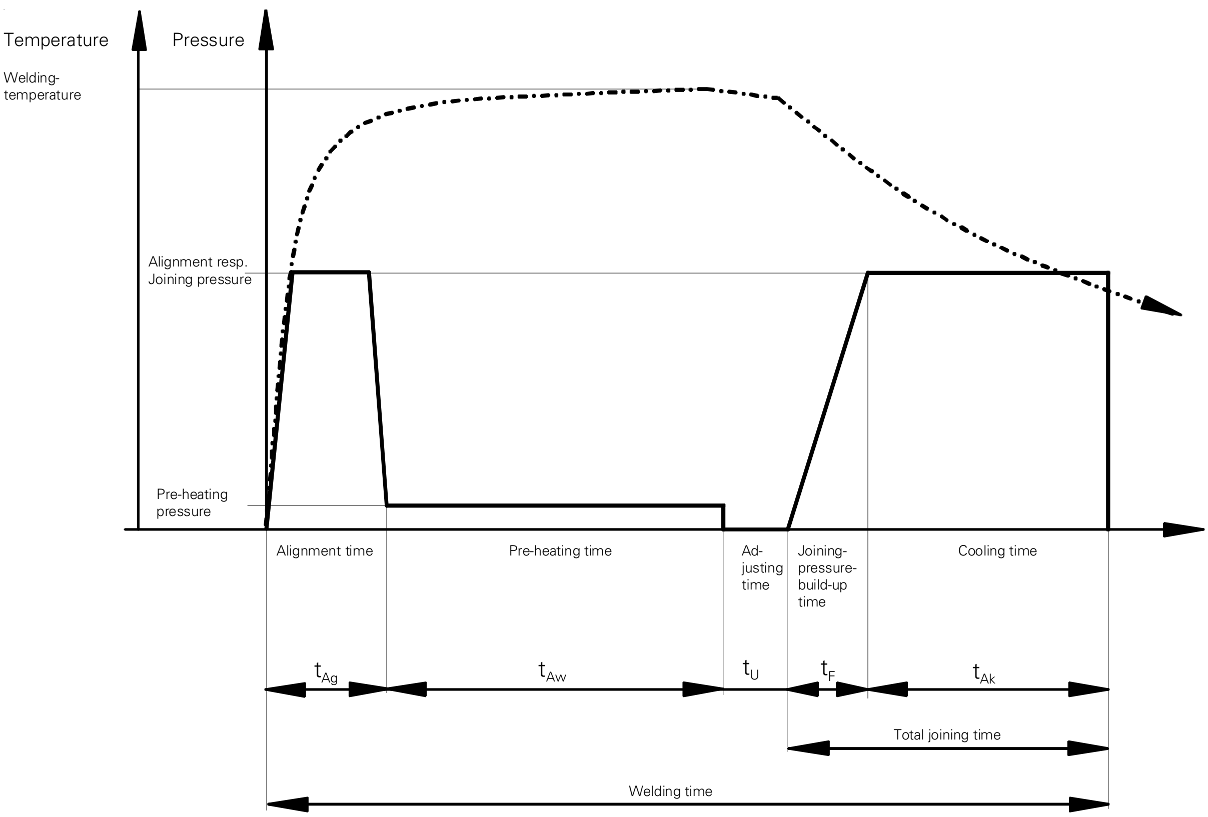
Performing of the welding process

On heating element butt welding the areas to be joined get warm up to the requested welding temperature with heating elements and after the removal of the heating element they join togehter under pressure. The heating element temperatures are listed in the following table.Generally the aim is to use higher temperatures for smaller wall thicknesses and the lower temperatures for larger wall thicknesses (see chart).

	PE
Heating element temperature [°C]	200 up to 220



The gradually sequences of the welding process



Heating element butt welding

Welding parameters

Reference values for heating element butt welding of PE pipes and fittings at outside temperatures of about 20°C and low air-speed rates.

Type of material	Wall thickness [mm]	Bead height [mm]	Pre-heating time t_{AW} [sec]	Adjusting time t_U [sec]	Joining pressure build-up time t_F [sec]	Cooling time t_{Ak} [min]
		P=0,15 N/mm²	P≤0,02 N/mm²		P=0,15 N/mm²	
PE80 PE100	 4,5	0,5	 45	5	5	6
	4,5 7,0	1,0	45 70	5 6	5 6	6 10
	7,0 12,0	1,5	70 120	6 8	6 8	10 16
	12,0 19,0	2,0	120 190	8 10	8 11	16 24
	19,0 26,0	2,5	190 260	10 12	11 14	24 32
	26,0 37,0	3,0	260 370	12 16	14 19	32 45
	37,0 50,0	3,5	370 500	16 20	19 25	45 60
	50,0 70,0	4,0	500 700	20 25	25 35	60 80

Specific heating pressure

In most cases, the heating pressure [bar] or the heating force [N], which have to be adjusted, may be taken from the tables on the welding machines. For checking purposes or if the table with pressure data are missing, the required heating pressure has to be calculated according to the following formula:

When using hydraulic equipment, the calculated welding force [N] has to be converted into the necessary adjustable hydraulic pressure.

Calculation of the welding area:

$$A_{Rohr} = \frac{\left(da^2 - di^2\right) \cdot \pi}{4}$$

oder

$$\approx d_m \cdot \pi \cdot s$$

Calculation of the welding force:

$$F = p_{spez} \cdot A_{Rohr}$$

Heating element butt welding

Alignment

Here adjusting surfaces to be joined are pressed on the heating element until the whole area is situated plane parallel on the heating element. This is seen by the development of beads. The alignment is finished when the bead height has reached the requested values on the whole pipe circumference or on the whole sheet surface. The bead height indicates that the joining areas completely locate on the heating element. Before the welding process of pipes with a larger diameter (>630mm) the sufficient bead development also inside the pipe must be controlled with a test seam. The alignment pressure works during the whole alignment process.

	PE
Specific heating pressure [N/mm²]	0,15 N/mm²

Pre-Heating

During the pre-heating process the joining areas must contact the heated tool with low pressure. At which the pressure will fall nearly to zero (<0,01 N/mm²). On pre-heating the warmth infiltrate in the parts to be welded and heat up to the welding temperature.

Adjustment

After the pre-heating the adjusting surfaces should be removed from the heating elements. The heating element should be taken away from the adjusting surfaces without damage and pollution. After that the adjusting surfaces must join together very quickly until immediately prior to contact. The adjusting time should be keept as short as possible, otherwise the plasticised areas will cool down and the welding seam quality would be influenced in a negative way.

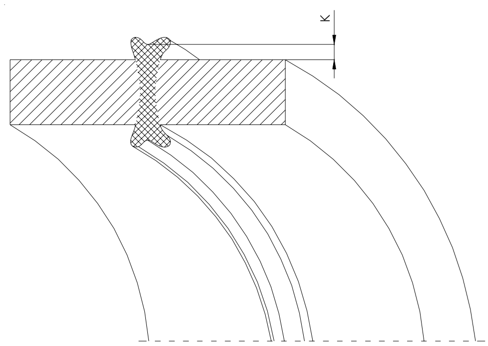
Joining

The areas to be welded should coincide by contact with a velocity of nearly zero. The required times are shown in the table (page 50).
Raised mechanical loads during or directly after the declamping are allowed only after cooling is finished. The joining pressure has to be kept completely during the cooling time at ambient temperature (see page 50).

The reduction of the cooling time up to 50 %, that means joining pressure release and remove of the welded part from the welding equipment, is allowed under the following requirements:

- the welding is done under workshop conditions
- the removal from the welding equipment and the temporary storage are causing only slight loads to the joint
- it concerns components with a wall thickness of ≥ 15 mm.

After joining, a double bead surrounding the whole circumference must have been created. The bead development gives an orientation about the regularity of the weldings. among each other. Possible differences in the formation of the beads may be justified by different flow behaviour of the joined materials. From experience with the commercial semi finished products in the indicated MFR-field can be assumptioned from the welding tendency, even when this can lead to unsymetrical welding beads. K must be bigger than 0.



Performing of pressure test

Before the pressure testing, all welding joints have to be completely cooled down (as a rule, 1 hour after the last welding process). The pressure test has to be performed according to the relevant standard regulations (e. g. DVS® 2210 Part 1 - see table pressure test).
The piping system has to be protected against changes of the ambient temperature (UV-radiation).

Pressure test according to DVS® 2210 part 1:

object		pre-test	main-test	short-test
Test pressure		1,5 x PN max. PN + 5 bar	1,3 x PN max. PN + 3 bar	1,5 x PN max. PN + 5 bar
test period	piping systems without branches compl. L ≤ 100m	minimum 3 h	minimum 3 h	minimum 1 h
	piping systems without branches compl. L ≥ 100m	minimum 6 h	minimum 6 h	minimum 3 h
control during test procedure		each 1 h **with** restore of test-pressure	each 1,5 h **without** restore of test-pressure	each 1 h **without** restore of test-pressure
material specific pressure drop (average value)		up to 0,8 bar/h	up to 0,8 bar/h	up to 0,8 bar/h
note for the respective test		standard		special case (agreement with client required)

Heating element butt welding

Requirements on the welding device used for heating element butt welding
(following to DVS® 2208, part 1)

Clamping device

In order to avoid high local stresses in the pipe and deformations, the clamping devices should surround at least the pipe casing as parallel as possible to the welding plane. By their high stability, it must be provided that the geometric circular form of the pipes will be maintained. They must not change their position in relation to the guide elements, even under the highest working forces. For fittings, such as stub flanges and welding neck flanges, special clamping devices which prevent deformations of the workpiece have to be used.

The pipe clamped at the mobile machine side has eventually to be supported and exactly adjusted by means of easy-running dollies so that the working pressures and conditions required for welding can be maintained.

It is recommendable to use clamp elements adjustable in height to allow a better centering of the workpieces.

Guide elements

Together with the clamping devices, the guide elements have to ensure that the following maximum values for gap width (measured on cold joining surfaces) are not surpassed due to bending or beaming at the least favourable point in the respective working area of the machine at max. operating pressure and with wide pipe diameters (see table on page 53).

The gap width is measured by inserting a spacer at the point opposite to the guide while the plane-worked pipes are clamped. Guide elements have to be protected against corrosion at the sliding surfaces, e. g. by means of hard chrome plating.

Heating elements

The heating element has to be plane-parallel with its effective area.
Permissible deviations from plane-parallelity (measured at room temperature after heating the elements to maximum operating temperature at least once):

Pipe outside Ø resp. edge length	admissible deviation
÷ 250 mm	≤ 0,2 mm
÷ 500 mm	≤ 0,4 mm
> 500 mm	≤ 0,8 mm

For processing in a workshop, the heating element is in general permanently mounted to the device. In case of a not permanently attached heating element, adequate devices have to be provided for its insertion (e.g. handles, hocks, links).

If the size and nature of the heating elements necessitates its machine-driven removal from the joining surfaces, adequate equipment has to be provided too.

The power supply has to be protected against thermal damage within the range of the heating elements. Likewise, the effective surface of the heating element has to be protected against damage.

Protecting devices are to be used for keeping the heating element during the intervals between the welding processes.

Heating element butt welding

Requirements on the welding device used for heating element butt welding (following to DVS® 2208, part 1)

Devices for welding seam preparation

An adequate cutting tool has to be prepared with which the joining surfaces of the clamped pipe can be machined in a plane-parallel way. Maximum permissible deviations from plane-parallelity at the joining surfaces are:

Pipe outside Ø da [mm]	deviation [mm]
< 400	≤ 0,5
≥ 400	≤ 1,0

The surfaces may be worked with devices which are mounted on or which can be introduced easily (e. g. saws, planes, milling cutters).

Control devices for pressure, time and temperature

The pressure range of the machine has to allow for a pressure reserve of 20 % of the pressure, which is necessary for the maximum welding diameter and for surmounting the frictional forces.
Pressure and temperature have to be adjustable and reproducible. Time is manually controlled as a rule.

In order to ensure reproducibility, a heating element with electronic temperature control is to be preferred. The characteristic performance and tolerance values have to be ensured.

Machine design and safety in use

In addition to meet the above requirements, machines used for site work should be of light-weight construction.
Adequate devices for transportation and introduction into the trench have be available (e. g. handles, links).
Especially if voltages above 42 V are applied, the relevant safety regulations of VDE and UVV have to be observed in the construction and use of the machines.

Heating elemet socket welding

Heating element socket welding (following to DVS® 2207, part 1 for PE-HD)

Welding method

On heating element socket welding, pipe and fittings are lap-welded. The pipe end and fitting socket are heated up to welding temperature by means of a socket-like and spigot-like heating element and afterwards, they are joined.

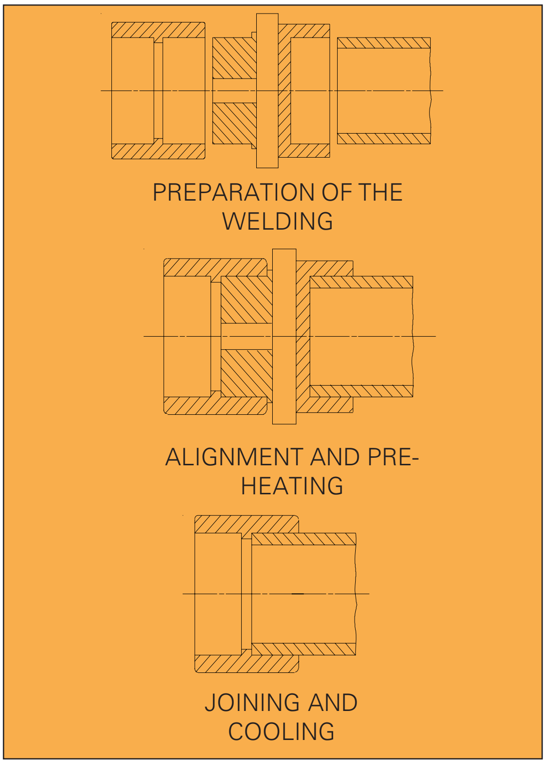
The dimensions of pipe end, heating element and fitting socket are coordinated so that a joining pressure builds up on joining (see schematic sketch).

Heating element socket weldings may be manually performed up to pipe outside diameters of 40 mm. Above that, the use of a welding device because of increasing joining forces is recommended.
The guidelines of the DVS® are to be adhered to during the whole welding process!

Welding temperature (T)

PE-HD	250 ÷ 270 °C

Schematic sketch of the welding process



Welding parameters

Reference values for the heating element socket welding of PP and PE-HD pipes and fittings at an outside temperature of about 20°C and low air-speed rates

Material type	Pipe outside diameter da [mm]	Welding temperature [°C]	Pre-heating time t_{AW} [sec]		Adjusting time t_U [sec]	Cooling time t_{Ak}	
			SDR 17,6; 17	SDR 11; 7,4; 6		fixed [sec]	overall [min]
PEHD	16		-	5	4	6	2
	20	250 ÷ 270	-	5	4	6	2
	25		1)	7	4	10	2
	32		1)	8	6	10	4
	40	250 ÷ 270	1)	12	6	20	4
	50		1)	18	6	20	4
	63		1)(PEHD); 10 (PP)	24	8	30	6
	75	250 ÷ 270	15	30	8	30	6
	90		22	40	8	40	6
	110	250 ÷ 270	30	50	10	50	8
	125	250 ÷ 270	35	60	10	60	8

1) not recommended because of too low wall thickness

Processing guidelines
Heating element socket welding

Preparation of welding place

Assemble welding equipment, prepare tools and machinery, control welding devices

Preparation of welding seam

(at any rate immediately before starting the welding process)

Cut off pipe faces at right angles and remove flashes on the inside with a knife.
The pipe-ends should be chamfered following to DVS® 2207; part 1 and the opposite table.
Work the pipe faces with a scraper until the blades of the scraper flush with the pipe face.
Thoroughly clean welding area of pipe and fittings with fluffless paper and cleansing agents (acetone or similar).
If peeling is not necessary, work the pipe surface with a scraper knife and mark the depth (t) on pipe.

Pipe diameter d [mm]	Pipe chamfer for PEHD b [mm]	Insert length for PEHD l [mm]
16	2	13
20	2	14
25	2	15
32	2	17
40	2	18
50	2	20
63	3	26
75	3	29
90	3	32
110	3	35

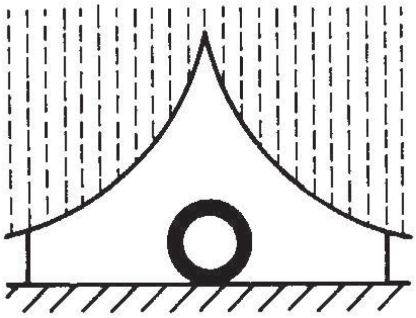
Preparations before welding

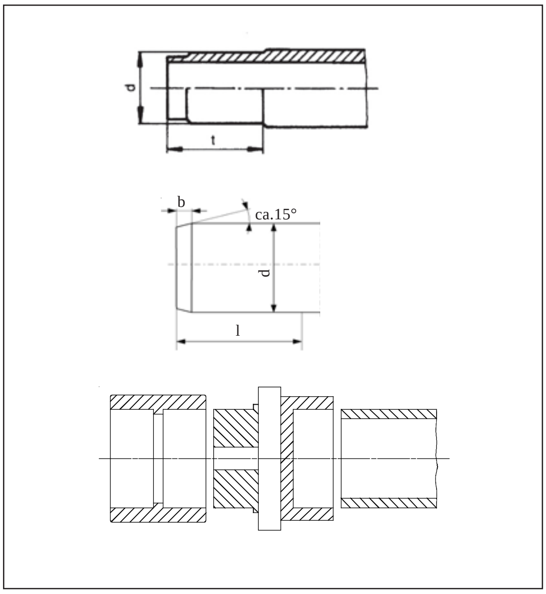
Check temperature of heating element (on heating spigot and on heating socket).
Thoroughly clean heating spigot and heating socket immediately before each welding process (with fluffless paper). At any rate, be careful that possibly clogging melt residues are removed.

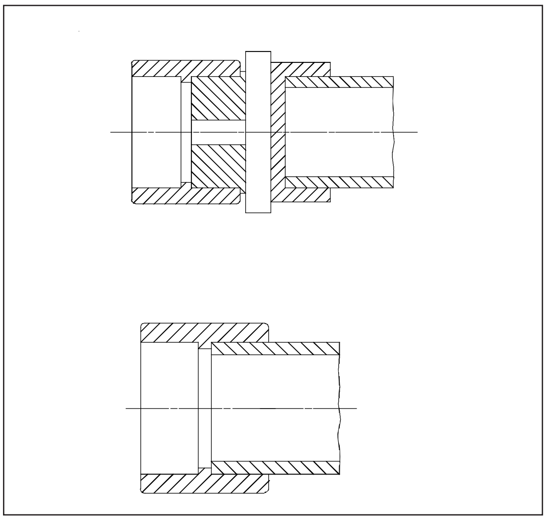
Performing of welding process

Quickly push fitting and pipe in axial direction onto the heating spigot or into the heating socket until the end stop (or marking). Let pass by pre-heating time according to table values.
After the pre-heating time, pull fitting and pipe off the heating element with one heave and immediately fit them into each other without twisting them until both welding beads meet.
Let the joint cool down, then remove clamps.
Only after the cooling time, the joint may be stressed by further laying processes.

Welding by hand:
Adjust the parts and hold them fast under pressure for at least one minute. (see table: page 54:fixed cooling time)







Material Properties
Installation Guidelines
Calculation Guidelines
Connection Systems
Applications and References
Approvals and Standards

Processing guidelines
Heating element socket welding

Visual welding seam control

Check out bead of welding seam. It must be visible along the whole circumference of the pipes.

Performing of pressure test

Before the pressure testing, all welding joints have to be completely cooled down (as a rule, 1 hour after the last welding process). The pressure test has to be performed according to the relevant standard regulations (e. g. DVS® 2210 Part 1, DIN 4279 part 8 - see tabele on page 41).
The hereby imposed maximum test pressure is 1,5 x PN, whereby during the test period (10 minutes at least) no pressure drop is allowed. The piping system has to be protected against changes of the ambient temperature (UV-radiation).

Requirements on the welding device used for heating element socket welding (following to DVS® 2208, part 1)

Devices for heating element socket welding are used in workshops as well as at building sites. As single purpose machines, they should allow for a maximum degree of mechanization of the welding process.

Clamping devices

Marks on workpiece surfaces caused by special clamping devices for pipe components must not affect the mechanical properties of the finished connection.

Guide elements

Together with clamping devices and heating element, the guide elements have to ensure that the joining parts are guided centrically to the heating element and to each other. If necessary, an adjusting mechanism has to be provided.

Machine design and safety in use

In addition to meet the above requirements in construction and design, the following points should be considered for the machine design:
- Stable construction
- Universal basic construction (swivelling or retractable auxiliary tools and clamps)
- Quick clamping device
- Maximum degree of mechanization (reproducable welding process)

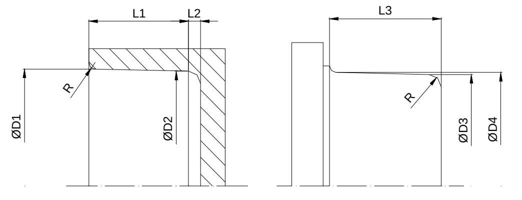
Heating element socket welding

Requirements on the welding device used for heating element socket welding (following to DVS® 2208, part 1)

Heating elements

Contained in the table the values (correspond to the draft of ISO TC 138 GAH 2/4 draft, document 172 E) apply to the dimensions of the heating tools.

Dimensions of heating elements for heating element socket welding fittings
Type B (with mechanical pipe working)



Heating socket   Heating spigot

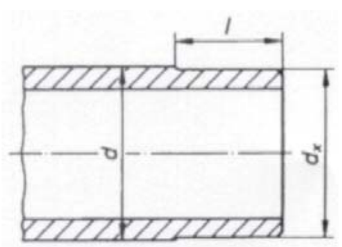
Pipe diameter [mm]	ØD1 [mm]	ØD2 [mm]	ØD3 [mm]	ØD4 [mm]	L1 [mm]	L2 [mm]	L3 [mm]	R [mm]
16	15,9	15,76	15,37	15,5	14	4	13	2,5
20	19,85	19,7	19,31	19,45	15	4	14	2,5
25	24,85	24,68	24,24	24,4	17	4	16	2,5
32	31,85	31,65	31,17	31,35	19,5	5	18	3,0
40	39,8	39,58	39,1	39,3	21,5	5	20	3,0
50	49,8	49,55	49,07	49,3	24,5	5	23	3,0
63	62,75	62,46	61,93	62,2	29	6	27	4,0
75	74,75	74,42	73,84	74,15	33	6	31	4,0
90	89,75	89,38	88,75	89,1	37	6	35	4,0
110	109,7	109,27	108,59	109	43	6	41	4,0
125	124,7	124,22	123,49	123,95	48	6	46	4,0

1)Dimensions are valid at 260 ÷ 270°C

Dimensional tolerances:÷ 40 mm ± 0,04 mm
> 50 mm ± 0,06 mm

Tools for welding seam preparation

At heating element socket welding with mechanical pipe working (method type B), a scraper is required for calibrating and chamferring the joining surfaces of the pipe. This has to correspond to the heating element and to the fitting socket. The scraper is adjusted with a plug gauge.



For the socket welding prepared pipe end (dimensions see table)

Calibration diameter and length for the machining of pipe ends with method, type B

Pipe outside diameter [mm]	Calibration diameter dx [mm]	Calibration length l [mm]
20	19,9 ± 0,05	14
25	24,9 ± 0,05	16
32	31,9 ± 0,05	18
40	39,85 ± 0,10	20
50	49,85 ± 0,10	23
63	62,8 ± 0,15	27
75	74,8 ± 0,15	31
90	89,8 ± 0,15	35
110	109,75 ± 0,20	41
125	124,75 ± 0,20	44

Detachable joints

Flange connections and Unions of piping systems
If pipe joints are connected by means of flanges, the following guidelines have to be adhered to:

Aligning of parts
Before applying of the screw initial stress, the sealing faces have to be aligned planeparallel to each other and fit tight to the sealing. The drawing near of the flange connection with the resulting occurrence of tensile stress has to be avoided under any circumstances.

Tightening of screws
The length of the screws has to be chosen such a way that the screw thread is flush with the nut. Washers have to be placed at the screw head and also at the nut.
The connecting screws have to be screwed by means of a torque key (torque values see table).

Unions of piping systems
To avoid of unpermissible loads at the installation, unions with round sealing rings should be applied.

The union nut should be screwed manually or by means of a pipe band wrench (pipe wrenches should not be used).

Prevent the application of unions at areas with bending stresses in the piping systems.

Generally
It is recommend to brush over the thread, e. g. with molybdenum sulphide, so that the thread stays lubricated for a longer operation time.
On choosing the sealing material, special attention has to be paid to chemical and thermal suitability.

da OD [mm]	p [bar]	DN [mm]	screws		
			number	thread	[Nm]
20	16	15	4	M 12	15
25	16	20	4	M 12	15
32	16	25	4	M 12	15
40	16	32	4	M 16	25
50	16	40	4	M 16	35
63	16	50	4	M 16	35
75	16	65	4	M 16	40
90	16	80	8	M 16	40
110	16	100	8	M 16	40
125	16	100	8	M 16	45
140	16	125	8	M 16	50
160	16	150	8	M 20	60
180	16	150	8	M 20	60
200	16	200	8	M 20	70
225	16	200	8	M 20	70
250	16	250	12	M 20	100
280	16	250	12	M 20	100
315	16	300	12	M 20	110
355	16	350	16	M 20	160
400	16	400	16	M 24	170
450	10	500	20	M 24	190
500	10	500	20	M 24	190

Application

Bind of highquality drinkingwaterreservoir in to an urban waterwork

Onsite extrusion:
Pipe length up to 2,5km
joining: Flange connection with steel casing
admissible operating pressure: up to 20 bar
length 8,6 km (6,5 km in the lake 2,1 km in the river)
Dimension: da 315 x 35mm and da 315 x 27mm

Material:
Eltex Tub 121 schwarz – MRS 10 according ISO 9080
excellent long-term pressure strength
Good resistance to slow and rapid crack growth

Quality Assurance:
automatic recording through continuous ultrasonic wall thickness measurement
accompanying tests through „TGM Vienna"

Installation:
Weigh down with concrete blocks
Conntrolled lowering due to water filling
Up to an installation depth of 168m

Connection of different towns to the gas network

Pipesystem:
Material: PE 80 yellow - MRS 8 acc. ISO 9080
Dimension: ø 160 x 14,6 mm
Operating pressure: up to 4 bar
Connectiontechnic: Heating element butt welding
Length of pipeline: 9.029 m
length of piperope:: up to 120 m

Quality Assurance:
continuous ultrasonic wall thickness measurement and quality controls during the whole production by a according to ISO 9001 certified production.

Installation:
Steerable drilling system with a minimum installation depth of 1,0 m

Reference projects

Fire water pipeline for an engine factory

The underground pressure piping systems for the fire water are implemented with FM (Factory Mutual) approved PE 100 pipes and fittings by company AGRU Kunststofftechnik GmbH. The supplied pipes and fittings of the dimensions Ø 90 to Ø 400 are FM Class NUMBER 1613 „Pipes & fittings for Underground Fire Protection service" approved.

All pipes and fittings were joined together tight and material conform by heating element butt welding or electro fusion welding. And so the danger of corrosion or leakage is impossible. Consequently therefore it is also possible to enlarge and/or to extend the piping system without larger efforts.

More than 1200 m PE 100 pipes in the dimensions from Ø 90 to Ø 400 were processed for the fire water supply. Additionally to the pipes also fittings such as elbows, tees, reducers and end caps in the dimensions mentioned above were integrated into the piping system. The complete piping system is designed for a lifetime of more than 50 years.

Drinking water supply in a regional level

Material:	PE 100 black with blue stripes MRS 10 acc. ISO 9080
Dimension:	ø 250 x 22,7 mm
Operating pressure:	up to 16 bar
Length of pipeline:	4700 m

Joining technology:
The pipes are connected outside of the trench with heating element butt welding to pipelengths of approx. 100m. Afterwards the connection of the pipeline in the trench has been done by electro fusion welding.

Installation:
Steerable drilling system with a minimum installation depth of 1,5 m

Reference projects

Drinking water supply in the mining industrie

Pipingsystem:

Material:	PE 100 schwarz MRS 10 nach ISO 9080
Dimension:	Ø560 x 50,8 mm
Operating pressure:	up to 16 bar
Length of pipeline:	8000 m

Joining technology:
The pipes are connected with heating element butt welding to one pipeline.
Afterwards the pipeline will put into the trench by a digger.

Piping systems for water supply in liquid gas treatment plants

Securing the potable water supply for a new liquid gas plant and an oil terminal means an installation of a piping system in a difficult territory. To provide a durable potable water supply it was required to install 2 pipelines parallel in a pipe trench with a total length of 7 km

Joining technology:
The pipes are connected outside of the trench with heating element butt welding to pipelengths of approx. 600m.

After retracting the pipes into the pipe trench the complete piping system has been embedded in sand, filled and consolidated with excavation material.

Reference projects

artificial snow for different skiing regions

To guarantee a snow reliability during the whole winter period, skiing regions invest in an expansion of artificial snow equipment. For the supply of water and compressed air up to a sea level of 2100 m AGRU pipes and fittings are used. The installer decided to connect all pipes and fittings with electro fusion welding. This welding technology can be used down to an ambient temperature of –10°C.

As shown on the pictures AGRU electro fusion fittings demonstrated that under compliance with the working instruction according to DVS 2207 part 1 and to the AGRU welding guidelines the welding without clamping device is possible in spite of most difficult installation situations.

The complete piping system has been welded outside of the trench. After the welding the pipeline was put into the trench.

Tunnel drainage
Upper Austria, Austria

For the drainage of the tunnels at the motor highway A9 the customer used PE 100 pipes OD 315mm SDR 17.

The pipes are connected with electro fusion couplers and installed in open trench construction.

Reference list

Germany:
REWAG Regensburg
Gasag Berlin
E.ON edis AG,
Gasversorgung Thüringen
KW Hanau
EWE AG Oldenburg
GVG Franken
SW Marburg

England:
British Gas

France:
Gaz de France

Columbia:
Gas Natural- Bogota

Italy:
ACEGAS-APS SPA Disvisione Acqua -Gas - Trieste /Padova
AGAM Ambiente Gas Acqua Monza SPA - Monza
AIM Vicenca Gas SPA - Vicenca
AMAG SPA Azienda Multiutilities Acqua-Gas - Alessandria
ASA SPA Azienda Servizi Amientali - Livorno
ASM Moratara SPA - Mortara
ASM Vigevano e Lomellina SPA - Vigevano
ASM Voghera SPA Azienda Servizi Municipiali - Voghera

Spain:
Gaz Natural - Barcelona

Mexico:
Gas Natural - Monterey

Brazil:
Comgas - Sao Paulo

Croatia:
Energija Rijeka
Brod PLim
Koming
TEMEX

Austria:
OOE Ferngas - Linz
EVN - Wr. Neudorf
Wiengas - Vienna
BEGAS - Eisenstadt
GFB - Sulz
VEG - Dornbirn
Stadtwerke - Innsbruck
SBL Linz - Linz
Tassilo Kurbetriebe - Bad Hall

Japan:
Mesco

Tunisia:
Steg

Australia:
The Australian Gas light Company Ltd
Origin Energy Ltd
Agility Ltd

New Zealand:
AGRU New Zealand Ltd
Stockma General
Auckland Metro Water
Auckland North Shore City
Vector Ltd

Norway:
Polarcirkel AS
Plastsveis AS
Preplast Industrier AS

Sweden:
Gothenburg Water

Russia:
Polyplastic Group

Algeria:
Sonelgaz

3rd party control

In addition to internal controls, regular tests on products and of internal procedures, performed by independently accredited test institutes, are of prime importance. This 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.

Presently following institutes are commissioned for the production:

TUV - Bayern
MPA - Darmstadt
IIP - Milano
SKZ - Wuerzburg
Versuchsanstalt fuer Kunststoff- und Umwelttechnik am TGM - Vienna

The high quality standard of our products is documented by a series of approvals.

The AGRULINE program is in following countries for the gas and water supply certified.

	Land	Gas	Water
OEVGW	Austria	✓	✓
DVGW	Germany	✓	✓
SVGW	Swiss	✓	✓
IIP - UNI	Italia	✓	
DIN Gost TUEV	Russia	✓	✓
EN 12201	Europe		✓
EN 1555	Europe	✓	
EN 13244	Europe	Sewage	
BELGAQUA	Belgium		✓
Gaz de France	France	✓	
Electrabel	Belgium	✓	
Watermark	Australia / New Zealand		✓
Install	Poland	✓	✓
GAS NATURAL	Spain	✓	
Dibt	Germany		✓

FM - Approved Pipes and Fittings according to FM Class 1613 - "Plastic pipes and fittings for underground fire protection service"

Standards

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

Hereafter a summary of the most important standards for PE.

OENORM B 5014, Teil 1

DIN 8074/8075
Pipes out of Polyethylen (PE)

DIN 16963, part 1 - part 15
Pipe joints and their elements for pipes of high density polyethylene (HDPE) under pressure

EN 1555, part 1 - part 5
Plastics piping systems for gassupply - Polyethylene (PE)

EN 12201, part 1 - part 5
Plastics piping systems for water supply - Polyethylene (PE)

EN 13244, part 1 - part 5
Plastics piping systems for buried and above-ground pressure systems for water for general purposes, drainage and sewerage – Polyethylene (PE)

ISO 1872
Kunststoffe - Polyethylen (PE) - Formmassen

ISO 4065
Thermoplastic pipes - Universal wallthickness table

ISO 4427
Polyethylene (PE) pipes for water supply - Specifications

ISO 4437
Plastic pipes and fittings - Buried polyethylene (PE) pipes for the supply of gaseous fuels - Metric series - Specifications

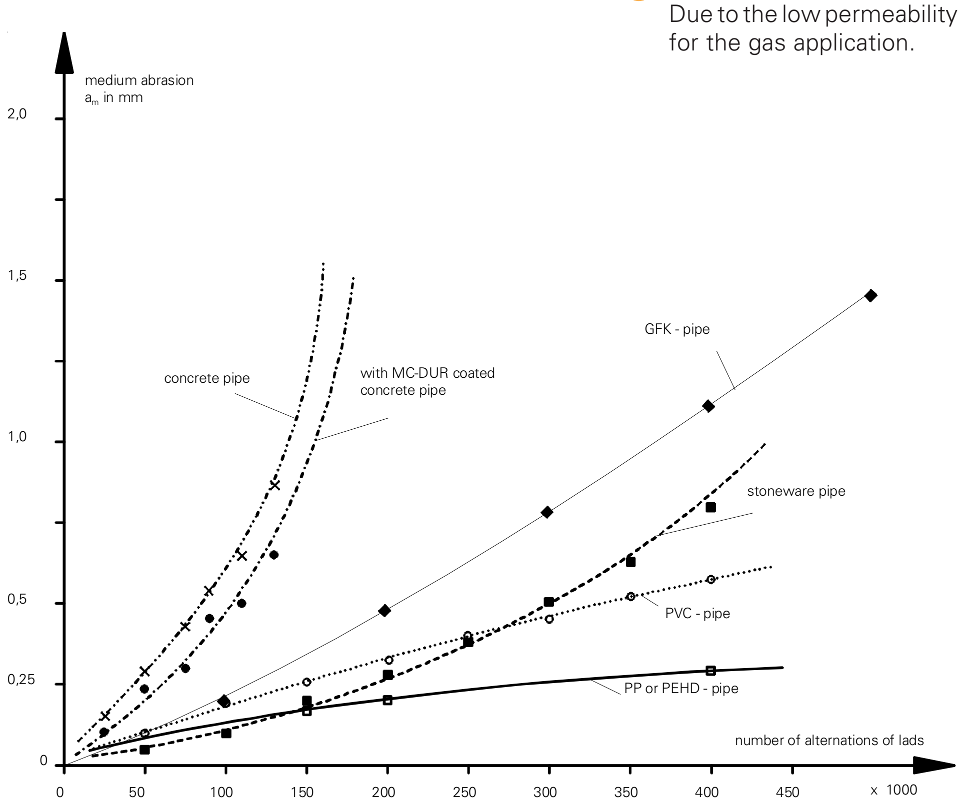
System of units

Size	Technical system of units	SI - unit (MKS-system) Legal unit	ASTM - unit
Length	m	m 1m = 10dm = 100cm = 1000mm 1000m = 1km	ft 1,609km(statute) = 1Meile = 1,852km (naut.) = 1Mile 0,9144m = 1yd = 3ft 25,4mm = 1 inch
Area	m²	m² 1m² = 100dm² = 10000cm²	yd² 0m836m² = 1yd 1yd² = 9ft²
Volume	m³	m³ $1m^3 = 10^3dm^3 = 10^6cm^3$	yd³ 0,765m³ = 1yd³ 1yd³ = 27ft³
Force	kp 1N = 0,102kp 1kp = 9,81N	N $1N = 1kgm/s^2 = 10^5$ dyn	lb 1lbf = 4,447N = 32poundals
Pressure	kp/m² 1N/cm² = 0,102kp/cm² 0,1bar = 1mWS 1bar = 750Torr 1bar = 750 mmHg 1bar = 0,99atm	bar $1bar = 10^5Pa = 0,1N/mm^2$ $10^6Pa = 1MPa = 1N/mm^2$	psi 1bar = 14,5psi = 14,5lb/sq in
Mechanical stress	kp/mm² 1N/mm² = 0,102kp/mm²	N/mm²	psi 1N/mm² = 145,04psi = 145,04lb/sq in
Velocity	m/s	m/s	ft/sec. 1m/s = 3,2808ft/sec.
Density	g/cm³	g/cm³	psi $1g/cm^3 = 14,22x10^{-3}psi$
Volume	m³	m³	cu ft 1m³ = 35,3147 cu ft = 1,3080 cu yd 1cm³ = 0,061 cu in
Temperature	°C	°C 1°C = 1K	°F °F = 1,8 x °C + 32

General Advantages of Polyethylene

Flexibility
The flexibility of the pipe ensures that minor deviations in the excavated trench can be taken up by the pipe without the use of fittings.
The „water hammer“ event is allowed up to a height of 2 times the nominal pressure (detailed information see on page 70).
The flexibility of PE enables the pipe to follow ground settlements. The installation can be performed trenchless (ploughing or shooting in of a pipe).

Abrasion Resistance
The abrasion time of polyethylene is much more lower than that of substitute materials as concrete, cast iron, steel, FRP or PVC.



Low Weight
Polyethylene is much lighter than concrete, cast iron or steel. The result is an easier handling and installing and also reduce manpower and equipment on site.

Favourable Transportation
Due to the fact that Polyethylene pipes can be delivered on coils up to 300 meters, the number of joints can be reduced.

Chemical Resistance
Polyethylene is resistant to most aggressive chemicals and corrosive elements.

Weathering Resistance
Polyethylene is stabilized with minimum 2% of well dispersed carbon black, giving the compound long term resistance to weathering.

Weldability
Welding is the safest way to perform the connection of pipes and fittings. Polyethylene distinguishes itself by excellent welding properties.

No Deposits and no Overgrowth
Due to the smooth internal surface of polyethylene pipes and fittings no deposits and no overgrowth can occur.

Suitable for Potable Water
AGRU Polyethylene resins are NSF approved for potable water.

Low Permeability
Due to the low permeability polyethylene is suitable for the gas application.

Molding Material

The material used for manufacture is PPI listed as PE 4710 former 3408 (equivalent to PE100) in PPI TR-4 and NSF approved.
This listing of the „**P**lastics **P**ipe **I**nstitute“ is a basic prerequisite for the application on the American market.
The PE 4710/3408 designation is essentially a classification of the strength. According to ASTM D 2837 the material corresponds to a strength of 1600 psi at a temperature of 73,4°F and a life time of 100.000 hours (~11,4 years). This strength is designated as HDB (**H**ydrostatic **D**esign **B**asis).
PE 100 types (acc. ISO 9080) correspond normally to this PE 4710/3408 classification.

The detailed specification is done by ASTM D 3350 by cell classification.
This classification allows more specific identification of the density, melt index, flexural modulus, tensile strength, environmental stress crack resistance and the hydrostatic design basis. Also the colour and the UV stabilizer are defined by this classification (e.g. C: black with 2% minimum carbon black).

One typical resin used for manufacture complies with the cell classification of 445574C according to ASTM D3350:

Property	Test Method	Classification			
		3	4	5	7
Density [g/cm³]	ASTM D 1505	0,940 - 0,955	**>0,955**	-	specify value
Melt index condition E [g/10min]	ASTM D 1238	<0,4 - 0,15	**<0,15**	-	specify value
Flexural modulus [psi]	ASTM D 790	40,000 - <80,000	80,000 - <110,000	**110,000 - 160,000**	specify value
Tensile Strength at yield [psi]	ASTM D 638	2600 - <3000	3000 - <3500	**3500 - 4000**	specify value
Enviromental stress crack resistance [hrs]	ASTM D 1693	192	600	-	**5000**
Hydrostatic design basis [psi]	ASTM D 2837	1250	**1600**	-	

Material:

The resin used for manufacture complies with the cell classification of 445574C according to ASTM D3350. The material is PPI listed as PE 4710/3408 in PPI TR-4 and NSF approved.

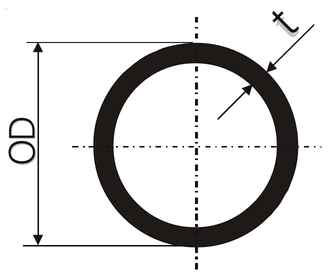
The material is stabilized with min. 2% of well dispersed carbon black, giving the compound long term resistance to weathering.

Property	Test Method	Nominal Values*
Density (flake)	ASTM D 4883	0.9485gm/cc
Density (pigmented)	ASTM D 4883	0.959gm/cc
Melt Flow Rate (190/21,6)	ASTM D 1238	10 g/10min
Tensile Strength 1) @ Yield @ Break	 ASTM D 638 ASTM D 638	 3625 psi 5500 psi
Elongation 1) @ Break	 ASTM D 638	 > 600 %
Flexural Modulus 2)	ASTM D 790	150000 psi
Vicat Softening Point	ASTM D 1525	259 °F
Hardness (Shore D)	ASTM D 2240	66
Environmental Stress Crack Resistance 3)	 ASTM D 1693	 >2000 hrs
Environmental Stress Crack Resistance 4) Hydrostatic Design Basis	 ASTM D 1693 ASTM D 2837	 >5000 hrs 1600 psi @ 73,4 °F 1000 psi @ 140 °F
Cell Classification	ASTM D 3350	445574C

1) 2in/min
2) 2% Secant-Method 1
3) Condition B, 10%
4) Condition C

*Nominal values are intended to be guide values only

SDR - Standard Dimension Ratio



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

SDR ... Diameter - wall thickness relation
OD ... outside diameter [inches]
t ... wall thickness [inches]

Example:
da = 4,5 inch
t = 0,264 inch

$$SDR = \frac{OD}{t} = \frac{4.5}{0.264} = 17$$

S - series

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

SDR ... Diameter - wall thickness relation

Example:
SDR11

$$S = \frac{SDR - 1}{2} = \frac{11 - 1}{2} = 5$$

Component operating pressure

$$P = \frac{2 \cdot HDB}{(SDR - 1) \cdot DF}$$

P ... Admissible Working Pressure [psi]
HDB... Hydrostatic design basis [psi]
(1600 psi for PE 4710/3408)
(1250 psi for PE 2406)
SDR ... Standard dimension ratio
DF ... Design factor

Example:
PE 3408, 73,4°F, 50 years, water (HDB = 1600 psi)
SDR11
DF=2,0

$$P = \frac{2 \cdot HDB}{(SDR - 1) \cdot DF} = \frac{2 \cdot 1600}{(11 - 1) \cdot 2} = 160 \text{ psi}$$

Design factor

The component operating pressure is calculated with a design factor of 2.0 (an industry accepted standard). This is valid for a temperature of 73,4°F and medium water.

Table of Working Pressure Rating
In Dependency of the Temperature

The pressure rating is influenced by the ambient temperature and the temperature of the medium. For higher temperatures than 73.4°F the working pressure ratings have to be reduced.
In the following table the recommended working pressure ratings of PE 4710 materials are shown in dependency of the temperature (basis is the hydrostatic design basis of 800 psi at 140°F):

Pressure Surge / Water Hammer Events

A „Water Hammer“ in a piping system is a pressure surge due to a sudden change of velocity in a non-compressible fluid media. The change in velocity could be caused by a sudden opening or closing of a valve, starting and stopping of pumps, pump failure or other dynamic event.

The magnitude of the pressure surge (**P_s**) can be calculated by the following equation:

$$S = 12 \cdot \left(\frac{K \cdot E}{(w/g)\cdot(E+(K\cdot SDR))} \right)^{½}$$

$$P_s = \frac{w \cdot S \cdot V_c}{144 \cdot g}$$

S	...	Speed of the pressure wave	[ft/s]
K	...	Bulk modulus of the liquid (300.000 for water)	[psi]
E	...	Modulus of elasticity (PE~100.000)	[psi]
SDR	...	Standard dimension ratio	
w	...	Fluid weight (water 62.4)	[lbs/ft^3]
g	...	Acceleration due to gravity (32.2)	[ft/s^2]
P_S	...	Change in pressure	[psi]
V_C	...	Change in velocity	[ft/s]

Example:
PE 3408 water piping system (K=300,000 / E=100.000 / w=62.4 / g= 32.2)
SDR 17
Working velocity 5 ft/s (sudden closing of a valve: V_C=5)

P_S = ?

$$S = 12 \cdot \left(\frac{K \cdot E}{(w/g)\cdot(E+(K\cdot SDR))} \right)^{½} =$$

$$=12 \cdot \left(\frac{300,000 \cdot 100,000}{(62.4/32.2)\cdot(100,000+(300,000\cdot 17))} \right)^{½} = 655 \text{ ft/s}$$

$$P_s = \frac{w \cdot S \cdot V_c}{144 \cdot g} = \frac{62.4 \cdot 655 \cdot 5}{144 \cdot 32.2} = 44 \text{ psi}$$

According to AWWA C906 PE can withstand repetitive surges up to 150% and occasional surges up to 200% of the designed working pressure rating. If the pressure surge is higher than this recommended values, the magnitude of the water hammer can be influenced by the time of changing the flow velocity (e.g. closing time of valves). This time should be greater than two times the length of the piping system divided by the speed of the pressure wave.

t	...	Time of changing the flow[	s]
L	...	Length of the piping system	[ft]
S	...	Speed of the pressure wave	[ft/s]

$$t \geq \frac{2 \cdot L}{S}$$

Pressure Loss in Fittings

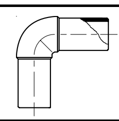
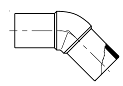
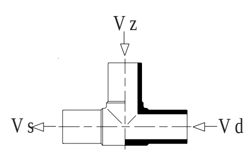
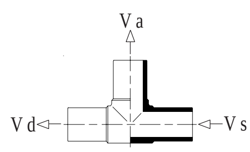
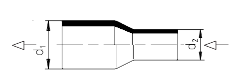
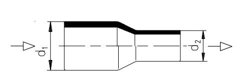
Beside the pipe cross section, the length of a piping system, the roughness of a piping system, ... also the pressure loss in fittings is a part of the total pressure loss of a piping system. This pressure loss in fittings is influenced by the design of a fitting. For AGRU-fittings the pressure loss can be calculated by the following equation:

$$\Delta P = \frac{\zeta \cdot w \cdot V^2}{g \cdot 288}$$

ΔP	...	Pressure loss	[psi]
ζ	...	Resistance coefficient	[-]
V	...	Velocity	[ft/s]
w	...	Fluid weight (water 62.4)	$[lbs/ft^3]$
g	...	Acceleration due to gravity (32.2)	$[ft/s^2]$

*	positive ζ-values:	fall of pressure
*	negative ζ-values:	rise of pressure

Va: outgoing flow rate
Vd: passing flow rate
Vs: total flow rate
Vz: additional flow rate

Fitting	Code	Characteristic	Resistance coefficient ζ*		Drawing flow direction
90° Elbows	113		0,8		
45° Elbows	110		0,3		
Tees flow collection Vs=Vd+Vz	115	**Vz / Vs**	**ζz**	**ζs**	
		0,0	-1,2	0,06	
		0,2	-0,4	0,20	
		0,4	0,1	0,30	
		0,6	0,5	0,40	
		0,8	0,7	0,50	
		1,0	0,9	0,60	
Tees flow splitting Vs=Vd+Va	115	**Va / Vs**	**ζa**	**ζd**	
		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	
Reducers enlargement	118	**d_1 / d_2**			
		1,2	0,2		
		1,4	0,5		
		1,6	1,5		
		1,8	3,0		
		2,0	5,3		
Reducers contraction	118	**d_1 / d_2**			
		1,2	0,010		
		1,4	0,013		
		1,6	0,015		
		1,8	0,016		
		2,0	0,017		

Example:
PE 3408 water piping system (w=62.4 / g= 32.2)
90° Elbow: ζ (Resistance coefficient) = 0,8
Working velocity 15 ft/s

ΔP = ?

$$\Delta P = \frac{\zeta \cdot w \cdot V^2}{g \cdot 288} = \frac{0.8 \cdot 62.4 \cdot 15^2}{32.2 \cdot 288} = 1.2 \text{ psi}$$

Dog bone load

Dog bones should prevent a sliding or moving of the piping system in each direction. They serve furthermore for compensation of the reaction forces of compensators such as sliding sockets and push-fit fittings. The dog bone has to be dimensioned for all appearing forces:

Force by hindered thermal length expansion
Weight of vertical piping systems
Specific weight of the flow medium
Operating pressure
Inherent resistance of the compensators

Dog bones which have not been determined should be chosen in a way so as to make use of direction alterations in the course of the piping system for the absorption of the length alterations. As dog bones, edges of fittings sockets or special dog bone fittings are suitable.
Swinging clips are not appropriate to be used as dog bones or the clamping of the pipes.

Rigid system

If the length alteration of a piping system is hindered, a fixed system is developed.
The rigid or fixed piping length has no compensation elements and has to be considered concering the dimensioning as special application.

The following system sizes have to be determined therefore by calculation:

- Dog bone load
- Permissible guiding element distance under consideration of the critical buckling length
- Appearing tensile and pressure stresses

Dog bone load at fixed systems

The largest dog bone load appears at the straight, fixed piping. It is in general kind:

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

F_{FP}	...	Dog bone force	[N]
A_R	...	Pipe wall ring area	[mm²]
E_C	...	Creep modulus for t=100min	[N/mm²]
ε	...	Prevented length expansion by heat expansion, internal pressure or swelling	[-]

Under consideration of the possible loads, ε has to be determined as follows:

Load by heat expansion

$$\varepsilon = \alpha \cdot \Delta T$$

α	...	Linear heat expansion coefficient	[1/°K]
ΔT	...	Max. temperature difference	[°K]

Load by internal pressure

$$\varepsilon = \frac{0{,}1 \cdot p \cdot (1 - 2\mu)}{E_c \cdot \left(\frac{da^2}{di^2} - 1\right)}$$

p	...	Operating pressure	[bar]
μ	...	Transversal contraction coefficient	[-]
E_c	...	Creep modulus for t=100min	[N/mm²]
da	...	Pipe outside diameter	[mm]
d_i	...	Pipe inside diameter	[mm]

Calculation of support distances for pipes

The support distances from the thermoplastic piping systems should be determined under consideration of the licensed bending stress and the limited deflection of the pipe line. On calculating of the support distances, a maximum deflection of $L_A/500$ to $L_A/750$ has been taken as basis. Under consideration of the previous deflection of a pipe line between the centers of tire impact results a permissible support distance of the pipe system.

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

L_A	...	Permissible support distance	[mm]
f_{LA}	...	Factor for the deflection (0,80 ... 0,92)	[-]
E_c	...	Creep modulus for t=25a	[N/mm²]
J_R	...	Pipe inactivity moment	[mm⁴]
q	...	Line load out of Pipe-, filling- and additional weight	[N/mm]

Remark: The factor fLA is determined depending on the pipe outside diameter. There is the following relation valid:

$$\min \leftarrow da \rightarrow \max$$
$$0{,}92 \leftarrow f_{LA} \rightarrow 0{,}80$$

The support distances in the table may be changed for other pressure ratings, SDR-rows or materials as follows:

SDR 17	**- 8%**
SDR 7,4	**+ 7%**

For the transportation of **gases** with a density of < 0,01 g/cm³, the support distances can be increased as stated below:

SDR 17	**+45 %**
SDR 11	**+30 %**
SDR 7,4	**+21 %**

Usual Support distances can be taken from the following tables.

PE80, SDR11 (acc. DVS 2210, Tab.13)

da	Support distance L_A in [mm] at				
[mm]	20°C	30°C	40°C	50°C	60°C
16	500	450	450	400	350
20	575	550	500	450	400
25	650	600	550	550	500
32	750	750	650	650	550
40	900	850	750	750	650
50	1050	1000	900	850	750
63	1200	1150	1050	1000	900
75	1350	1300	1200	1100	1000
90	1500	1450	1350	1250	1150
110	1650	1600	1500	1450	1300
125	1750	1700	1600	1550	1400
140	1900	1850	1750	1650	1500
160	2050	1950	1850	1750	1600
180	2150	2050	1950	1850	1750
200	2300	2200	2100	2000	1900
225	2450	2350	2250	2150	2050
250	2600	2500	2400	2300	2100
280	2750	2650	2550	2400	2200
315	2900	2800	2700	2550	2350
355	3100	3000	2900	2750	2550
400	3300	3150	3050	2900	2700

Support distances for PE 100

As there are no valid creep modulus curves available for PE 100 at the moment, we recommend you to raise the values in the table for PE 80 contained support distances after eventually necessary conversion (f_1- and f_2-factor) by 10%.

Calculation of the change in length

Changes in length of a plastic piping systems are caused by changes in the operating or test process. There are the following differences:

- Change in length by temperature change
- Change in length by internal pressure load
- Change in length by chemical influence

Change in length by temperature change

If the piping system is exposed to different temperatures (operating temperature or ambient temperature) the situation will change corresponding to the moving possibilities of each pipe line. A pipe line is the distance between two dog bones.

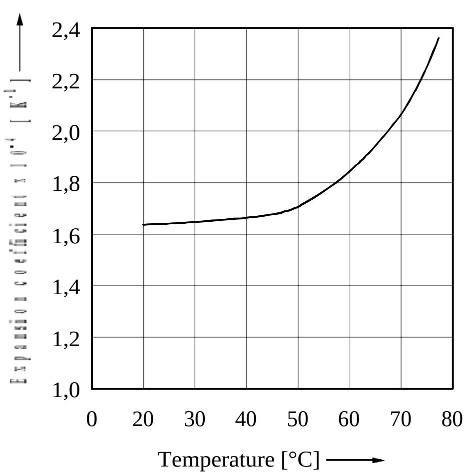
For the calculation of the change in length use the following formula:

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

ΔL_T ... Change in length due to temperature change [mm]
α ... Linear expansion coefficient [mm/m·°K]
L ... Pipe length [m]
ΔT ... Difference in temperature [°K]

The lowest and hightest pipe wall temperature T_R by installation, operation or standstill of the system is basis at the determination of ΔT.

α-average value	mm/(m.°K)	1/°K
PE	0,18	$1{,}8 \times 10^{-4}$



Change in length by internal pressure load

The by internal pressure caused length expansion of a closed and frictionless layed piping system is:

$$\Delta L_P = \frac{0{,}1 \cdot p \cdot (1 - 2\mu)}{E_c \cdot \left(\frac{da^2}{di^2} - 1 \right)} \cdot L$$

ΔL_P ... Change in length by internal pressure load [mm]
L ... Length of piping system [mm]
p ... Operating pressure [bar]
μ ... Transversal contraction coefficient [-]
E_c ... Creep modulus [N/mm²]
da ... Pipe outside diameter [mm]
d_i ... Pipe inside diameter [mm]

Calculation of the minimum straight length

Changes in length are caused by changes in operating or ambient temperatures. On installation of piping systems above ground, attention must be paid to the fact that the axial movements are sufficiently compensated.
In most cases, changes in direction in the run of the piping may be used for the absorption of the changes in length with the help of the minimum straight lengths. Otherwise, compenstion loops have to be applied.

The minimum straight length is expressed by:

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

L_S	...	Minimum straight length	[inch]
ΔL	...	Thermal expansion (contraction) of the pipe	[inch]
OD	...	Pipe outside diameter	[inch]
k	...	Material specific proportionality factor (see table below)	

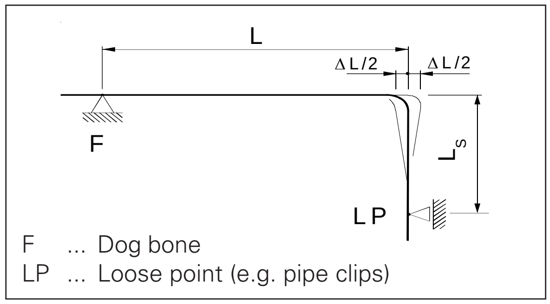
If this cannot be realised, use compensators of possibly low internal resistance. Depending on the construction, they may be applied as axial, lateral or angular compensators.
Between two dog bones, a compensator has to be installed.Take care of appropriate guiding of the piping at loose points whereby the resulting reaction forces should be taken into account.

Material specific proportionality factors k

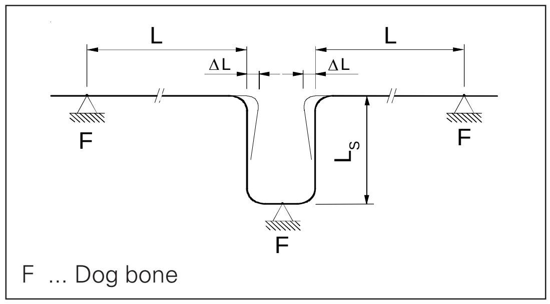
	0°C	10°C	30°C	40°C	60°C
	at change in temperature				
PE	16	17	23	28	-
	one-time change in temperature				
PE	12	12	16	17	-

Note: An installation temperature of 20°C is basis at the calculation of the k-values. At low temperatures, the impact strength of the material has to be taken into account.
The k-values can be reduced by 30% for pressureless pipes (e.g. ventilation).

Principle drawing L-compensation elbow



Principle drawing U-compensation elbow



Calculation of straight lengths

Straight lengths in [inch] for pipes out of polyethylene
depending on the change in length ΔL

Minimum Straight Length Ls [inch]									
Nominal Diameter [inch]	**OD** [inch]	**Thermal Expansion (Contraction)** [inch]							
		2,5	**5**	**7,5**	**10**	**12,5**	**15**	**17,5**	**20**
¾" IPS	1,050	42	60	73	84	94	103	111	119
1" IPS	1,315	47	67	82	94	105	115	125	133
1¼" IPS	1,660	53	75	92	106	118	130	140	150
1½" IPS	1,900	57	80	98	113	127	139	150	160
2" IPS	2,375	63	90	110	127	142	155	168	179
3" IPS	3,500	77	109	133	154	172	188	203	218
4" IPS	4,500	87	123	151	174	195	214	231	247
6" IPS	6,625	106	150	183	212	237	259	280	299
8" IPS	8,625	121	171	209	241	270	296	319	341
10" IPS	10,750	135	191	233	270	301	330	357	381
12" IPS	12,750	147	208	254	294	328	360	388	415

Chemical Resistance

Polyethylene High-density (PE-HD):
Resistant to hydrous solutions of acids, alcalis and salts as well as to a large number of organic solvents.
Unsuitable for concentrated oxydizing acids.

The resistance of Polyethylene to liquid chemicals has been determined according to DIN ISO 175 and assessed against the following criteria:

+ resistant
Swelling <3% or elongation at break not substantially changed, no change in appearance.

/ of limited resistance
Swelling 3-8% and/or elongation at break lower by <50% and/or slight change in appearance.

- not resistant
Swelling >8% and/or elongation at break lower by >50% and/or major change in appearance

aq. .... aqueous
sat. ... saturated at room temperature

A	%-Conc.	73.4°F	140°F
Acetic acid	100	+	+
Acetic acid	50	+	+
Acetic acid	10	+	+
Acetic anhydride	100	+	
Acetone	100	+	+
Akkumulator acid	38	+	+
Alum	sat.	+	+
Aluminium salt, aq.	sat.	+	+
Ammonia, aq.	sat.	+	+
Ammonium salts, aq.	sat.	+	+
Amyl alcohol	100	+	+
Aniline	100	+	+
Antifreeze glycol	50	+	+
Asphalt	100	+	/

B	%-Conc.	73.4°F	140°F
Barium salts, aq.	sat.	+	+
Benzaldehyde	100	+	+
Benzene	100	/	-
Benzine	100	+	/
Benzine, normal	100	+	/
Benzine, super	100	/	-
Benzoic acid, aq.	sat.	+	+
Bleaching solution			
12,5 % active chlorine	30	/	/
Bone oil	100	+	+
Borax, aq.	sat.	+	+
Boric acid, aq.	sat.	+	+
Break fluid	100	+	+
Bromine	100	-	
Bromine water	sat.	-	-
Butane, liquid	100	+	
Butyl acetate	100	+	/
Butyl alcohol, -n	100	+	+
Butylacetate	100	+	/

C	%-Conc.	73.4°F	140°F
Calcium salts, aq.	sat.	+	+
Carbon disulphide	100	/	
Carbon tetrachloride	100	/	-
Carbonic acid, aq.	sat.	+	+
Caustic potash solution	50	+	+
Chlorbenzene	100	/	-
Chloride of lime		+	+
Chlorine water	sat.	/	-
Chlorine, liquid	100	-	
Chloroform	100	/	-
Chlorosulfonic acid	100	-	-
Chromic acid	20	+	+
Chromic/sulphuric acid	conc.	-	-
Chromium salts, aq.	sat.	+	+
Chromiumtrioxide, aq.	sat.	+	-
Copper (II)-salts, aq.	sat.	+	+
Cresol, aq.	sat.	+	/
Cumolhydroperoxide	70	+	
Cyclohexane	100	+	+
Cyclohexanole	100	+	+
Cyclohexanone	100	+	/

Chemical Resistance

D	%-Conc.	73.4°F	140°F
Decahydronaphthalene	100	/	-
Detergents, aq.	10	+	+
Dibutylphthalate	100	+	/
Dibutylsebacate	100	+	/
Diesel oil	100	+	/
Diethylether	100	+	
Dihexylphthalate	100	+	+
Diisononylphthalate	100	+	+
Dimethylformamide	100	+	+
Dinonyladipate	100	+	
Dioctyladipate	100	+	
Dioctylphthalate	100	+	+
Dioxane, -1,4	100	+	+
Dixan solution	5	+	+

E	%-Conc.	73.4°F	140°F
Ethanol	96	+	+
Ethanol amine	100	+	+
Ethyl hexanol, -2	100	+	
Ethyl-2-hexane acid	100	+	
Ethyl-2-hexane acid chloride	100	+	
Ethyl-2-hexyl chloroformiat	100	+	
Ethylacetate	100	+	/
Ethylbenzene	100	/	-
Ethylchloride	100	/	
Ethylene chlorhydrin	100	+	+
Ethylene chloride	100	/	/
Ethylene diamine tetraacetic acid, aq.	sat.	+	+
Ethylglykolacetate	100	+	

F	%-Conc.	73.4°F	140°F
Fatty acids > C6	100	+	/
Ferrous salt, aq.	sat.	+	+
Fixing salt, aq.	10	+	+
Floor polish	100	+	/
Fluoride, aq.	sat.	+	+
Fluosilicic acid	32	+	+
Formaldehyde, aq.	40	+	+
Formalin	commercial	+	+
Formic acid	98	+	+
Formic acid	50	+	+
Formic acid	10	+	+
Frigen 11	100	/	
Fuel oil	100	+	/
Furfuryl alcohol	100	+	/

G	%-Conc.	73.4°F	140°F
Glycerine	100	+	+
Glycerine, aq.	10	+	+
Glycol	100	+	+
Glycol acid	70	+	+
Glycol, aq.	50	+	+

H	%-Conc.	73.4°F	140°F
Heptane	100	+	/
Hexafluosilicic acid, aq.	sat.	+	+
Hexane	100	+	+
Humic acids, aq.	1	+	+
Hydrazine, aq.	sat.	+	+
Hydriodic acid, aq.	sat.	+	
Hydrochinone, aq.		+	
Hydrochloric acid	38	+	+
Hydrochloric acid	10	+	+
Hydrofluoric acid	40	+	+
Hydrofluoric acid	70	+	/
Hydrogen peroxide	30	+	+
Hydrogen peroxide	3	+	+
Hydrogen sulphide	low	+	+
Hydrosylammonium-sulphate	sat.	+	+
Hydroxyacetone	100	+	+

I	%-Conc.	73.4°F	140°F
Iodine tincture DAB 6		+	
Isononan acid	100	+	/
Isononan acid chloride	100	+	
Isooctane	100	+	/
Isopropanol	100	+	+

L	%-Conc.	73.4°F	140°F
Lactic acid, aq.	90	+	+
Lactic acid, aq.	10	+	+
Lauric acid chloride	100	+	
Lithium salts	sat.	+	+
Lysol	commercial	+	/

Chemical Resistance

M	%-Conc.	73.4°F	140°F
Magnesium salts, aq.	sat.	+	+
Menthol	100	+	
Mercuric salts, aq.	sat.	+	+
Mercury	100	+	+
Methan sulphonic acid	50	+	
Methanol	100	+	+
Methoxyl butanol	100	+	/
Methoxyl butyl acetate	100	+	/
Methyl cyclohexane	100	+	/
Methyl ethyl ketone	100	+	+
Methyl glycol	100	+	+
Methyl isobutyl ketone	100	+	/
Methyl sulphuric acid	50	+	
Methyl-4-pentanol-2	100	+	+
Methylacetate	100	+	+
Methylene chloride	100	/	
Mineral oil	100	+	/
Monochloracetic acid ethyl ester	100	+	+
Monochloracetic acid methyl ester	100	+	+
Morpholine	100	+	+
Motor oil	100	+	/

N	%-Conc.	73.4°F	140°F
Na-dodecyl benz. sulphon.	100	+	+
Nail polish remover	100	+	/
Neodecane acid	100	+	
Neodecane acid chloride	100	+	
Nickel salts, aq.	sat.	+	+
Nitric acid	50	/	/
Nitric acid	25	+	+
Nitrobenzene	100	+	/
Nitrohydrochloric acid: HCl:HNO3	3 : 1	+	-
Nitromethane	100	+	

O	%-Conc.	73.4°F	140°F
Oils, etherial		+	
Oils, vegetable	100	+	+
Oleic acid	100	+	/
Oleum	> 100	-	-
Oxalic acid, aq.	sat.	+	+

P	%-Conc.	73.4°F	140°F
Paraffin oil	100	+	/
Paraldehyde	100	+	
PCB	100	/	
Pectin	sat.	+	+
Perchlorethylene	100	/	-
Perchloric acid	20	+	+
Perchloric acid	50	+	/
Perchloric acid	70	+	-
Petroleum	100	+	/
Petroleum ether	100	+	/
Phenol, aq.	sat.	+	+
Phenylchloroform	100	/	
Phosphates, aq.	sat.	+	+
Phosphoric acid	85	+	/
Phosphoric acid	50	+	+
Photographic developers	commercial ready for use	+	+
Potassium permanganate, aq.	sat.	+	+
Potassium persulphate, aq.	sat.	+	+
Potassium salt, aq.	sat.	+	+
Potassium soap	100	+	+
Propane, liquid	100	+	
Pyridine	100	+	/

S	%-Conc.	73.4°F	140°F
Salad oil	100	+	+
Salted water	sat.	+	+
Sea water		+	+
Shoe polish	100	+	/
Silicone oil	100	+	+
Silver salts, aq.	sat.	+	+
Soap solution	sat.	+	+
Soap solution	10	+	+
Soda lye	60	+	+
Sodium chlorate, aq.	25	+	+
Sodium chlorite, aq.	5	+	+
Sodium hypochlorite, aq.	5	+	+
Sodium hypochlorite, aq.	30	/	/
Sodium hypochlorite, aq.	20	+	+
Sodium salts, aq.	sat.	+	+
Succinic acid, aq.	sat.	+	+
Sulphur dioxide, aq.	low	+	+
Sulphuric acid	96	-	-
Sulphuric acid	50	+	+
Sulphuric acid	10	+	+

Material Properties
Calculation Guidelines
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Chemical Resistance

T	%-Conc.	73.4°F	140°F
Tannic acid	10	+	+
Tar	100	+	/
Tartaric acid, aq.	sat.	+	+
Test fuel, aliphatic	100	+	/
Tetrachlorethane	100	/	-
Tetrachlorethylene	100	/	-
Tetrahydro naphthalene	100	+	-
Tetrahydrofuran	100	/	-
Thiophene	100	/	/
Tin-II-chloride, aq.	sat.	+	+
Toluene	100	/	-
Transformer oil	100	+	/
Trichlorethylene	100	/	-
Tricresyl phosphate	100	+	+
Trioctyl phosphate	100	+	/
Two-stroke oil	100	+	/

U	%-Conc.	73.4°F	140°F
Urea, aq.	sat.	+	+
Uric acid	sat.	+	+
Urine		+	+

W	%-Conc.	73.4°F	140°F
Washing-up liquid, fluid	5	+	+
Water glass	100	+	+
Wetting agent	100	+	/

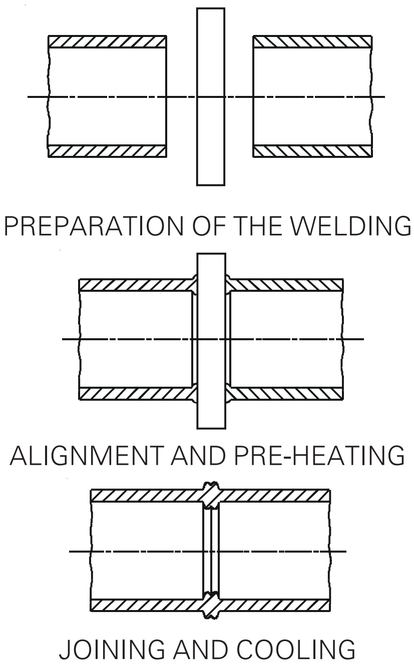
X	%-Conc.	73.4°F	140°F
Xylene	100	/	-

Z	%-Conc.	73.4°F	140°F
Zinc salts, aq.	sat.	+	+

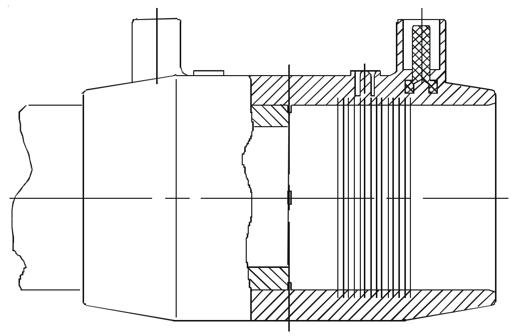
Welding Parameter

AGRU PE 3408 fittings can be welded to each PE 2406, PE 4710 and PE 3408 pipe according pipe manufacturer recommended welding instruction.

Schematic sketch of the Butt welding process



Schematic sketch of a electrofusion coupler



Fusion Compatibility

If required for specific material combination, AGRU-America can provide a testing report about fusion compatibility according Code of Federal Regulations (CFR) title 49 § 192.283.

Minimum Hydrostatic Burst Pressure according ASTM D 2513

Tensile Test following ASTM D 638

Fitting Characteristics:

The fittings are produced in an injection molding process according to ASTM D3261. The fittings are fully pressure rated and provide a working pressure equal to that of a pipe of PE 4710/3408 with the same SDR.

Pressure Ratings (at 73,4 °F):

SDR 17 Fittings:	100 psi
SDR 11 Fittings:	160 psi

Marking:

<u>Injection molded marking:</u>

Type of Information	Fitting Marking
Manufacturers Name	AGRU
Material	PE 4710
Nominal Diameter	e.g. ND 6" IPS
SDR	e.g. SDR 11
Production Batch	e.g 08/1

Packaging:

The fittings are single bagged in a PE-foil for dust protection. In addition the fittings are multi packaged in a cardboard box. Packaging lists are available on request.

Weldability:

The fittings can be fusion joined in accordance with pipe manufacturers fusion guidelines.

Quality:

Works certificates shall be delivered for the fittings for each production series. All controls and tests shall be documented on these certificates.

Quick Specification for PE 4710/3408 Fittings:

Fittings are to be manufactured of a HDPE resin which comply with the cell classification of 445574C according to ASTM D3350.

The fittings shall provide a working pressure equal to that of a pipe of PE 4710/3408 with the same SDR.