General properties of PE (Polyehylene)

As a 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) for pressure pipe applications is no longer classified by its density (for example PE-LD, PE-MD, PE-HD) as it is now divided into MRS-strength classes.

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.
The new classification is based on the minimum required strength (MRS), which has to be applied for designing long-term loaded PE pipes operating at a temperature of +20°C for at least 50 years. Thus the first-generation pipes are named PE32, PE40 and PE63 and the second-generation pipes PE80, the third-generation are named PE100.The figures stand for the MRS values in bar. Expressed in megapascal the design stresses for PE80 and PE100 pipes will consequently be 8,0 and 10,0 MPa.

Other essential advantages of this material are the UV-stability (if its 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 ÖNORM 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

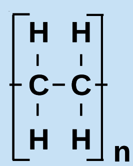
- UV-resistance (black PE)
- Flexibility
- Low specific weight of app. 0,95g/cm^3
- Favourable transportation (e. g. coils)
- Very good chemical resistance
- Weathering resistance
- Radiation resistance
- Good weldability
- Very good abrasion resistance
- No deposits and no overgrowth possible
  Due 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.

Modified polyethylene PE 80-el (Polyethylene, electro-conductable)

Due to the electro-conductibility, PE 80-el is often used for the transport of easy combustible media or for the conveying of dust as for these piping systems, a connection to earth can be performed.



Chemical structure of polyethylene

General properties of PP

According to DIN 8078, three, different types of polypropylene are recognised:
Type 1: PP-H (homopolymere)
Type 2: PP-B (block-copolymere)
Type 3: PP-R (random-polymere)

By copolymerisating with ethylene special properties are achieved as in PP types 2 and 3, which result in an improved processability (e.g. lower danger of shrinkage cavitation at the injection molding process) and higher impact strength of the products in comparison to PP-H.

PP-R and copper

In direct contact with copper and PP-R deteriorates, especially at higher temperatures, the physical properties of PP-R. Due to the accelerated thermal oxidation, heat ageing is faster.

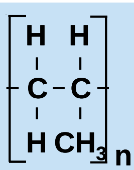
Physiological non-toxicity

With respect to its composition, polypropylene complies with the relevant food stuff regulations (according OENORM B 5014 Part 1, FDA, BGA, KTW guidelines).

AGRU pipes, sheets and round bars are made of nucleoid PP-H (Beta (β)-PP) since the middle of the seventies.
Fittings are also produced out of PP-R (polypropylene-random-copolymere) since the end of the seventies.
Both types have been stabilized against high temperatures and are the best suited materials for the production of pressure piping systems.

In comparison to other thermoplastics such as PE-HD and PVC, PP shows a thermal stability up to 100°C (short-time up to 120°C for pressureless systems).

PP shows good impact strength in comparison to PVC. The impact strength depends on temperature, increases with rising temperatures decreases with falling temperatures.



Chemical structure of PP

Advantages of Polypropylene

- low specific weight of 0,91g/cm^3 (PVC 1,40g/cm^3)
- high creep resistance
- excellent chemical resistance
- TiO2 pigmentation
- high resistance to ageing by thermal stabilizing good weldability
- excellent abrasion resistance
- smooth inside surface of the pipes, therefore
- no deposits and no growth over possible due to less frictional resistance
- less pressure losses in comparison with e. g. metals
- non-conductive, therefore the structure is not affected by tracking currents
- very good processable thermoplastic (e. g. by deep drawing)
- PP is a bad conductor of heat - therefore in most cases, no thermal insulation is required for hot water piping systems

General properties of Polypropylene (Standard types)

Behaviour at radiation strain

At an absorbed dose of < 10^4 Gray polypropylene piping systems can be applied without essential resistance decrease.
At a higher energy rays than 10^4 Gray it may come to a temporary resistance increase due to cross-linking of the molecular struc-ture. But at durable radiation strain, it comes to a rupture of the molecular chains and therefore by the damage of the material to a serious resistance decrease.

Behaviour at UV-radiation

Grey polypropylene pipe lines are not UV-stable so they must be adequately protected. As effective protection against direct solar radiation, a protection layer (AGRU-Coating) or an insulation is possible.
It is furthermore possible to compensate the arising damage of the surface by a corresponding wall thickness addition as the damage only occurs on the surface (according to the DVS standard 2210-1). The wall thickness addition may not be less than 2 mm, a maximum expected operating period of 10 years has to be taken into account.
As polypropylene is not equipped with light-stable colour pigments normally, it may come to a change of colour (fading) by long-time weathering.
As an alternative a high-temperature-resistant, black PP material can be used. The black PP material is stabilized against UV radiation for 10 years.The application conditions should be clarified with the technical engineering department.

General properties of PP

General properties of modified PP

On account of the most specific requirements arising in the construction of piping systems for the chemical indu-stry and in apparatus engineering flame retardant and electro-conductive special types have been developed.
For example static charging due to the flow of fluids or dust can arise at the operation of thermoplastic piping systems. Electro-conductable polypropylene types have therefore been developed in order to enable a connection to earth can be performed.

By supplement of additives, these modified properties are achieved. But there result alterations of the mechanical, thermal and also chemical properties in comparison to the standard type.

It is therefore necessary to clarify all projects with our technical engineering department.

Physiological properties

Modified PP types (flame-retardant resp. electro-conductable PP) correspond in their composition due to the supplement of additives n o t to the relevant food stuff regulations and may therefore not be used for potable water pipes and in contact

Differences to standard types of PP

PP-R, black:

(Polypropylene-random-copolymere, black coloured)
The essential advantage of this black coloured material type is the UV resistance for an operating period of 10 yaers, which is not available with grey PP.
However there is an insignificant decrease of the impact strength.

PP-B 2222, grey:

PPB 2222 is a polypropylene block copolymer grey coloured similar to RAL 7032 (pebble grey). The product is characterized by its excellent impact properties, as well as a high heat stability and extremely high extraction stability.

PP-R, natural:

(Polypropylene-random-copolymere, natural)
As PP-R natural contains no colour additives, it is applied mainly for high purity water piping systems. However this material is not UV resistant.

PP-s:

(Polypropylen-homopolymere, flame-retardant)
Due to the higher stiffness of PP-s, it is well suited for ventilation and degassing pipes as well as for flue lining systems. It may not be used for outdoors applications due to the missing UV stabilization.

PP-R-s-el:

(Polypropylene-random-copolymere, flame retardant, electro-conductive)
This material reconciles the positive properties of the flame retardant and electro-conductable PP types. It is therefore due to safety reasons mostly applied for the transport of easy ignitable media and replaces often expensive stainless steel ductings.

There is however a reduced impact strength of PP-s-el as well as a slightly amended chemical resistance (see page 119).

General properties of PVDF (Polyvinylidene fluoride)

PVDF is an extremly pure polymer and contains in comparison with a lot of other plastics no stabilizers UV-, Thermostabilizers, softener, lubricants or flame-retardant additives. Its particular suitable for ultra-pure water constructions and for the transport of clear chemical liquids in the semi-conductor industry. Due to its chemical inertness, reaction against most media is nearly impossible.

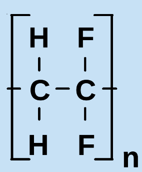
Pipes and components out of suitable standard types fulfil the high demands of the semi-conductor industry; e. g. they are in the position to maintain the specific resistance of deionizationed ultra-pure water over 18 MΩcm.

PVDF offers with its properties an ideal compromise, in connection with a very easy processing and an advantageous price-performance ratio.

Polyvinylidene fluoride (PVDF) is a thermoplastic and has the following typical properties:

- easy processing
- good weldability
- good heat formability

PVDF is distinguished by its high mechanical strength and the very good chemical resistance, even for applications in the presence of critical chemical media in the high temperature range.



Chemical structure of PVDF

Advantages of PVDF

- wide temperature range, high heat deflection temperature
- very good chemical resistance, even in connection with high temperatures
- good resistance against UV- and γ-radiations therefore high ageing resistance
- excellent abrasion resistance (low friction coefficient)
- very good anti-friction properties
- good mechanical properties
- excellent insulaing characteristics in connection with very good electrical values
- flame retarding
- physiologically non-toxic
- good and easy processing

PVDF is a halogen and also offers an excellent fire protection without flame-retardant additives. During combustion of PVDF only a slight amount of smoke development arises. But like every other organic substance also PVDF is inflammable and in adequate ambient temperature PVDF is inflammable.

Solubility

The PVDF-homopolymere swells in high polar solvents e.g. acetone and ethylacetat and is soluble in polar solvents, e.g. dimethylformamide and dimethylacetamide.

General properties of ECTFE (Ethylenechlorotrifluorethylene)

ECTFE has a unique combination of properties, which results due to its chemical structure - a copolymere with a changing constitution of ethylene and chlorotrifluorethylene.

Physiological properties

ECTFE is suitable for the safe application of products in continuous contact with food stuff accoringg to "BGA Deutschland". For avoiding every influence of smell and taste it is recommended to clean the food with water which has direct contact with ECTFE parts.

Thermal properties

ECTFE has a remarkable resistance against decomposition trought heat, intensive radiation and weathering. For a long time it is resistant against temperatures up to 150°C and it is one of the best plastics with a good resistance against radiation.

Resistance against the weathering

ECTFE shows only a slight change of the properties or apperance weathering in the sunlight. Reaped weathering tests showed a remarkable stability of the polymers particularly the elongation at break, which is a good indicator for the polymer-decomposition. Even after 1000 hours in a "Weather - Ometer" with xenon-light the important properties are hardly influenced.

Radiation resistance

ECTFE shows an excellent resistance against different radiations. It has even good values after irridation with 200 megarad cobalt 60.

Mechanical properties

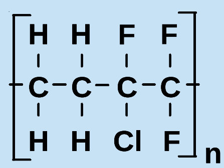
ECTFE is a solid, very impact resistant plastic, which hardly changes its properties over a wide range of temperatures. Besides the good impact strength ECTFE has a good breaking strain and a good abrasion behaviour. To emphasize is also the good behaviour by low temperatures, especially the high impact strength.

Advantages of ECTFE

- wide temperature application range (thermal resistance up to short-term 150°C).
- good resistance against UV- and γ-radiation, therefore favourable ageing resistance.
- flame retardent (UL 94-V0-material) - oxygen index 60
- excellent abrasion resistance
- extreme good chemical resistance against most technical acids, alkalies and solvents as well as in contact with chlorine.
- excellent insulating properties in connection with very good electrical values
- physiological non-toxic
- very good surface slip characteristics

Reproduction of microorganisms on ECTFE

The surface of a product out of ECTFE is unfavourable to the proliferation of microorganisms - as with glass. This conclusion is the result of an examination which has been executed within the framework of a test of the HP-suitability of ECTFE. Due to these properties, ECTFE is applied in the food and drug industry and for ultra-pure water ranges.



Chemical structure of ECTFE

Specific material properties PE

	Property	Standard	Unit	**PE80**	**PE100**	**HDPE-el**
	Density at 23°C	ISO 1183	g/cm³	0,94	0,95	0,99
	Melt flow index MFR 190/5 MFR 190/2,16 MFR 230/5 MFI range	ISO 1133 ISO1872/1873	g/10min	0,9 T012	0,3 <0,1 T003	 T001
Mechanical Properties	Tensile stress at yield	ISO 527	MPa	20	25	26
	Elongation at yield	ISO 527	%	10	9	7
	Elongation at break	ISO 527	%	>600	>600	
	Impact strength unnotched at +23°C Impact strength unnotched at -30°C	ISO 179	kJ/m²	no break no break	no break no break	
	Impact strength notched at +23°C Impact strength notched at 0°C Impact strength notched at -30°C	ISO 179	kJ/m²	12 4,5	16 6	5,0 3,0
	Ball indentation hardness acc. Rockwell	ISO 2039-1	MPa	36	46	
	Flexural strength (3,5% flexural stress)	ISO 178	MPa	18	24	
	Modulus of elasticity	ISO 527	MPa	750	1100	1150
Thermal Properties	Vicat-Softening point VST/B/50	ISO 306	°C	63	77	83
	Heat deflection temperature HDT/B	ISO 75	°C	60	75	
	Linear coefficient of thermal expansion	DIN 53752	K^{-1} x 10^{-4}	1,8	1,8	1,8
	Thermal conductivity at 20 °C	DIN 52612	W/(mxK)	0,4	0,4	0,43
	Flammability	UL94 DIN 4102	--	94-HB B2	94-HB B2	 B2
Electrical Properties	Specific volume resistance	VDE 0303	OHM cm	$>10^{16}$	$>10^{16}$	$\leq10^{8}$
	Specific surface resistance	VDE 0303	OHM	$>10^{13}$	$>10^{13}$	$\leq10^{6}$
	relative dielectric constant at 1 MHz	DIN 53483	--	2,3	2,3	
	Dielectric strength	VDE 0303	kV/mm	70	70	
	Physiologically non-toxic	EEC 90/128	--	Yes	Yes	No
	FDA	--	--	Yes	Yes	No
	UV stabilized	--	--	carbon black	carbon black	carbon black
	Colour	--	--	black	black	black

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

Specific material properties PP

	Property	Standard	Unit	**PP-H**	**PP-R**	**PP-B**	**PP-s**	**PP-s-el**
	Density at 23°C	ISO 1183	g/cm³	0,91	0,91	0,91	0,93	1,13
	Melt flow index MFR 190/5 MFR 190/2,16 MFR 230/5 MFI range	ISO 1133 ISO1872/1873	g/10min	 0,5 1,25 M003	 0,5 1,25	 0,5 1,3	 0,8 2,0	 0,6
Mechanical Properties	Tensile stress at yield	ISO 527	MPa	30	25	26	30	30
	Elongation at yield	ISO 527	%	10	12	10	10	
	Elongation at break	ISO 527	%	>300	>300	>50	>50	43
	Impact strength unnotched at +23°C Impact strength unnotched at -30°C	ISO 179	kJ/m²	no break	no break	no break 80	no break 28	
	Impact strength notched at +23°C Impact strength notched at 0°C Impact strength notched at -30°C	ISO 179	kJ/m²	8 2,8 2,2	22 4 2,5	40 8 3,2	9 2,8 2,2	9,5 - 2,3
	Ball indentation hardness acc. Rockwell	ISO 2039-1	MPa	60	45	50	72	
	Flexural strength (3,5% flexural stress)	ISO 178	MPa	28	20	20	37	
	Modulus of elasticity	ISO 527	MPa	1300	900	1100	1300	
Thermal Properties	Vicat-Softening point VST/B/50	ISO 306	°C	91	65	68	85	133
	Heat deflection temperature HDT/B	ISO 75	°C	96	70	75	85	47
	Linear coefficient of thermal expansion	DIN 53752	$K^{-1} \times 10^{-4}$	1,6	1,6	1,6	1,6	
	Thermal conductivity at 20 °C	DIN 52612	W/(mxK)	0,22	0,24	0,2	0,2	
	Flammability	UL94 EN 13501 DIN 4102	--	94-HB B2	94-HB B2	94-HB B2	V-2 E(d2) B1	V-0
Electrical Properties	Specific volume resistance	VDE 0303	OHM cm	$>10^{16}$	$>10^{16}$	$>10^{15}$	$>10^{15}$	$\leq 10^{8}$
	Specific surface resistance	VDE 0303	OHM	$>10^{13}$	$>10^{13}$	$>10^{15}$	$>10^{15}$	$\leq 10^{6}$
	relative dielectric constant at 1 MHz	DIN 53483	--	2,3	2,3			
	Dielectric strength	VDE 0303	kV/mm	75	70	30 bis 40	30 bis 45	
	Physiologically non-toxic	EEC 90/128	--	Yes	Yes	Yes	Yes	No
	FDA	--	--	Yes	Yes	No	No	No
	UV stabilized	--	--	No	No	No	No	Yes
	Colour	--	--	Ral 7032 grey	RAL 7032 grey	RAL 7032 grey	RAL 7037 dark grey	black

*) Fire classification B1 only valid for wall thickness of 2-10mm

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

Specific material properties PVDF and ECTFE

	Property	Standard	Unit	**PVDF**	**PVDF flex**	**ECTFE**
	Specific density at 23°C	ISO 1183	g/cm³	1,78	1,78	1,68
	Melt flow index MFR 275/2.16 MFR 230/5 MFI range	ISO 1133	g/10min	6	6	1
Mechanical Properties	Tensile stress at yield	ISO 527	MPa	50	20-35	30
	Elongation at yield	ISO 527	%	9	10-12	5
	Elongation at break	ISO 527	%	80	200-600	250
	Impact strength unnotched at +23°C Impact strength unnotched at -30°C	ISO 179	kJ/m²	124	- -	no break
	Impact strength notched at +23°C Impact strength notched at 0°C Impact strength notched at -30°C	ISO 179	kJ/m²	11	17 - -	no break
	Ball indentation hardness acc. Rockwell	ISO 2039-1	MPa	80	-	90
	Flexural strength	ISO 178	MPa	80	-	47
	Modulus of elasticity	ISO 527	MPa	2000	1000-1100	1690
Thermal Properties	Vicat-Softening point VST/B/50	ISO 306	°C	140	150	
	Heat deflection temperature HDT/B	ISO 75	°C	145	-	90
	Linear coefficient of thermal expansion	DIN 53752	$K^{-1} \times 10^{-4}$	1,2	1,4-1,6	0,8
	Thermal conductivity at 20 °C	DIN 52612	W/(mxK)	0,20	0,2	0,15
	Flammability	UL94 EN 13501 FM 4910	--	V-0 B yes	V-0	V-0 -- --
Electrical Properties	Specific volume resistance	VDE 0303	OHM cm	$>10^{13}$	$\geq 10^{14}$	$>10^{16}$
	Specific surface resistance	VDE 0303	OHM	$>10^{12}$	$\geq 10^{14}$	$>10^{14}$
	relative dielectric constant at 1 MHz	DIN 53483	--	7,25	7	2,6
	Dielectric strength	VDE 0303	kV/mm	22	20	30 bis 35
	Physiologically non-toxic	EEC 90/128	--	Yes	compliant	Yes
	FDA	--	--	Yes		in preperation
	UV stabilized	--	--	Yes		Yes
	Colour	--	--	natural	natural	natural

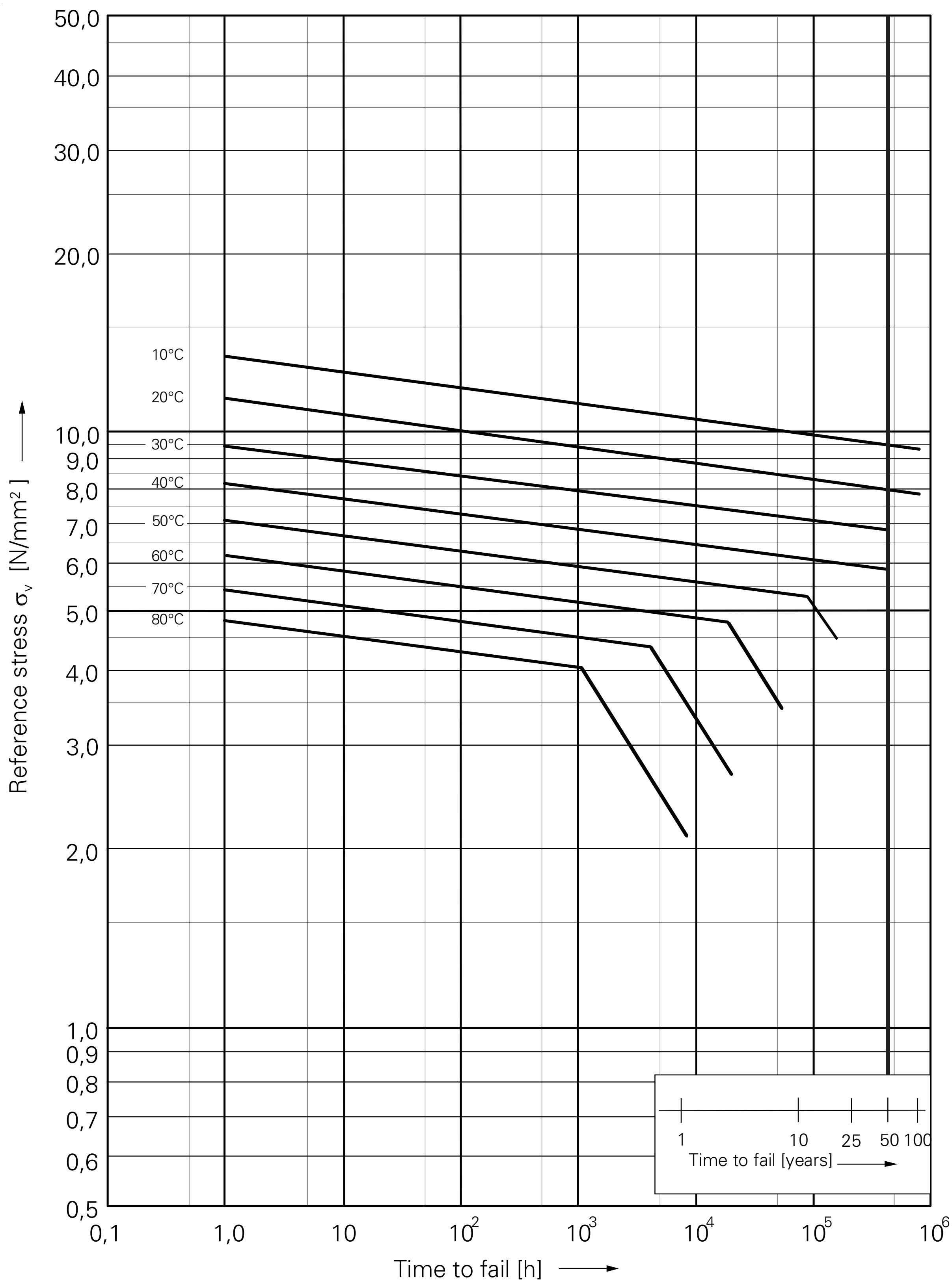
Note: The mentioned values are recommended values for the particular material.

Applications

The below mentioned table gives you a survey about the different application possibilities of our molding materials.

Range of applications	PP-H	PP-R	PP-s	PP-s-el	PE80	PE100	PEHD-el	PVDF	ECTFE
Industrial applications									
Piping systems for conveying of chemicals	■	■	■	■	■	■	■	■	■
Pipes for cooling water systems	■	■	■		■	■	■		
Pipes for the transport of solids	■	■			■	■	■	■	■
Piping systems in explosion-proof rooms				■					
High purity water piping systems		■			■			■	■
Water extraction and water preparation					■	■			
Pipes for swimming pools	■	■			■	■			
Protective pipes for district heating systems					■				
Protective pipes for cables					■				
Apparatus engineering and vessel construction	■	■	■		■	■	■	■	■
Ventilation and degassing piping systems	■	■	■	■	■		■		
Lining of containers and tanks	■	■	■	■	■		■	■	■
Construction of facilities	■	■	■	■	■	■	■	■	■
Distribution of compressed air						■			
Applications for environmental protection									
Pipes for drainage systems	■	■			■	■			
Lining of channels, channel relining		■			■	■			
Dual pipes	■	■			■	■		■	■
Piping systems for sewage treatment plants and lining	■	■			■	■			
Degassing pipes for waste disposal facilities					■	■	■		
Drainage pipes for landfill sites					■	■			
Discharge piping systems					■	■			
Applications for supply systems									
Pipes for irrigation systems					■	■			
Pipes for potable water systems	■	■			■	■			
Gas pipes					■	■			

Pressure curve for pipes out of PE 80
(acc. to EN ISO 15494 supplement B)



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

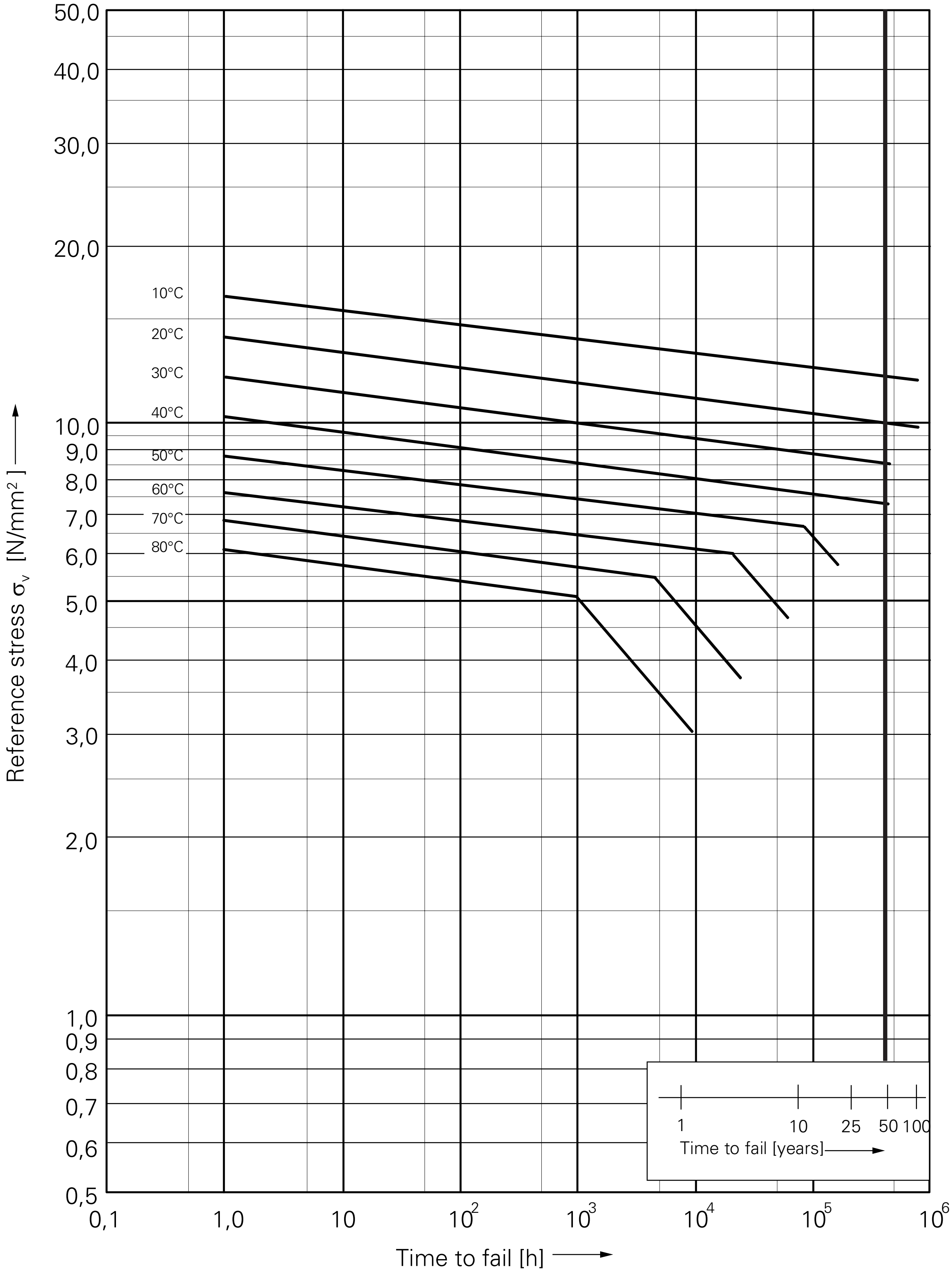
In the table stated the data apply to water. They were determined from the creep curve taking into account a safety coefficient of C=1,25.

Temperature [°C]	Operating period [years]	Diameter-wall thickness relation SDR						
		41	**33**	**26**	**17,6**	**11**	**7,4**	**6**
		Pipe series S						
		20	16	12,5	8,3	5	3,2	2,5
		PN						
		3,2	4	5	7,5	12,5	20	25
		permissible component operating pressure p_B [1) 2)] [bar]						
10	5	4,0	5,0	6,3	9,4	15,8	25,3	31,6
	10	3,9	4,9	6,2	9,3	15,5	24,8	31,0
	25	3,8	4,8	6,0	9,0	15,1	24,2	30,3
	50	3,8	4,7	5,9	8,9	14,8	23,8	29,7
	100	3,7	4,6	5,8	8,7	14,6	23,3	29,2
20	5	3,4	4,2	5,3	7,9	13,2	21,2	26,5
	10	3,3	4,1	5,2	7,8	13,0	20,8	26,0
	25	3,2	4,0	5,0	7,6	12,7	20,3	25,4
	50	3,2	4,0	5,0	7,5	12,5	20,0	25,0
	100	3,1	3,9	4,9	7,3	12,2	19,6	24,5
30	5	2,8	3,6	4,5	6,7	11,2	18,0	22,5
	10	2,8	3,5	4,4	6,6	11,0	17,7	22,1
	25	2,7	3,4	4,3	6,4	10,8	17,3	21,6
	50	2,7	3,3	4,2	6,3	10,6	16,9	21,2
40	5	2,4	3,1	3,8	5,8	9,6	15,5	19,3
	10	2,4	3,0	3,8	5,7	9,5	15,2	19,0
	25	2,3	2,9	3,7	5,5	9,2	14,8	18,5
	50	2,3	2,9	3,6	5,4	9,1	14,5	18,2
50	5	2,1	2,6	3,3	5,0	8,4	13,4	16,8
	10	2,0	2,5	3,2	4,8	8,1	12,9	16,2
	15	1,8	2,2	2,8	4,3	7,1	11,4	14,3
60	5	1,4	1,8	2,2	3,3	5,6	9,0	11,3
70	2	1,1	1,3	1,7	2,6	4,3	6,9	8,7

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

[2)] The operating pressure has to be reduced by the corresponding reducing coefficients (see page 142) for every application.

Pressure curve for pipes out of PE 100
(acc. to EN ISO 15494 supplement B)



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

In the tables stated 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						
		41	**33**	**26**	**17**	**11**	**7,4**	**6**
		Pipe series S						
		20	16	12,5	8	5	3,2	2,5
		PN						
		4	5	6,3	10	16	25	32
		Permissible component operating pressure p_B [1) 2)] [bar]						
10	5	5,0	6,3	7,9	12,6	20,2	31,5	40,4
	10	4,9	6,2	7,8	12,4	19,8	31,0	39,7
	25	4,8	6,0	7,6	12,1	19,3	30,2	38,7
	50	4,7	5,9	7,5	11,9	19,0	29,7	38,0
	100	4,6	5,8	7,3	11,6	18,7	29,2	37,4
20	5	4,2	5,3	6,6	10,6	16,9	26,5	33,9
	10	4,1	5,2	6,5	10,4	16,6	26,0	33,3
	25	4,0	5,0	6,4	10,1	16,2	25,4	32,5
	50	4,0	5,0	6,3	10,0	16,0	25,0	32,0
	100	3,9	4,9	6,1	9,8	15,7	24,5	31,4
30	5	3,6	4,5	5,6	9,0	14,4	22,5	28,8
	10	3,5	4,4	5,5	8,8	14,1	22,1	28,3
	25	3,4	4,3	5,4	8,6	13,8	21,6	27,6
	50	3,3	4,2	5,3	8,4	13,5	21,2	27,1
40	5	3,0	3,8	4,8	7,7	12,3	19,3	24,7
	10	3,0	3,8	4,7	7,6	12,1	19,0	24,3
	25	2,9	3,7	4,6	7,4	11,8	18,5	23,7
	50	2,9	3,6	4,5	7,2	11,6	18,2	23,3
50	5	2,6	3,3	4,2	6,7	10,7	16,7	24,4
	10	2,6	3,2	4,0	6,5	10,4	16,2	20,3
	15	2,3	2,9	3,7	5,9	9,5	14,8	19,0
60	5	1,9	2,4	3,0	4,8	7,7	12,1	15,5
70	2	1,5	1,9	2,4	3,9	6,2	9,8	12,5

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

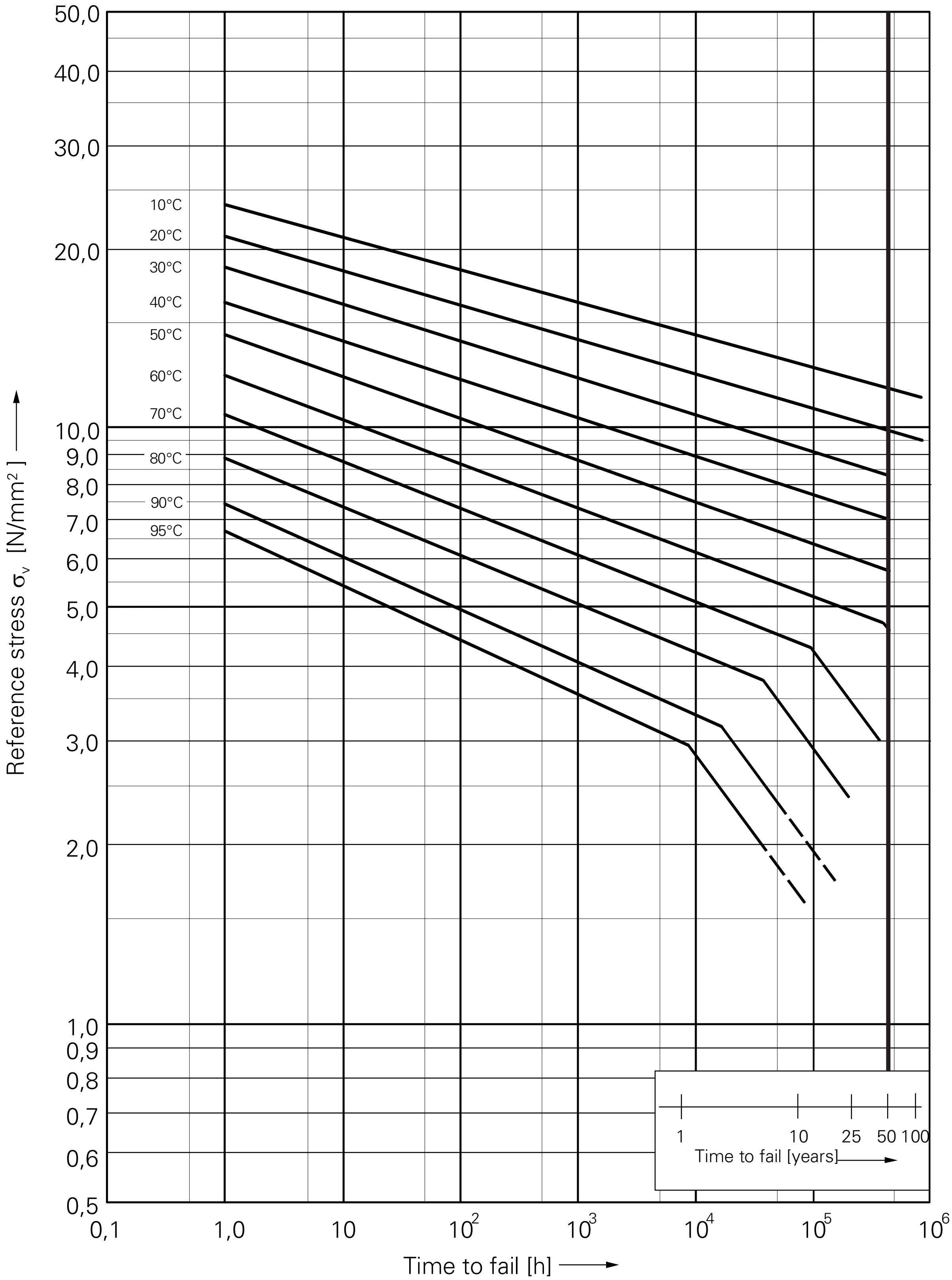
[2)] These operating pressure have to be reduced by the corresponding reducing coefficients (see page 142) for every application.

For pipes and fittings out of PE 100, a smaller wall thickness than for PE80 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-series, S-series and PN-pressure ratings in the below table.

SDR	S	PN-pressure rate [bar]	
		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

Pressure curve for pipes out of PP-H
(acc. to EN ISO 15494 supplement C)



Permissible component operating pressures p_B for PP-H depending on temperature and operation periond.

In the tables stated the data apply to water. They were determined from the creep curve taking into account a safety coefficient of C (C = 1,6 from 10 - under 40°C, C = 1,4 from 40 - under 60°C, C = 1,25 from 60°C).

Temperature [°C]	Operating period [years]	Diameter-wall thickness relation SDR						
		41	**33**	**26**	**17,6**	**11**	**7,4**	**6**
		Pipe series S						
		20	16	12,5	8,3	5	3,2	2,5
		PN						
		2,5	3,2	4	6	10	16	20
		Permissible component operating pressure p_B [1) 2) 3)] [bar]						
10	1	4,5	5,6	7,2	10,9	18,1	28,2	36,2
	5	4,1	5,1	6,6	10,0	16,6	25,9	33,2
	10	4,0	5,0	6,4	9,6	16,0	25,0	32,0
	25	3,8	4,7	6,1	9,1	15,2	23,8	30,4
	50	3,6	4,5	5,8	8,8	14,6	22,9	29,3
	100	3,5	4,4	5,6	8,5	14,1	22,1	28,2
20	1	3,9	4,8	6,2	9,4	15,6	24,4	31,2
	5	3,5	4,4	5,7	8,6	14,2	22,2	28,5
	10	3,4	4,2	5,4	8,2	13,7	21,4	27,4
	25	3,2	4,0	5,2	7,8	13,0	20,3	26,0
	50	3,1	3,9	5,0	7,5	12,5	19,5	25,0
	100	3,0	3,7	4,8	7,2	12,0	18,7	24,0
30	1	3,3	4,1	5,3	8,0	13,3	20,9	26,7
	5	3,0	3,8	4,8	7,3	12,1	18,9	24,2
	10	2,9	3,6	4,6	7,0	11,6	18,1	23,2
	25	2,7	3,4	4,4	6,6	11,0	17,2	22,0
	50	2,6	3,3	4,2	6,3	10,5	16,4	21,1
40	1	3,2	4,0	5,1	7,8	12,9	20,2	25,9
	5	2,9	3,6	4,6	7,0	11,6	18,2	23,3
	10	2,7	3,4	4,4	6,7	11,1	17,4	22,3
	25	2,6	3,2	4,2	6,3	10,5	16,4	21,0
	50	2,5	3,1	4,0	6,0	10,0	15,7	20,1
50	1	2,7	3,4	4,3	6,5	10,8	17,0	21,7
	5	2,4	3,0	3,9	5,8	9,7	15,2	19,4
	10	2,3	2,9	3,7	5,5	9,2	14,5	18,5
	25	2,1	2,7	3,4	5,2	8,7	13,6	17,4
	50	2,0	2,6	3,3	5,0	8,3	12,9	16,6
60	1	2,5	3,1	4,0	6,0	10,1	15,7	20,2
	5	2,2	2,8	3,5	5,4	8,9	14,0	17,9
	10	2,1	2,6	3,4	5,1	8,5	13,3	17,0
	25	1,9	2,4	3,1	4,8	7,9	12,4	15,9
	50	1,8	2,3	2,9	4,4	7,4	11,6	14,9
70	1	2,0	2,5	3,3	4,9	8,2	12,9	16,5
	5	1,8	2,2	2,9	4,3	7,2	11,3	14,5
	10	1,7	2,1	2,7	4,1	6,9	10,7	13,8
	25	1,4	1,7	2,2	3,4	5,6	8,9	11,3
	50	1,2	1,5	1,9	2,9	4,8	7,5	9,6
80	1	1,6	2,0	2,6	4,0	6,6	10,4	13,3
	5	1,4	1,7	2,2	3,3	5,5	8,7	11,1
	10	1,1	1,4	1,8	2,8	4,7	7,3	9,4
	25	0,9	1,1	1,5	2,2	3,7	5,8	7,5
90	1	1,3	1,6	2,1	3,1	5,2	8,2	10,5
	5	0,9	1,1	1,5	2,2	3,7	5,9	7,5
	10	0,8	1,0	1,2	1,9	3,1	4,9	6,3
95	1	1,1	1,4	1,8	2,7	4,6	7,2	9,2
	5	0,7	0,9	1,2	1,8	3,1	4,8	6,2
	(10)[4)]	0,6	0,8	1,0	1,5	2,6	4,1	5,2

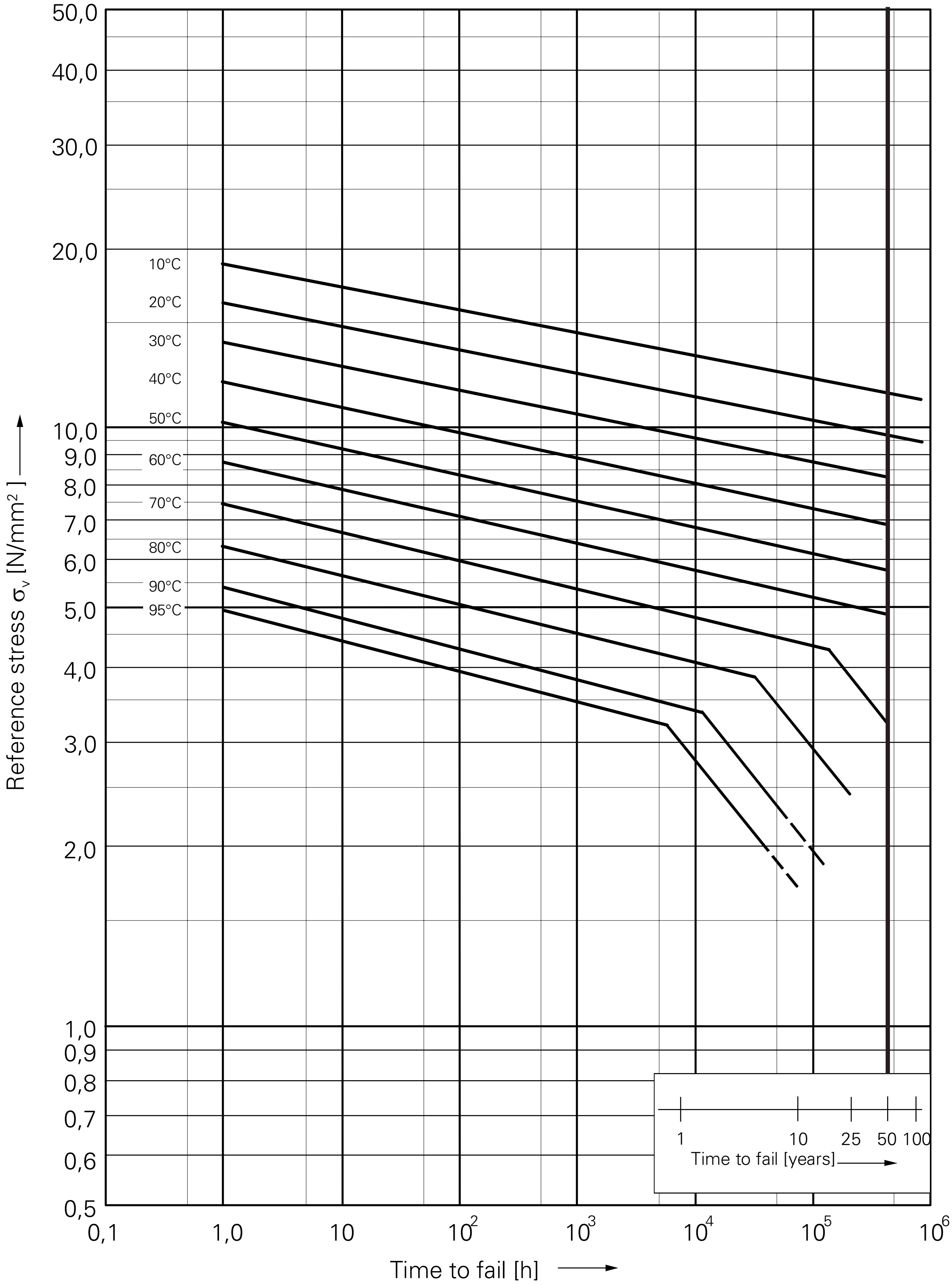
[1)] We recommend for the calculation of the operating pressure in free installed piping systems to multiply the in the table contained operating pressure with a system reduction coefficient f_s=0,8 (This value contains installation-technical influences such as welding joint, flange or also bending loads.).

[2)] These operating pressure have to be reduced by the corresponding reducing coefficients (see page 142) for eyery application.

[3)] ... Operating pressures do not apply to pipes exposed to UV radiation. Within 10 years of operation, this influence may be compensated res. essentially reduced corresponding additives (e.g. carbon black) to the molding material.

[4)] ... The values in brackets are valid at proof of longer testing periods than 1 year at the 110°C test.

Pressure curve for pipes out of PP-R
(acc. to EN ISO 15494 supplement C)



Permissible component operating pressures p_B for PP-R depending on temperature and operation period.

The in the tables stated data apply to water. They were determined from the creep curve taking into account a safety coefficient of C =1,25.Due to the different mechanical properties of the specific material PP-s-el, the maximum operating pressure has to be reduced to 50%!

Temperature [°C]	Operating period [years]	Diameter-wall thickness relation SDR							
		41	**33**	**26**	**17,6**	**17**	**11**	**7,4**	**6**
		Pipe series S							
		20	16	12,5	8,3	8	5	3,2	2,5
		PN							
		2,5	3,2	4	6	6,3	10	16	20
		Permissible component operating pressure p_B [1) 2) 3)] [bar]							
10	1	5,3	6,7	8,4	12,7	13,3	21,1	33,4	42,0
	5	5,0	6,3	7,9	12,0	12,5	20,0	31,6	39,8
	10	4,9	6,1	7,7	11,6	12,2	19,3	30,6	38,5
	25	4,7	5,9	7,4	11,2	11,8	18,7	29,6	37,3
	50	4,6	5,8	7,2	10,9	11,5	18,2	28,8	36,3
	100	4,5	5,6	7,1	10,7	11,2	17,7	28,1	35,4
20	1	4,5	5,7	7,2	10,8	11,3	18,0	28,6	36,0
	5	4,2	5,4	6,7	10,2	10,6	16,9	26,8	33,8
	10	4,1	5,2	6,5	9,9	10,4	16,4	26,1	32,8
	25	4,0	5,0	6,4	9,6	10	16,0	25,3	31,8
	50	3,9	4,9	6,2	9,3	9,7	15,5	24,5	30,9
	100	3,8	4,7	6,0	9,0	9,5	15,0	23,8	29,9
30	1	3,8	4,8	6,1	9,2	9,6	15,3	24,3	30,6
	5	3,6	4,5	5,7	8,6	9,0	14,4	22,8	28,7
	10	3,5	4,4	5,5	8,4	8,8	13,9	22,0	27,7
	25	3,4	4,2	5,3	8,1	8,4	13,4	21,3	26,8
	50	3,3	4,1	5,2	7,9	8,2	13,1	20,7	26,4
40	1	3,2	4,1	5,1	7,8	8,2	12,9	20,5	25,8
	5	3,0	3,8	4,8	7,3	7,6	12,1	19,2	24,2
	10	3,0	3,7	4,7	7,1	7,4	11,8	18,7	23,6
	25	2,8	3,6	4,5	6,8	7,1	11,3	18,0	22,6
	50	2,8	3,5	4,4	6,6	6,9	11,0	17,5	22,0
50	1	2,8	3,5	4,4	6,6	6,9	11,0	17,5	22,0
	5	2,6	3,2	4,1	6,1	6,4	10,2	16,2	20,4
	10	2,5	3,1	3,9	6,0	6,2	9,9	15,7	19,7
	25	2,4	3,0	3,8	5,8	6,0	9,6	15,2	19,1
	50	2,3	2,9	3,7	5,6	5,8	9,3	14,7	18,5
60	1	2,3	2,9	3,7	5,6	5,8	9,3	14,7	18,5
	5	2,2	2,7	3,4	5,2	5,4	8,6	13,7	17,2
	10	2,1	2,6	3,3	5,0	5,2	8,3	13,2	16,6
	25	2,0	2,5	3,2	4,8	5,0	8,0	12,6	15,9
	50	1,9	2,4	3,1	4,6	4,9	7,7	12,1	15,3
70	1	2,0	2,5	3,1	4,7	4,9	7,8	12,4	15,6
	5	1,8	2,3	2,9	4,3	4,5	7,2	11,4	14,3
	10	1,8	2,2	2,8	4,2	4,4	7,0	11,1	14,0
	25	1,5	1,9	2,4	3,6	3,8	6,1	9,6	12,1
	50	1,3	1,6	2,0	3,1	3,2	5,1	8,1	10,2
80	1	1,6	2,1	2,6	3,9	4,1	6,5	10,4	13,1
	5	1,4	1,8	2,3	3,5	3,6	5,7	9,1	11,5
	10	1,2	1,5	1,9	2,9	3,0	4,8	7,6	9,6
	25	1,0	1,2	1,5	2,3	2,4	3,8	6,1	7,6
95	1	1,2	1,5	1,8	2,8	2,9	4,6	7,3	9,2
	5	-	1,0	1,2	1,8	1,9	3,0	4,8	6,1
	(10)[4)]	-	-	(1,0)[4]	(1,5)[4]	(1,6)[4]	(2,6)[4]	(4,0)[4]	(5,1)[4]

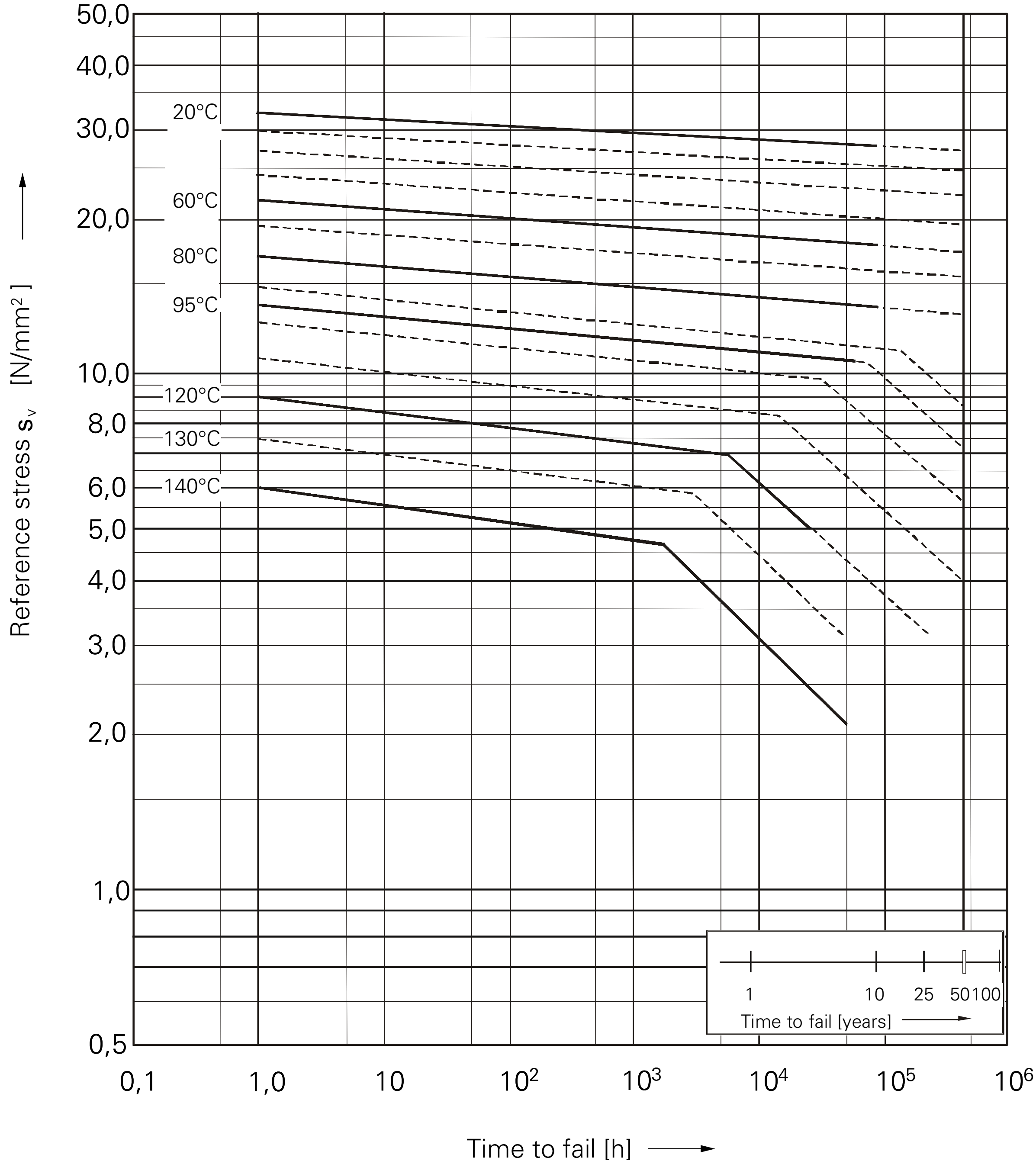
[1)] We recommend for the calculation of the operating pressure in free installed piping systems to multiply the in the table contained operating pressure with a system reduction coefficient f_s=0,8 (This value contains installation-technical influences such as welding joint, flange or also bending loads.).

[2)] These operating pressure have to be reduced by the corresponding reducing coefficients (see page 142) for eyery application.

[3)] ... Operating pressures do not apply to pipes exposed to UV radiation. Within 10 years of operation, this influence may be compensated res. essentially reduced corresponding additives (e.g. carbon black) to the molding material.

[4)] ... The values in brackets are valid at proof of longer testing periods than 1 year at the 110°C test.

Pressure curve for pipes out of PVDF
(acc. to EN ISO 10931 supplement A)



Permissible component operating pressures p_B for PVDF depending on temperature and operation period.

In the tables stated the data apply to water. They were determined from the creep curve taking into account a safety coefficient of C = 1,6.

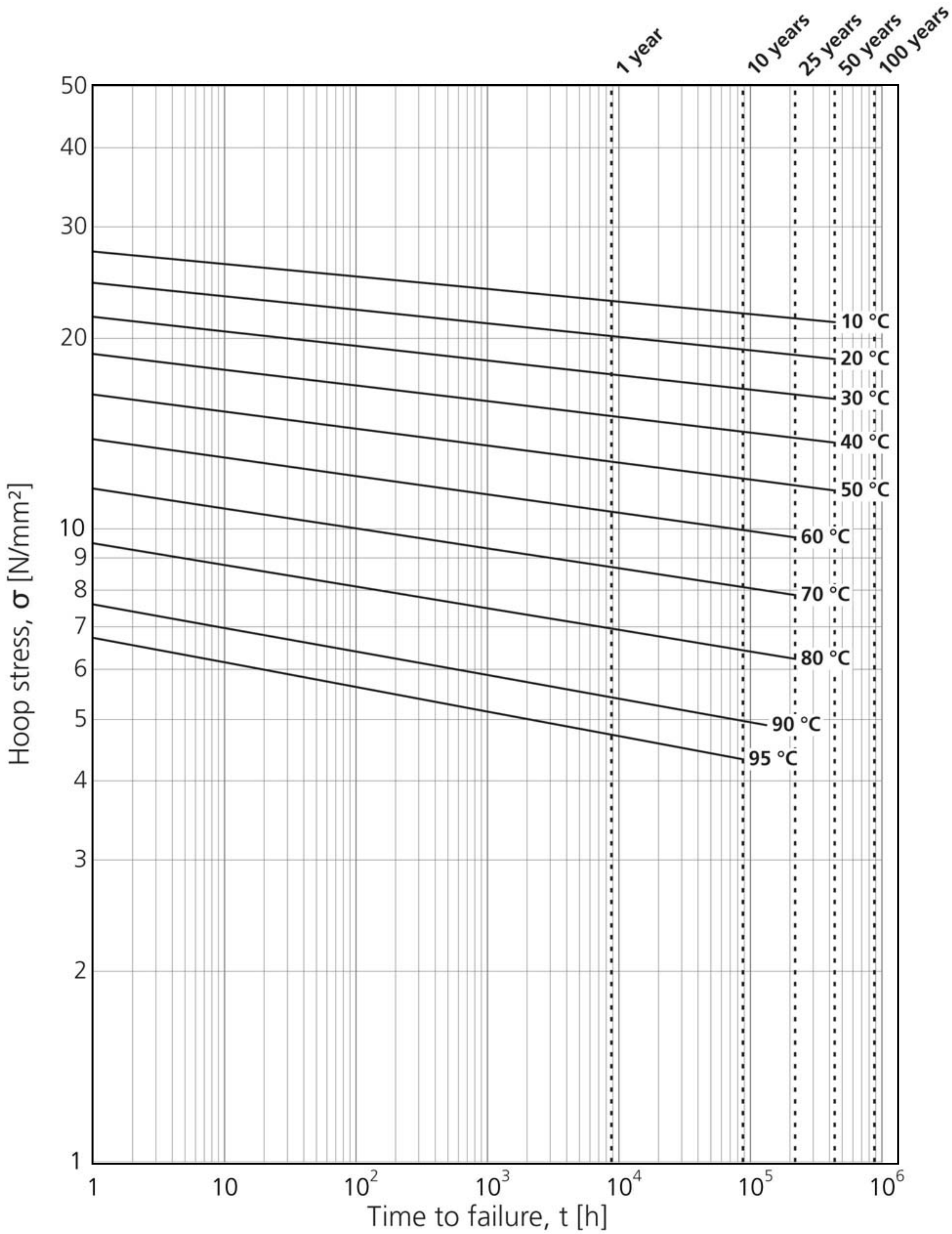
Temperature [°C]	Operating period [years]	Diameter-wall thickness relation SDR **33** / Pipe seris S 16 / PN 10	Diameter-wall thickness relation SDR **21** / Pipe seris S 10 / PN 16
		Permissible component operating pressure p_B [bar] [1) 2)]	
20	1	11,5	18,0
	10	11,0	17,3
	25	10,9	17,1
	50	10,8	17,0
30	1	10,2	16,0
	10	10,0	15,8
	25	10,0	15,7
	50	9,7	15,3
40	1	9,2	14,5
	10	9,1	14,3
	25	9,0	14,1
	50	8,8	13,9
50	1	8,3	13,1
	10	8,0	12,6
	25	7,7	12,2
	50	7,6	11,9
60	1	7,4	11,6
	10	7,1	11,1
	25	7,0	11,0
	50	6,9	10,8
70	1	6,6	10,3
	10	6,3	9,9
	25	6,2	9,8
	50	6,1	9,7
80	1	5,6	8,9
	10	5,4	8,4
	25	5,3	8,3
	50	5,2	8,2
95	1	4,4	6,9
	10	4,1	6,4
	25	3,3	5,3
	50	2,9	4,5
110	1	3,2	5,0
	10	2,2	3,5
	25	1,8	2,9
	50	1,6	2,5
120	1	2,5	4,0
	10	1,5	2,4
	25	1,3	2,0

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

[2] ... These operating pressure have to be reduced by the corresponding reducing coefficients (see page 142) for eyery application.

Material Properties
Installation Guidelines
Calculation Guidelines
Connection Methods
Double Containment Piping
APP-Rovals and Standards

Pressure curve for pipes of ECTFE
(acc. to DVS 2205-1 supplement 18)



Permissible component operating pressures P_B for ECTFE depending on temperature and operation period

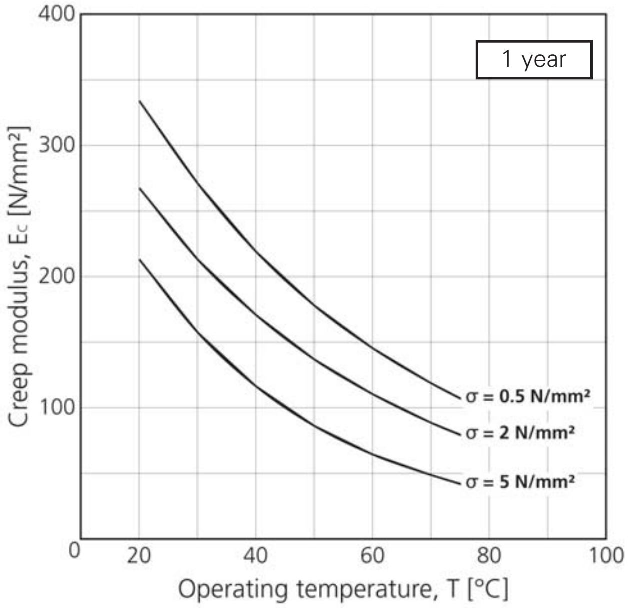
The in the tables stated data apply to water. They were detemined from the creep curve taking into account a safety coefficient of C = 1,6

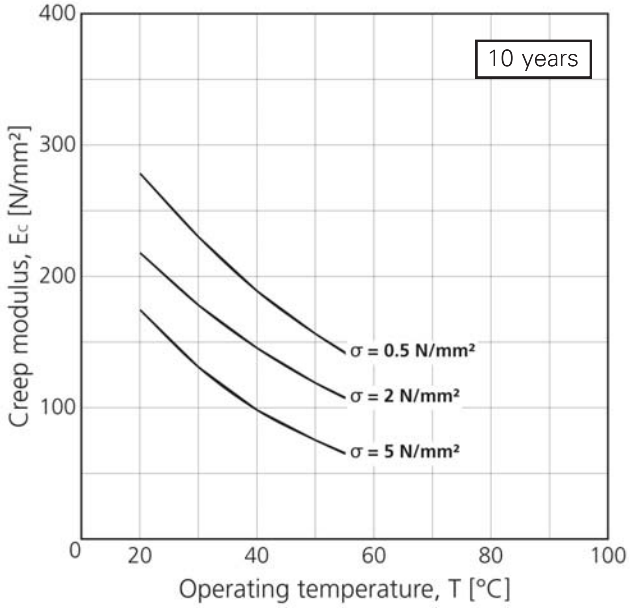
Temperature [°C]	Operating period [years]	Diameter-wall thickness relation SDR 33	21
		Pipe series S 16	10
		Permissible component operating pressure p_B [bar] 1) 2)	
10	1	8,9	14,3
	5	8,6	13,8
	10	8,5	13,6
	25	8,4	13,4
	50	8,2	13,2
20	1	7,8	12,6
	5	7,6	12,1
	10	7,4	11,9
	25	7,3	11,7
	50	7,2	11,5
30	1	6,8	10,9
	5	6,6	10,5
	10	6,5	10,4
	25	6,3	10,1
	50	6,2	10,0
40	1	5,8	9,4
	5	5,6	9,0
	10	5,5	8,9
	25	5,4	8,7
	50	5,3	8,5
50	1	4,9	7,9
	5	4,7	7,6
	10	4,6	7,5
	25	4,5	7,3
	50	4,4	7,1
60	1	4,1	6,6
	5	3,9	6,3
	10	3,8	6,2
	25	3,7	6,0
70	1	3,3	5,4
	5	3,2	5,1
	10	3,1	5,0
	25	3,0	4,9
80	1	2,7	4,3
	5	2,5	4,1
	10	2,5	4,0
	25	2,4	3,8
90	1	2,1	3,3
	5	1,9	3,1
	10	1,9	3,1
	15	1,9	3,0
95	1	1,8	2,9
	5	1,7	2,7
	10	1,6	2,7

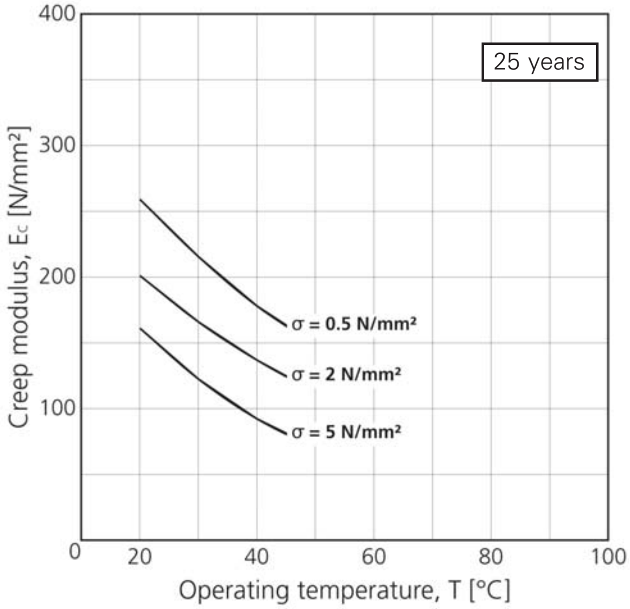
1) We recommend for the calculation of the operating pressure in free installed piping systems to multiply the in the table contained operating pressure with a system reduction coefficient f_s=0,8 (This value contains installation-technical influences such as welding joint, flange or also bending loads).

2) These operating pressures have to be reduced by the corresponding reducing coefficients (see page 142) for eyery application.

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





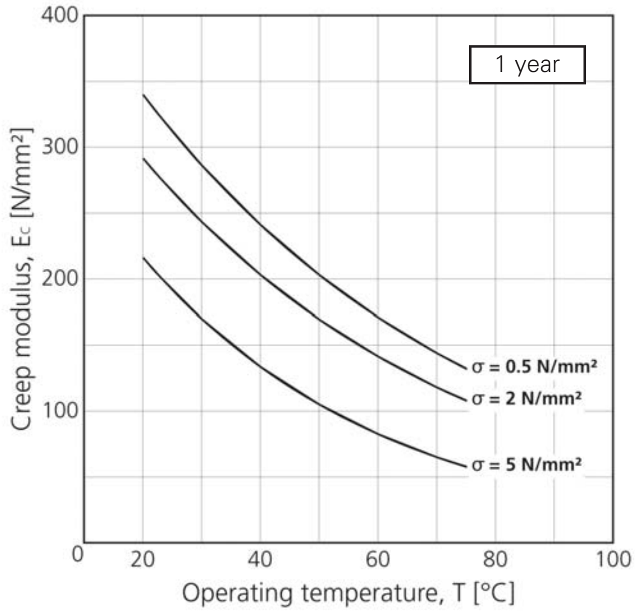


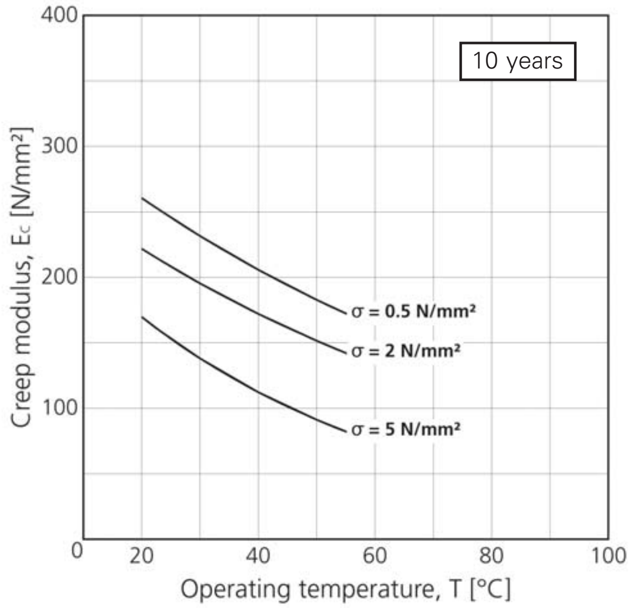
Reducing of the creep modulus

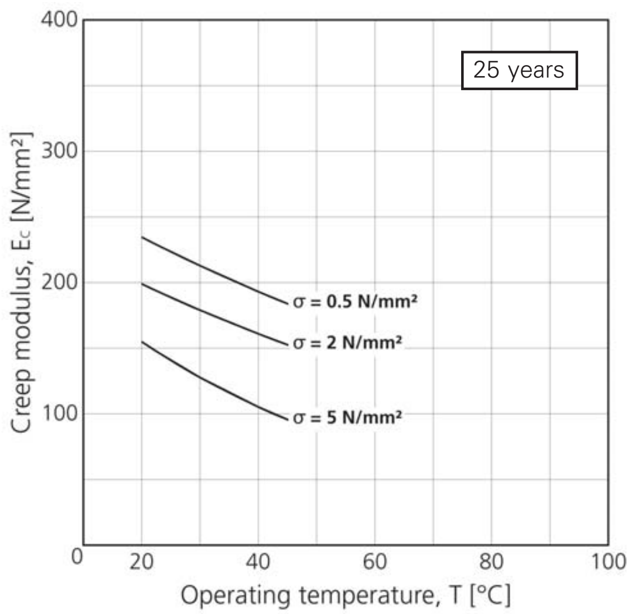
In the stated diagrams the calculated creep modulus still has to be reduced by a safety coefficient of ≥ 2 for stability calculations.

Influences by chemical attack or by eccentricity and unroundness have to be taken into account separately.

Creep modulus curves for PE 100
(acc.to DVS 2205, part 1)



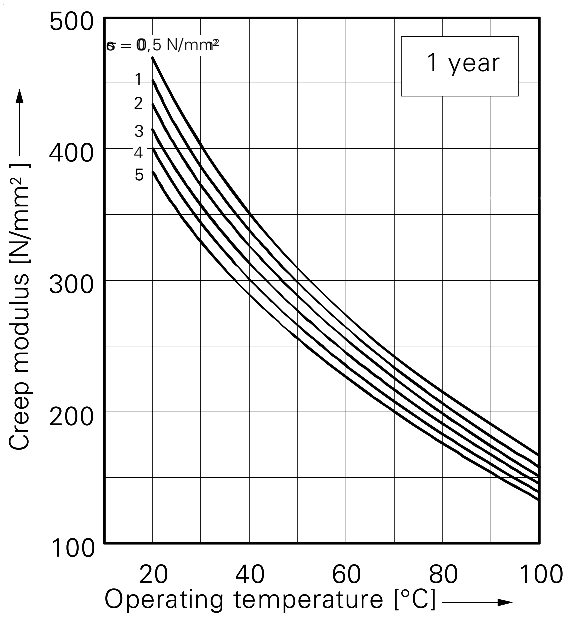


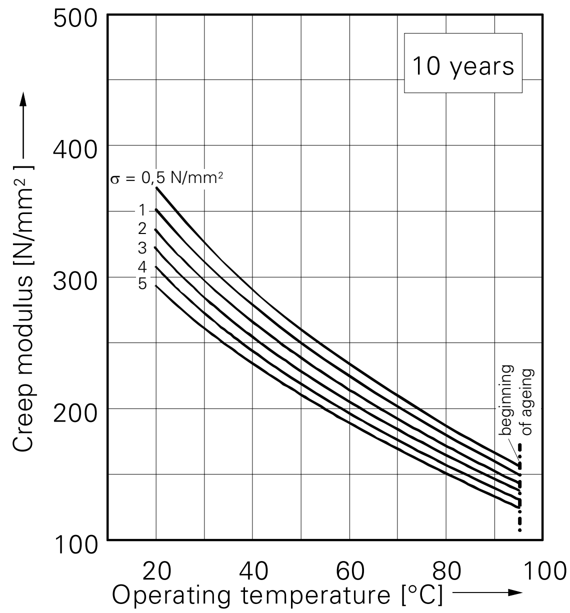


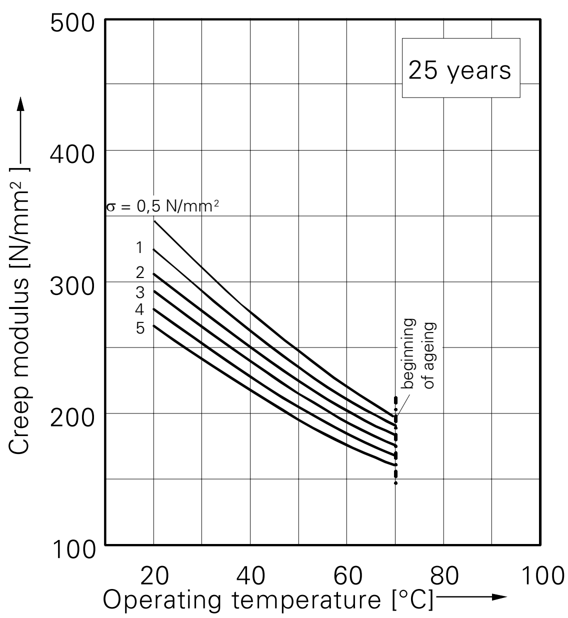
Reducing of the creep modulus

In the stated diagrams the calculated creep modulus still has to be reduced by a safety coefficient of ≥ 2 for stability calculations.

Creed modulus curves for PP-H (acc. to DVS 2205, part 1)



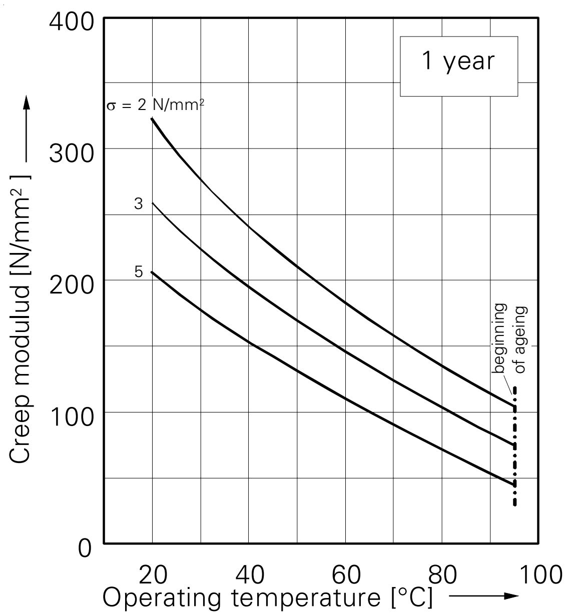


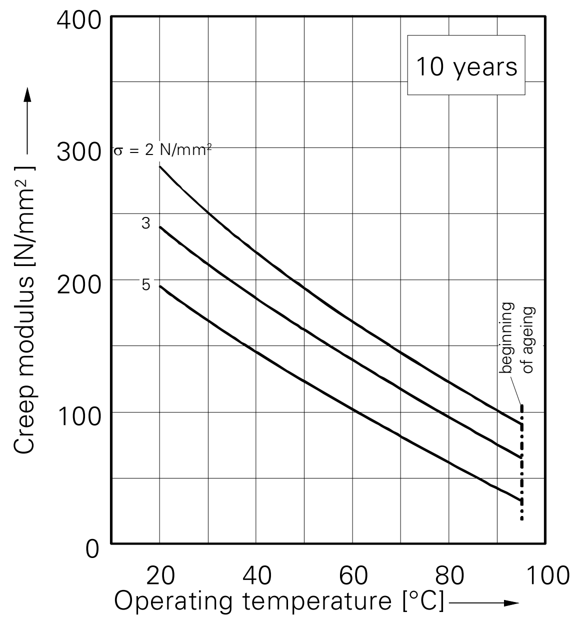


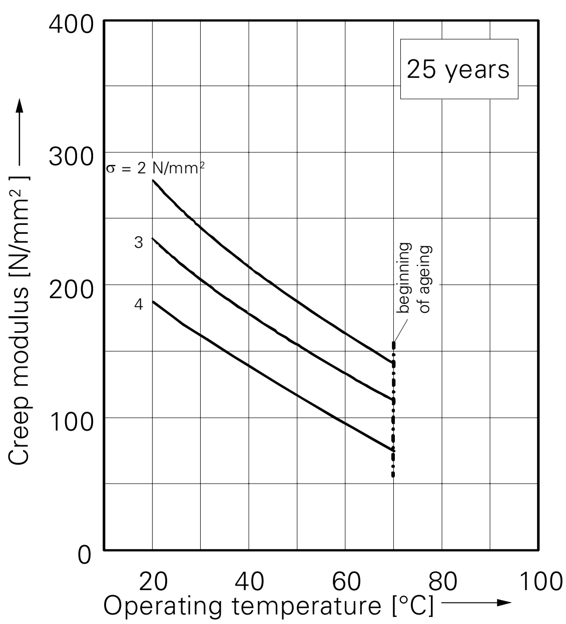
Reducing of the creep modulus

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 curves for PP-R/PP-B (acc, to DVS 2205, part 1)



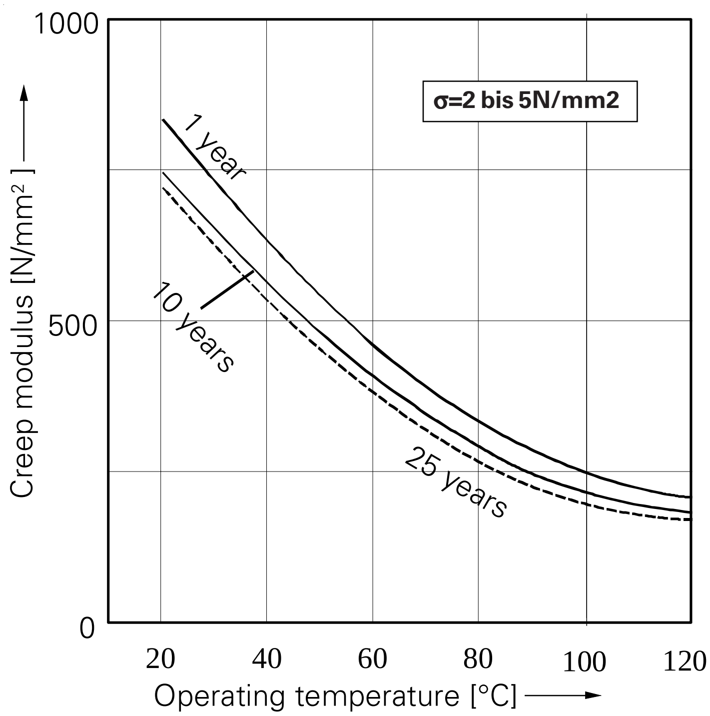




Reducing of the creep modulus

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 curves for PVDF (acc. to DVS 2205-1)



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.

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 periods [years]	SDR-series 41		33		17,6		11	
		S-series 20		16		8,3		5	
		Permissible buckling pressure 1) [bar]							
		PE80	**PE100**	**PE80**	**PE100**	**PE80**	**PE100**	**PE80**	**PE100**
20	1	0,048	0,053	0,095	0,104	0,681	0,745	3,117	3,410
	10	0,039	0,041	0,076	0,079	0,545	0,566	2,496	2,952
	25	0,035	0,036	0,069	0,071	0,498	0,508	2,278	2,326
30	1	0,038	0,044	0,075	0,087	0,542	0,622	2,482	2,845
	10	0,031	0,036	0,062	0,070	0,445	0,499	2,038	2,284
	25	0,029	0,033	0,057	0,064	0,411	0,457	1,880	2,092
40	1	0,031	0,037	0,060	0,072	0,434	0,519	1,988	2,374
	10	0,026	0,031	0,050	0,061	0,363	0,439	1,664	2,011
	25	0,024	0,029	0,047	0,057	0,339	0,411	1,551	1,882
50	1	0,024	0,031	0,048	0,060	0,348	0,433	1,593	1,981
	10	0,021	0,028	0,041	0,054	0,297	0,387	1,358	1,772
60	1	0,020	0,026	0,039	0,050	0,280	0,361	1,283	1,653
70	1	0,016	0,022	0,031	0,042	0,225	0,301	1,029	1,379
80	1	0,012	0,018	0,024	0,035	0,178	0,251	0,818	1,151

1) ...This buckling pressures have been calculated according to formula on page 144. These buckling pressures have to be decreased by the corresponding reducing factors due to chemical influence or unroundness for any application.

Permissible buckling pressures for PP-H and PP-R

In the tables stated values apply to water. Contained in the tables the maximum permissible buckling pressures in [bar] were determined taken into account a safety coefficient of 2,0 (minimum safety coefficient for stability calculations).

Temperature [°C]	Operation periods [years]	SDR-series							
		41		33		17,6		11	
		S-series							
		20		16		8,3		5	
		Permissible buckling pressure 1) [bar]							
		PP-H	PP-R	PP-H	PP-R	PP-H	PP-R	PP-H	PP-R
20	1	0,080	0,060	0,170	0,125	1,11	0,83	5,15	3,80
	10	0,060	0,050	0,130	0,110	0,86	0,73	3,95	3,35
	25	0,055	0,050	0,120	0,110	0,78	0,70	3,65	3,25
30	1	0,070	0,050	0,150	0,110	0,96	0,71	4,45	3,30
	10	0,055	0,045	0,115	0,100	0,75	0,64	3,50	2,95
	25	0,050	0,045	0,110	0,095	0,71	0,61	3,30	2,85
40	1	0,060	0,045	0,130	0,095	0,83	0,62	3,85	2,85
	10	0,050	0,040	0,105	0,090	0,68	0,57	3,15	2,65
	25	0,045	0,040	0,100	0,085	0,64	0,55	2,95	2,55
50	1	0,050	0,040	0,110	0,080	0,73	0,53	3,40	2,45
	10	0,045	0,035	0,095	0,075	0,61	0,49	2,85	2,30
	25	0,040	0,035	0,090	0,075	0,57	0,48	2,65	2,20
60	1	0,045	0,035	0,100	0,070	0,64	0,47	2,95	2,15
	10	0,040	0,030	0,085	0,065	0,55	0,43	2,55	2,00
	25	0,035	0,030	0,080	0,065	0,52	0,42	2,40	1,95
70	1	0,040	0,030	0,085	0,060	0,57	0,41	2,65	1,90
	10	0,035	0,025	0,075	0,055	0,49	0,37	2,25	1,70
	25	0,030	0,025	0,070	0,055	0,46	0,36	2,15	1,65
80	1	0,035	0,025	0,075	0,050	0,50	0,34	2,30	1,60
	10	0,030	0,020	0,065	0,045	0,44	0,31	2,20	1,45
95	1	0,030	0,020	0,065	0,040	0,41	0,27	1,90	1,25
	10	0,025	0,015	0,055	0,035	0,35	0,23	1,65	1,05

1) ...This buckling pressures have been calculated according to formula on page 144. These buckling pressures have to be decreased by the corresponding reducing factors due to chemical influence or unroundness for any application.

Admissible buckling pressures for PVDF

In the tables stated values apply to water. Contained in the tables the maximum permissible buckling pressures in [bar] were determined taken into account a safety coefficient of 2,0 (minimum safety coefficient for stability calculations).

Temperature [°C]	Operation periods [years]	SDR-series **33** / S-series 16	SDR-series **21** / S-series 10
		Permissible buckling pressure 1) [bar] **PVDF**	
20	1	0,28	1,18
	10	0,26	1,08
	25	0,25	1,04
30	1	0,26	1,05
	10	0,23	0,95
	25	0,23	0,92
40	1	0,23	0,93
	10	0,21	0,85
	25	0,20	0,82
50	1	0,20	0,82
	10	0,18	0,70
	25	0,17	0,70
60	1	0,17	0,63
	10	0,16	0,60
	25	0,15	0,60
70	1	0,15	0,60
	10	0,13	0,53
	25	0,12	0,50
80	1	0,13	0,52
	10	0,11	0,45
	25	0,10	0,42
90	1	0,11	0,43
	10	0,09	0,37
	25	0,08	0,35
100	1	0,09	0,36
	10	0,08	0,32
	25	0,07	0,29
110	1	0,07	0,30
	10	0,06	0,26
	25	0,06	0,23
120	1	0,06	0,26
	10	0,06	0,24
	25	0,05	0,21

1) ...This buckling pressures have been calculated according to formula on page 144. These buckling pressures have to be decreased by the corresponding reducing factors due to chemical influence or unroundness for any application.

Permissible buckling pressures for ventilation pipes out of PP-H and PE.

100000 Pa = 1bar

Contained in the tables the maximum permissible buckling pressures in Pascal were determined taken into account a safety coefficient of 2,0 (minimum safety coefficient for stability calculations).

Pipe dimension Ø x s [mm]	Material	Permissible buckling pressures in Pascal [Pa] for different operation temperatures and periods							
		20°C		30°C		40°C		50°C	
		10 years	25 years	10 years	25 years	10 years	25 years	10 years	25 years
140 x 3,0	PP-H	4200	3800	3650	3450	3350	3100	3000	2800
160 x 3,0	PP-H	2750	2500	2400	2300	2200	2050	1950	1850
180 x 3,0	PP-H	1900	1750	1700	1600	1550	1400	1350	1250
200 x 3,0	PP-H	1400	1250	1200	1150	1100	1050	1000	900
225 x 3,5	PP-H	1550	1400	1350	1300	1250	1150	1100	1050
250 x 3,5	PP-H	1100	1000	1000	900	900	850	800	750
280 x 4,0	PP-H	1200	1100	1050	1000	950	900	850	800
315 x 5,0	PP-H	1650	1500	1450	1350	1300	1250	1150	1100
355 x 5,0	PP-H	1150	1050	1000	950	900	850	800	750
400 x 6,0	PP-H	1400	1250	1200	1150	1100	1050	1000	900
400 x 8,0	PP-H	3400	3050	2950	2800	2700	2500	2400	2250
400 x 8,0	PE100	2035	1815	1705	1540	1375	1265	1100	-
450 x 6,0	PP-H	950	900	850	800	750	700	700	650
450 x 8,0	PP-H	2350	2150	2050	1950	1850	1750	1650	1550
450 x 8,0	PE100	1375	1265	1155	1045	935	880	770	-
500 x 8,0	PP-H	1700	1550	1500	1400	1350	1250	1200	1000
500 x 8,0	PE100	990	935	825	770	660	605	550	-
500 x 10,0	PP-H	3400	3050	2950	2800	2700	2500	2400	2250
500 x 10,0	PE100	2035	1815	1705	1540	1375	1265	1100	-
560 x 8,0	PP-H	1200	1100	1050	1000	950	900	850	800
560 x 10,0	PP-H	2400	2150	2100	1950	1900	1750	1700	1600
560 x 10,0	PE100	1430	1265	1210	1045	990	880	770	-
630 x 10,0	PP-H	1650	1500	1450	1350	1300	1250	1150	1100
630 x 10,0	PE100	990	880	825	715	660	605	550	-
710 x 12,0	PP-H	2000	1850	1750	1650	1600	1500	1450	1350
710 x 12,0	PE100	1210	1100	990	880	825	715	660	-
800 x 12,0	PP-H	1400	1250	1200	1150	1100	1050	1000	900
900 x 12,0	PE100	825	770	660	605	550	495	440	-
900 x 15,0	PP-H	1900	1750	1700	1600	1550	1400	1350	1250
900 x 15,0	PE100	1155	1045	935	880	770	715	605	-
1000 x 15,0	PP-H	1400	1250	1200	1150	1100	1050	1000	900
1000 x 15,0	PE100	825	770	660	605	550	495	440	-
1200 x 18,0	PP-H	1400	1250	1200	1150	1100	1050	1000	900
1200 x 18,0	PE100	825	770	660	605	550	495	440	-
1400 x 20,0	PP-H	1200	1100	1050	1000	950	900	850	800
1400 x 20,0	PE100	715	660	605	550	495	440	385	-

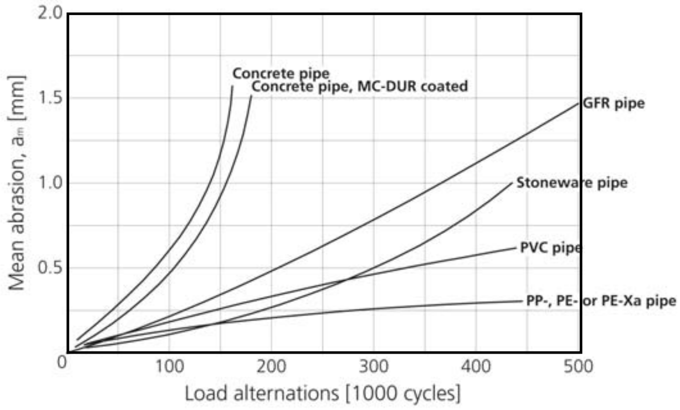
This buckling pressures were calculated with the formula from page 144. These operating pressure have to be reduced by the corresponding reducing coefficients through chemical influences or unroundness .

Behaviour at abrasive fluids

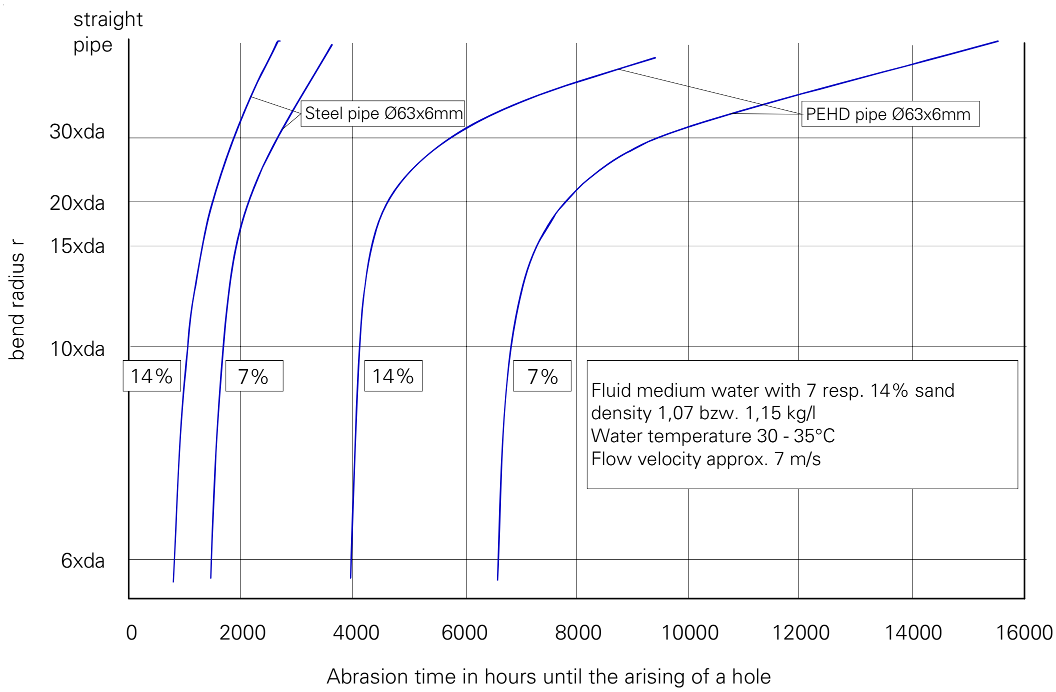
In principle, thermoplastic pipes are better suited for the conveying of fluid-solid-mixtures than e. g. concrete pipes or also steel pipes. We have already resulted positive experiences of different applications.
At the of the Technische Hochschule Darmstadt developed method, a 1 m long half-pipe is 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.

Abrasion behavior according to method Darmstadt

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



Abrasion time of HDPE- and Steel elbows of different bending radii in dependance on solid portion



In a more practical tests the medium is pumped through pipe samples which are built-in in a piping system. A possibility to check the abra-sion behaviour of such a system is to determine the time until the arising of a hole. As it can been seen from the opposite diagram, thermoplastic pipes (in this special case, PE pipes have been applied whereby with PP pipes the same or slightly better results will be achieved) have an essential advan-tage compared with steel pipes.

For conveying of dry abrasive acting fluids polypropylene can only be applied conditionally. There should only be used electro-conductable mate-rials (PE-el, PP-R-s-el, PP-R-el) be-cause of a possible static load.
The use for each single application has to be clarified with our technical engineering department.

General chemical properties of PE & PP

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 und PP are 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 PP and PE and can therefore be applied without problems, unlike to PVDF or other fluoroplastics.

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, PP and PE are rather only suitable for pressureless piping systems and tanks.

Hydrocarbons

PP is only conditionally resistant against hydrocarbons (benzine as well as other fuels) already at ambient temperature (swelling > 3 %).
PE however can be used 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 is PE conditonally resistant as the swelling is > 3 %.

Acids

Sulphuric Acid

Concentrations up to aPP-Roximately 70% change the properties of PP and PE only slightly. Concentrations higher than 80 % cause already at room temperature oxidation. At higher temperatures, this oxidation can even go to a carbonization of the surface of the PP semi-finished products.

Hydrochloric acid, hydrofluoric acid

Against concentrated hydrochloric acid and hydrofluoric acid, PP and PE are chemically resistant. But there appears a diffusion of HCl (concentrations > 20 %) and of HF (concentrations > 40 %) at PP, 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, PP and PE is also resistant at higher concentrations and at raised temperatures.

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

Actual lists of chemical properties are available on www.agru.at

Chemical resistance PVDF

PVDF is resistant to a wide range of chemicals.

It has an outstanding resistance to most anorganic and organic acids, oxidising media, aliphatic and aromatic hydrocarbons, alcohols and halogenated solvents.

PVDF is also resistant to halogens (chlorine, bromine, iodine), but not fluorine.

Generally PVDF is unsuitable for the following media, because they can lead to decomposition:

- amine, basic media with a index of pH $\geq$ 12
- joints, which can produce free radicals under certain circumstances
- smoking sulfuric acid
- high polar solvents (acetone, ethyl acetate, dimethyl-formamide, dimethylsulphoxide, ...); here PVDF can solve or swell.
- melted alkaline metals or amalgam.

Please note that there is the possibility of tension crack development (stress cracking). This can happen when PVDF is situated in a milleu with a pH-factor $\geq$ 12 or in the presence of free radicals (for example elemental chlorine) and it is exposed to a mechanical use in the same time.

Maximum permissible H_2SO_4-concentration for PVDF pipes depending on temperature (based on ttests with the Dechema Console).

Maximum permissible H_2SO_4 - concentration

Example: sulfuric acid

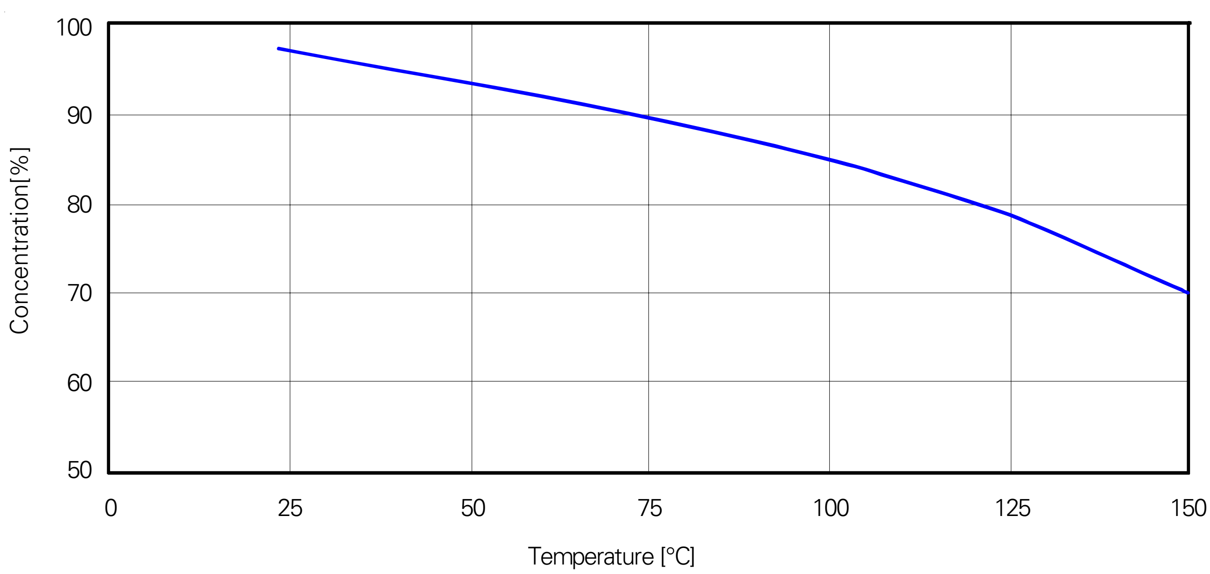
PVDF is exposed to the attack of concentrated sulfuric acid. Through free SO_3 in the sulfuric acid tension chrack development (stress cracking) can happen if it is also exposed to a mechanical use. Among high temperatures the concentration of free SO_3 even by strong diluted sulvuric acid solution can lead to tension crack development.

To determine the permissible pressure in presence of sulfuric acid and depending on the temperature we have analysed the behaviour of pipes out of PVDF by different pressures and temperatures in the DECHEMA-bracket.

The following essential paramenters should be considered in every cases:

- Properties of the finished piece out of PVDF
- Chemical structure and physical state of the joint(s), which come in contact with the fitting out of PVDF.
- Concentration
- Temperature
- Time
- Possible diffusion or solubility

Actual lists of chemical properties are available on www.agru.at



Chemical resistance ECTFE

ECTFE has an outstandingly good chemical resistance and a remarkable barrier-property. It practicaly won´t be attacked from most of the industrial used corrordible chemicals, e.g. strong mineral and oxidized acids, alkaline, metal-etching-products, liquid oxygen and all organic solvents, except hot amines (z.B. aniline, dimethylamine).

The constancy datas for solvents in the following table were tested with undiluted solvents. A chemical attack depends on the concentration, by lower concentration of the listed media is expected a smaller effect as shown in the table.

Like other fluorine plastics ECTFE will be attacked by sodium and potassium. The attack depends on the induction period and the temperature. ECTFE and other fluorinepolymeres can swam in contact with special halogenated solvents;
this effect has normally no influences on the usability. If the solvent is taken away and the surface is dry, the mechanical properties come back to their origin values, which shows that no chemical attack take place.

Actual lists of chemical properties are available on www.agru.at

Chemical	Temperature [°C]	Weight gain [%]	Influence on tensile modulus	Influence on elongation at break
Mineral acid				
Sulfuric acid 78%	23	< 0,1	U	U
	121	< 0,1	U	U
Hydrochloric acid 37%	23	< 0,1	U	U
	75-105	0,1	U	U
Hydrochloric acid 60%	23	< 0,1	U	U
Chlorosulfonic acid 60%	23	0,1	U	U
Oxidizing acid				
Nitric acid 70%	23	< 0,1	U	U
	121	0,8	A	C
Chromic acid 50%	23	< 0,1	U	U
	111	0,4	U	U
Aqua regia	23	0,1	U	U
	75-105	0,5	U	U
Solvents				
Aliphates	23	0,1	U	U
Hexane	54	1,4	A	U
Isooctane	23	< 0,1	U	U
	116	3,3	A	U
Aromates				
Benzene	23	0,6	U	U
	74	7	C	U
Toluene	23	0,6	U	U
	110	8,5	C	U
Alcoholes				
Methanol	23	0,1	U	U
	60	0,4	A	U
Butanol	23	< 0,1	U	U
	118	2,0	A	U
Classical plastic solvents				
Dimethyl formamide	73	2,0	A	U
	250	7,5	C	U
Dimethyl sulphoxide	73	0,1	U	U
	250	3,0	U	U

U-Insignificant
A-Reduction by 25-50%
B-Reduction by 50-75%
C-Reduction by > 75%

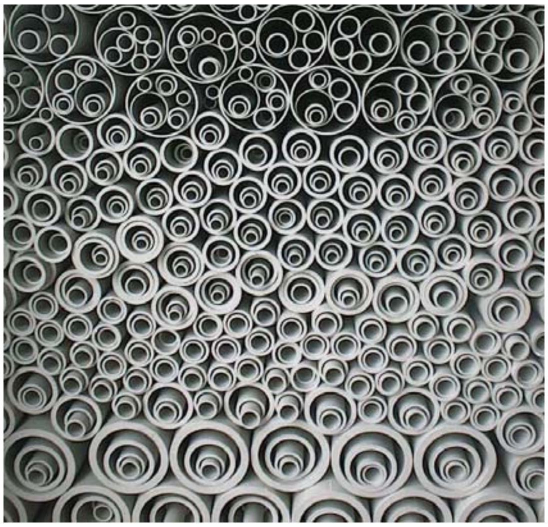
Transport and handling

At the transport and handling of pipes and fittings, the following guidelines have to be observed in order to avoid damages:

Pipes out of PP-H, special materials (PP-R-s-el, PP-H-s, PE-el) and prefabricated components (for example segmented bends) may only be loaded resp. transported with special care at pipe wall temperatures below 0°C.

Impact- and bending stresses at temperatures < 0°C have to be avoided.

Damages of the surface (scratches, marks, ...), as they occur at dragging of pipes, have to be avoided.



Storage

At the storage of pipes and fittings, the below stated regulations have to be observed in order to avoid a quality decrease:

The storage area has to be even and free from waste, such as stones, screws, nails, etc.

At piling of pipes, storage heights of 1 m may not be exceeded. In order to avoid a rolling away of the pipes, wooden wedges have to be situated at the outside pipes. At pipes > OD 630mm, maximum two rows may be stored on top of one another. Pipes > OD 1000mm have to be stored loosely.

Pipes have to be stored flat and without bending stress, if possible in a wooden frame.

Natural and grey coloured products have to be protected against UV radiation at a storage outdoors. According to the standard EN 12207-2 pigmented (orange, blue) pipes can be stored outside for a period of 12 months.

Pipes and fittings out of PP-R-s-el and PE-el have to be protected at storage against humidity and UV radiation (no outdoor exposure, use of dry ware-houses).

Attention!
As the special types PP-R-s-el and PE-el suffer the danger of absorption of humidity at a storage period above 12 months, it is recommended to check the usability of the material by means of a welding test.

General Installation guidelines

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

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, position 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 surface qualities of the attachments should help to 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 advantegous.

Fixing by means of pipe clips

Attachments made of steel or of thermoplastics are available for plastics pipes. Steel clips have at any rate to be lined with tapes made of PE or elastomers, as otherwise the surface of the plastics pipe may be damaged. AGRU plastics pipe clips as well as pipe holders are very good suitable for installation. These may be commonly applied and have especially been adjusted to the tolerances of the plastics pipes.

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

It is recommended for smaller pipe diameters (< da 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.

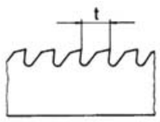
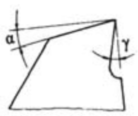
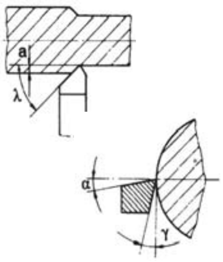
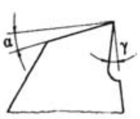
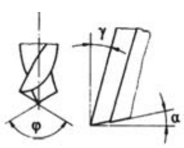
Installation guidelines for electro-conductable materials

The general installation guidelines are valid fundamentally.
At the installation of earthing clips it has to be taken care that the pipe surface below the clip is abraded. It is therefore absolutely necessary to remove the eventually present oxide film in order to be able to guarantee the necessary surface resistance of $< 10^6$ Ohm.

At flange joints, electro-conductable flanges or steel flanges have to be applied.

The end-installed and connected to earth piping system has to be subjected to a final evaluation by competent professional employees regarding the bleeder resistors in any case.

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

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

Machining of PVDF and ECTFE

The machining of PVDF and ECTFE fittings and pipes can be carried out without any particular problems if the following guidelines are observed:

If necessary, remove remaining stresses of larger surfaces by annealing before processing.

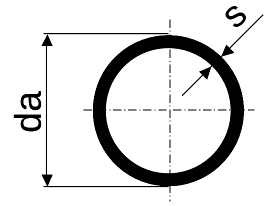
The cutting speed, conveying and cutting geometry should be designed in a way that any subsequent heat can mainly be removed through the shavings (too much pre-heating can lead to melding resp. discolouration of the processed surface).

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 1Meile (naut.) = 1,852km 0,9144m = 1yd = 3ft 25,4mm = 1 inch
Area	m²	m² 1m² = 100dm² = 10000cm²	yd² 0,836m² = 1yd² 1yd² = 9ft²
Volume	m³	m³ 1m³ = 10^3dm³ = 10^6cm³	yd³ 0,765m³ = 1yd³ 1yd³ = 27ft³
Force	kp 1N = 0,102kp 1kp = 9,81N	N 1N = 1kgm/s² = 10^5 dyn	lb 1lb = 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/mm² 10^6Pa = 1MPa = 1N/mm²	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/cm³ = 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 = 1[°C+273,15]°K	°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, water (d.h. σ_v=10)
SDR11
C_{min}=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		
PE 100	1,25		
PP-H	1,6	1,4	1,25
PP-R	1,25		
PVDF	1,6		
ECTFE	2,0		

Operating pressure for water-dangerous media

In order to calculate the respective permissible highest operating pressure at the conveying of water-dangerous fluids, the operating pressure as initial value can be looked up for the corresponding parameter in the relevant table for permissible system operating pressures (valid for water).
Then, this operating pressure has to be reduced by the relevant reducing coefficients.The total safety coefficient is thereby in all cases 2,0 at a minimum, at impact sensitive modified materials higher (at HDPE 2,4, at PP-s and PP-R-s-el 3,0).

$$p_a = \frac{p_B}{f_{AP} \cdot f_{CR} \cdot A_Z}$$

p_a ...Operating pressure of the relevant application [bar]

p_B ...Component operating pressure, valid for water [bar] (see page 112 to 123)

f_{AP} ....application factor
is an additional reducing factor which results a total safety coefficient of 2,0 at a minimum by multiplication with the C-factors according to DIN (see following table).

f_{CR} ....Chemical resistance factor according to DVS

A_Z ...Reducing factor for the specific tenacity

Example:
PE 100, 20°C, 50 years, water (d.h. σ_v=10)
SDR11
Cmin=1,25
Chemicals: H_2SO_4 (sulfuric acid), Concentration 53%, f_{CR} = 2,0 (acc. DVS 2205, part 1)

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

$$p_a = \frac{p_B}{f_{AP} \cdot f_{CR} \cdot A_Z} = \frac{16}{1{,}6 \cdot 2{,}0 \cdot 1} = 5$$

Reducing factor A_Z for the specific tenacity by low temperatures

Material	Reducing factor -10°C	Reducing factor +20°C
PE 80	1,2	1,0
PE 100	1,2	1,0
PE-el	1,6	1,4
PP-H	1,8	1,3
PP-R	1,5	1,1
PP-s	*)	1,7
PP-R-s-el	*)	1,7
PVDF	1,6	1,4

*) ... Not applicable

Application factors f_{AP} for water-dangerous media

Material	Application factor f_{AP}	C - factor (acc. ISO 12162)	Total safety factor by 20°C (f_{AP} x C)
PE 80	1,6	1,25	2,0
PE 100	1,6	1,25	2,0
PE-el	1,9	1,25	2,4
PP-H	1,25	1,6	2,0
PP-R	1,6	1,25	2,0
PP-R-el	2,4	1,25	3,0
PP-R-s-el	2,4	1,25	3,0
PVDF	1,25	1,6	2,0
ECTFE	1,0	2,0	2,0

Calculation of the permissible wall thickness s_{min}

In general strength calculations of thermoplastic piping systems are based on long term values. The strength values depanding on temperature are given in the pressure curves (see page 112 - 123). After calculation of the theoretical wall thickness the construction wall thickness has to be determined under consideration of the nominal pressure resp. SDR-class. Additional wall thickness have to be considered (e.g. application of PP piping systems outdoor without UV - protection or transport abrasive media).

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

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

$s_{\min}$ ....Minimum wall thickness[mm]

p ....Operating pressure [bar]

da ....Pipe outside diameter [mm]

σ_{zul} ....Reference stress [N/mm²]

σ_v ... Reference stress [N/mm²]

$C_{\min}$ ...Minimum safety factor (see page 141)

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 (i.e. s_V=10)
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 124 - 128) [N/mm^2] for t=25a

μ ....Transversal contraction factor (for thermoplastics generally 0,38)

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
PP-R pipe SDR33
40°C, 25 years
EC=220N/mm² (creep modulus curve - page 127)
outside diameter da=110
Wall thickness =3,4mm
Additional safety factor 2,0 (Minimum security factor for stability calculation).

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

$$= \frac{10 \cdot 220}{4 \cdot (1-0,4^2)} \left(\frac{3,4}{53,3}\right)^3 = 0,17$$

$$p_k = \frac{0,17}{2,0} = 0,085$$

$$\sigma_k = p_k \cdot \frac{r_m}{s} = 0,085 \cdot \frac{53,3}{3,4} = 1,33$$

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Calculation of the necessary stiffening for pipes with buckling strain

At higher buckling strains, there is very often applied a stiffening by means of welded-on ribs due to economic reasons in order to enable essentially thinner pipe wall thicknesses.

Basis for this is in slightly amended form the formulae for the buckling pressure calculation of smooth pipes.

It is necessary to know the present critical buckling pressure at this calculation and to choose the desired pipe wall thickness. Consequently, the maximum distance of the stiffening ribs can be calculated by help of the formula.

$$p_k = \frac{10 \cdot E_c}{4 \cdot (1-\mu^2)} \cdot \left(\frac{s}{r_m}\right)^3 \cdot \left[1 + 50 \cdot \left(\frac{r_m}{L}\right)^2\right]$$

p_k ...Critical buckling pressure [bar]

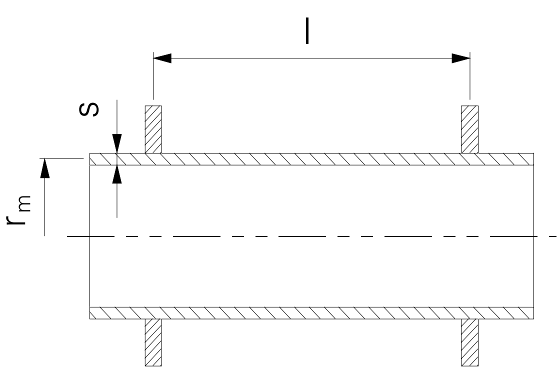
E_c ....Creep modulus (see tables page 124 - 128) [N/mm²] for t=25a

μ ....Transversal contraction factor (for thermoplastics generally 0,4)

s ....Wall thickness [mm]

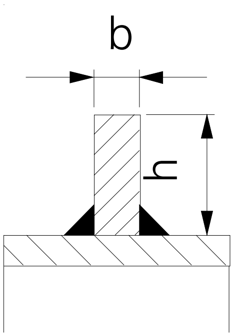
r_m ....Medium pipe radius [mm]

L ....Distance of stiffening ribs [mm]



By means of the stiffening rib distance, the required moment of inertia of the welded-on ribs can be determined.

Afterwards the height or width of the stiffening ribs can be calculated (one of these two parameter has to be chosen).



$$J = 3{,}35 \cdot \frac{r_m{}^2 \cdot s^3}{L}$$

$$J = \frac{b \cdot h^3}{12}$$

J ....Moment of inertia [mm⁴]

r_m ....Medium pipe radius [mm]

s ....Wall thickness [mm]

h ....Height of stiffening rib [mm]

b ....Width of stiffening rib [mm]

There is naturally the possibility to fix the desired stiffening ribs in their measurements at first and then to calculate the maximum permissible critical buckling pressure for the desired pipe wall thickness and dimension.

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 pressure 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 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/m^3]
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 148) 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/m^3]
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/m^3]
v ...Flow velocity [m/s]

The for the calculation necessary resistance coefficients can be seen in DVS 2210, table 10 (extract see page 149) or special technical literature.

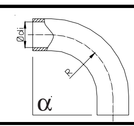
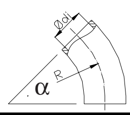
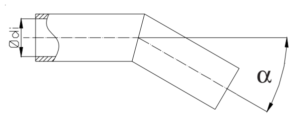
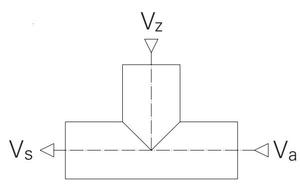
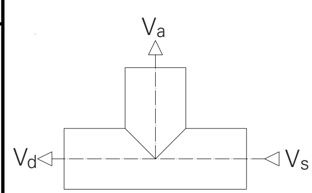
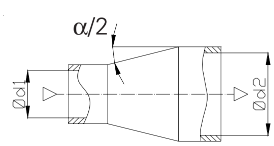
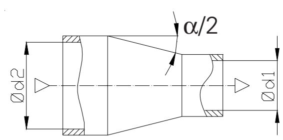
Pressure loss of finished joints or couplings Δp_{RV}

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 ζ_{RV} = 0,1 for each joints in a thermoplastic piping system, such as butt and socket welding as well as flanges.

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

Determination of the hydraulic pressure losses

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

Kind of Fitting	Parameter	Resistance coefficient ζ			Fitting geometry ⇄ =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°		ζz	ζs		
(flow collection)	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°		ζa	ζd		
(flow separation)	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	Angle α	4 ... 8°	16°	24°	
concentric	d_2/d_1=1,2	0,10	0,15	0,20	
(pipe extension)	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	Angle α	4°	8°	20°	
concentric	d_2/d_1=1,2	0,046	0,023	0,010	
(pipe throat)	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
V_a: outgoing volume flow
V_d: continuous volume flow
V_s: total volume flow
V_z: additional volume flow

Determination of the hydraulic pressure losses

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

Nominal width	MV	GSV	SSV	S	KH	K	RV	RK
Ø	Resistance coefficient (ζ)							
25	4,0	2,1	3,0				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	0,1 ... 0,3	0,1 ... 0,15	0,3 ... 0,6	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, 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

Row F=Flange construction acc. DIN 3202-1

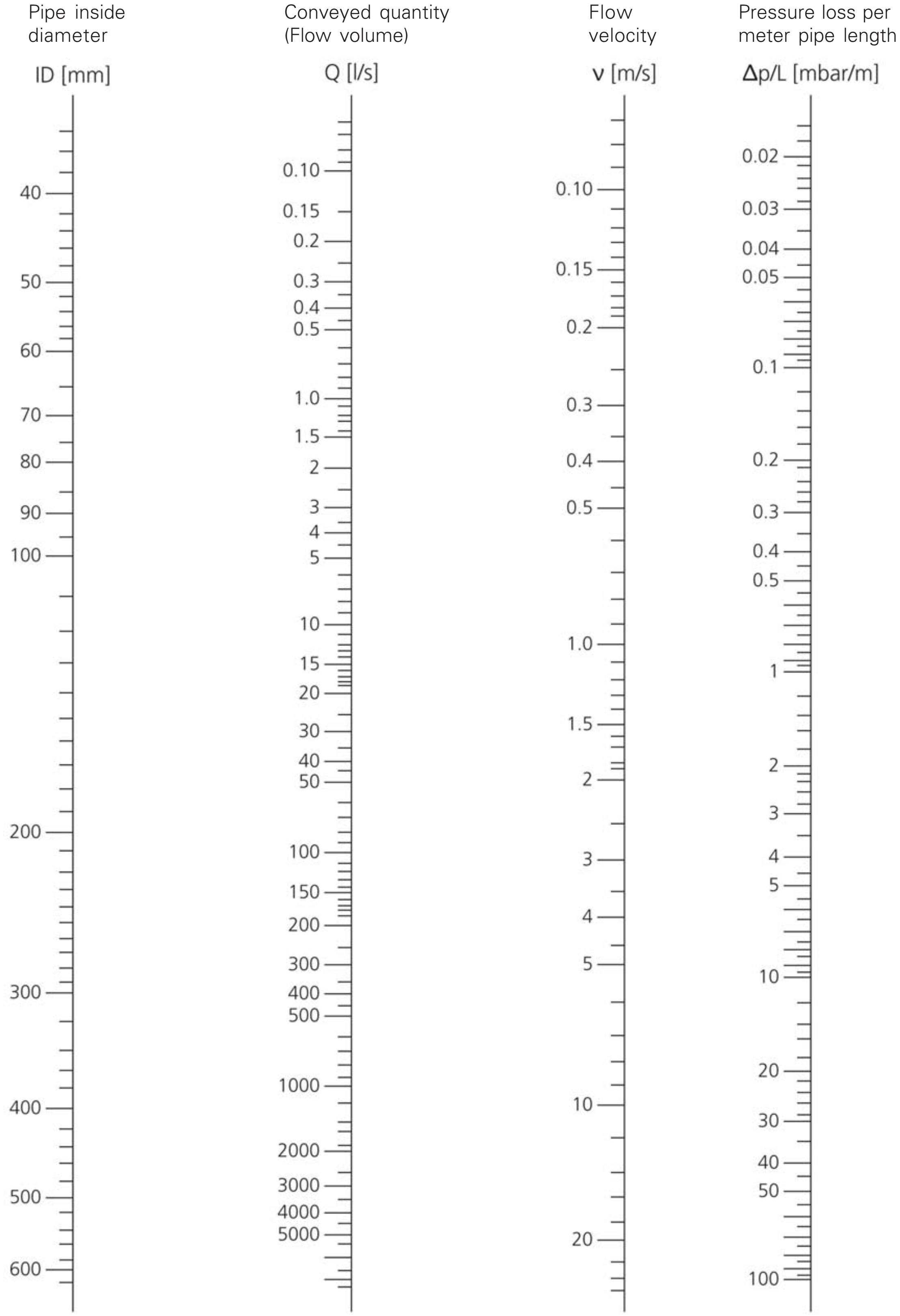
Row K=Connection flange construction acc.
DIN 3202-3

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

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 20m of pipe length are added for each tee, reducer and 90° elbow, about 10m of pipe for each bend r = d and about 5m of pipe length for each bend r = 1,5 x d.



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 concerning 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 and 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]

Load by swelling

$$\varepsilon = 0{,}025...0{,}040$$

A fixed system is not recommended for this load in general as due to the swelling, also a weakening of the material occurs (use of compensation elbows!).

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]

Usual Support distances can be taken from the following tables.

PE 80, SDR11 (acc. DVS 2210, Tab.13)

da [mm]	Support distance L_A in [mm] at				
	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
450	3550	3400	3300	3100	2900
500	3800	3650	3500	3350	3100
560	4100	3950	3800	3600	3350
630	4450	4250	4100	3900	3650

Remark: The factor f_{LA} is determined depending on the pipe outside diameter. There is the following relation valid:

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

PE 100 SDR11

OD [mm]	Support distance [mm]				
	20°C	30°C	40°C	50°C	60°C
20	633	605	550	495	440
25	715	660	605	605	550
32	825	825	715	715	605
40	990	935	825	825	715
50	1155	1100	990	935	825
63	1320	1265	1155	1100	990
75	1485	1430	1320	1210	1100
90	1650	1595	1485	1375	1265
110	1815	1760	1650	1595	1430
125	1925	1870	1760	1705	1540
140	2090	2035	1925	1815	1650
160	2255	2145	2035	1925	1760
180	2365	2255	2145	2035	1925
200	2530	2420	2310	2200	2090
225	2695	2585	2475	2365	2255
250	2860	2750	2640	2530	2310
280	3025	2915	2805	2640	2420
315	3190	3080	2970	2805	2585
355	3410	3300	3190	3025	2805
400	3630	3465	3355	3190	2970
450	3756	3586	3464	3304	3080
500	3980	3800	3670	3501	3264
560	4229	4038	3900	3720	3468
630	4526	4321	4174	3982	3712

PP-H, SDR11 (acc. DVS 2210, Tab.14)

da [mm]	Support distance L_A in [mm] at						
	20°C	30°C	40°C	50°C	60°C	70°C	80°C
16	650	625	600	575	550	525	500
20	700	675	650	625	600	575	550
25	800	775	750	725	700	675	650
32	950	925	900	875	850	800	750
40	1100	1075	1050	1000	950	925	875
50	1250	1225	1200	1150	1100	1050	1000
63	1450	1425	1400	1350	1300	1250	1200
75	1550	1500	1450	1400	1350	1300	1250
90	1650	1600	1550	1500	1450	1400	1350
110	1850	1800	1750	1700	1600	1500	1400
125	2000	1950	1900	1800	1700	1600	1500
140	2100	2050	2000	1900	1800	1700	1600
160	2250	2200	2100	2000	1900	1800	1700
180	2350	2300	2200	2100	2000	1900	1800
200	2500	2400	2300	2200	2100	2000	1900
225	2650	2550	2450	2350	2250	2150	2000
250	2800	2700	2600	2500	2400	2300	2150
280	2950	2850	2750	2650	2550	2450	2300
315	3150	3050	2950	2850	2700	2600	2450
355	3350	3250	3150	3000	2850	2750	2600
400	3550	3450	3350	3200	3050	2900	2750
450	3800	3700	3600	3450	3300	3100	2950
500	4100	4000	3850	3700	3500	3350	3150
560	4400	4300	4150	4000	3800	3600	3400
630	4800	4650	4500	4300	4100	3900	3700

Calculation of Support distances for pipes

PVDF Ø 16-50 SDR21, Ø 63-400 SDR33
(acc. DVS 2210, Tab.17)

da [mm]	Support distance L_A in [mm] at 20°C	30°C	40°C	50°C	60°C	70°C	80°C	100°C	120°C
16	725	700	650	600	575	550	500	450	400
20	850	800	750	750	700	650	600	500	450
25	950	900	850	800	750	700	675	600	500
32	1100	1050	1000	950	900	850	800	700	600
40	1200	1150	1100	1050	1000	950	900	750	650
50	1400	1350	1300	1200	1150	1100	1000	900	750
63	1400	1350	1300	1250	1200	1150	1100	950	800
75	1500	1450	1400	1350	1300	1250	1200	1050	850
90	1600	1550	1500	1450	1400	1350	1300	1100	950
110	1800	1750	1700	1650	1550	1500	1450	1250	1100
125	1900	1850	1800	1700	1650	1600	1500	1350	1200
140	2000	1950	1900	1800	1750	1700	1600	1450	1250
160	2150	2100	2050	1950	1850	1800	1700	1550	1350
180	2300	2200	2150	2050	1950	1900	1800	1600	1400
200	2400	2350	2250	2150	2100	2000	1900	1700	1500
225	2550	2500	2400	2300	2200	2100	2000	1800	1600
250	2650	2600	2500	2400	2300	2200	2100	1900	1700
280	2850	2750	2650	2550	2450	2350	2250	2000	1800
315	3000	2950	2850	2750	2600	2500	2400	2150	1900
355	3200	3100	3000	2850	2750	2650	2500	2250	2000
400	3400	3300	3200	3050	2950	2800	2650	2400	2100

ECTFE Ø 20-160
(acc. DVS 2210, Tab.17)

da [mm]	S [mm]	SDR	Support distance L_A in [mm] at 20°C	30°C	40°C	50°C	60°C	70°C	80°C	90°C	100°C	120°C
20	1,9	21	590	570	550	530	510	480	460	440	430	380
25	1,9	21	660	640	620	590	570	540	520	490	480	430
32	2,4	21	780	750	720	690	660	630	610	580	560	500
50	3	21	1000	960	930	890	850	810	780	750	720	640
63	3	21	1100	1060	1030	990	940	900	860	820	790	710
90	4,3	21	1400	1350	1300	1250	120	1140	1090	1050	1010	900
90	2,8	33	1250	1210	1170	1120	1070	1020	980	940	900	810
110	5,3	21	1610	1550	1490	1440	1370	1310	1250	1200	1160	1040
110	3	Liner	1380	1330	1290	1240	1180	1120	1080	1030	990	890
160	3	Liner	1590	1530	1480	1420	1360	1290	1240	1190	1150	1030

Conversion factors for support distances
(acc. DVS 2210, table 18)

For other SDR-rows, materials and fluids, the in the table stated conversion factors can be brought in.
(new support distance $L = L_A \times f_1 \times f_2$)

L_A = Permissible support distance according tables Page 152-153

Material	SDR-series	Wall thickness	Fluid: Gases	Fluid: Water	Fluid: others	
			Density [g/cm³]			
			< 0,01	1,00	1,25	1,50
Conversion factor		f_2	f_1			
PE-80	33	0,75	1,65	1,0	0,96	0,92
	17,6/17	0,91	1,47			
	11	1,00	1,30			
	7,4	1,07	1,21			
PP-H	33	0,75	1,65	1,0	0,96	0,92
	17,6/17	0,91	1,47			
	11	1,00	1,30			
	7,4	1,07	1,21			
PP-R	33	0,55	1,65	1,0	0,96	0,92
	17,6/17	0,70	1,47			
	11	0,75	1,30			
	7,4	0,80	1,21			
PVDF	33	1,00	1,48	1,0	0,96	0,92
	21	1,08	1,36			
ECTFE	Liner		1,75	1,0	0,93	0,82
	SDR 21		1,26			

Calculation of the Support distance at fixed piping systems

If piping systems are installed this way, that an axial movement is not possible, the critical buckling length has been noticed for the security. The calculated distance must provide a safety factor of 2,0 minimum.

Is the necessary support distance L_F smaller than the calculated support distance L_A, then L_A must be reduced to L_F.

If fixed piping systems are operating at raised temperatures, the calculated support destance LA has to be reduced by 20 %. The raised operating temperatuers are summarized in the table below.

Material	PE	PP	PVDF
Temperature	>45°C	>60°C	>100°C

L_F is calculated as follows for a minimum safety of 2,0:

$$erfL_F = 3{,}17 \cdot \sqrt{\frac{J_R}{\varepsilon \cdot A_R}} \geq L_A$$

L_F ... Required support distance [mm]

J_R ...Moment of inertia [mm^4]

A_R ...Pipe wall ring area [mm^2]

ε ...Prevented heat expansion S. 49

An simplified determining of the support distances is possible by the help of the following table.

da	Required support distance L_F [mm] depending on the hindered length expansion [-]								
[mm]	0,001	0,002	0,004	0,006	0,008	0,01	0,012	0,015	0,02
16	505	355	250	205	175	160	145	130	110
20	645	455	320	260	225	200	185	165	140
25	805	570	400	330	285	255	230	205	180
32	1030	730	515	420	365	325	295	265	230
40	1290	910	645	525	455	405	370	330	285
50	1615	1140	805	660	570	510	465	415	360
63	2035	1440	1015	830	720	640	585	525	455
75	2425	1715	1210	990	855	765	700	625	540
90	2910	2060	1455	1185	1030	920	840	750	650
110	3560	2515	1780	1450	1255	1125	1025	915	795
125	4045	2860	2020	1650	1430	1275	1165	1040	900
140	4530	3200	2265	1845	1600	1430	1305	1165	1010
160	5175	3660	2585	2110	1830	1635	1495	1335	1155
180	5825	4120	2910	2375	2060	1840	1680	1500	1300
200	6475	4575	3235	2640	2285	2045	1865	1670	1445
225	7280	5150	3640	2970	2575	2300	2100	1880	1625
250	8090	5720	4045	3300	2860	2555	2335	2085	1805
280	9065	6405	4530	3700	3200	2865	2615	2340	2025
315	10195	7210	5095	4160	3605	3220	2940	2630	2280
355	11495	8125	5745	4690	4060	3635	3315	2965	2570
400	12950	9155	6475	5285	4575	4095	3735	3340	2895

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	$1{,}8 \times 10^{-4}$
PP	0,16	$1{,}6 \times 10^{-4}$
PVDF	0,13	$1{,}3 \times 10^{-4}$
ECTFE	0,08	$0{,}8 \times 10^{-4}$

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] for t = 100min

da ... Pipe outside diameter [mm]

d_i ... Pipe inside diameter [mm]

Change in length by chemical influence

It may come to a change in length (swelling) of thermoplastic piping system as well as also to an increase of the pipe diameter under influence of certain fluids (e. g. solvents). At the same time, it comes to a reduction of the mechanical strength properties. To ensure a undisturbed operation of piping systems out of thermoplastics conveying solvents, it is recommended to take a swelling factor of

f_{Ch} = 0,025 ... 0,040 [mm/mm]

into consideration at the design of the piping system.

The expected change in length of a pipe line under the influence of solvents can be calculated as follows:

$$\Delta L_{Ch} = f_{Ch} \cdot L$$

ΔL_{Ch} ... Change in length by swelling [mm]

L .... Length of piping system [mm]

f_{Ch} .... Swelling factor [-]

Remark: For practically orientated calculations of piping systems conveying solvents out of thermoplastic plastics the f_{Ch}-factro has to be determined by specific tests.

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, compensation 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
Average values: PP 30, PE 26, PVDF 20
(exact values see table)

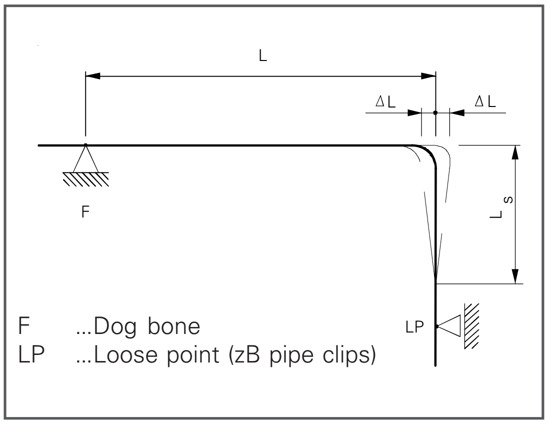
If this cannot be realised, use compensators of possibly low internal resistance. Depending on the construction, they may be applied as axial, lateral or angular compensators.
Between two dog bones, a compensator has to be installed.Take care of appropriate guiding of the piping at loose points whereby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

Material specific proportionality factors k

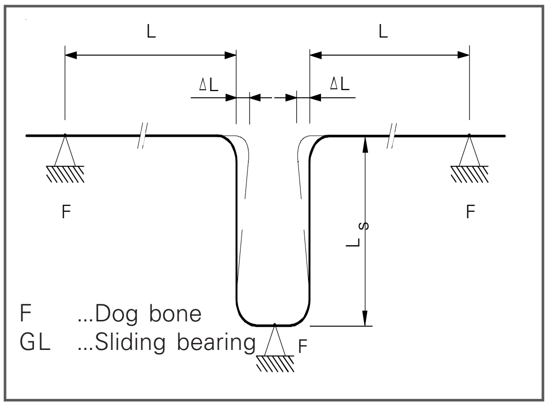
	0°C	10°C	30°C	40°C	60°C
at change in temperature					
PE	16	17	23	28	-
PP	23	25	29	31	40
one-time change in temperature					
PE	12	12	16	17	-
PP	18	18	20	20	24

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).

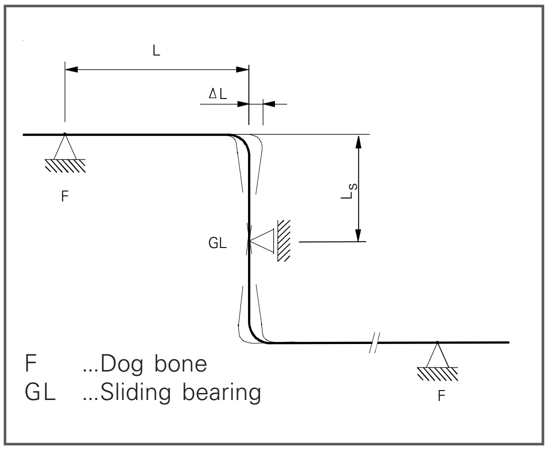
Principle drawing L-compensation elbow



Principle drawing U-compensation elbow



Principle drawing Z-compensation elbow



Calculation of straight lengths

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

da [mm]	Change in length ΔL [mm] 50	100	150	200	250	300	350	400	500
16	849	1200	1470	1697	1897	2078	2245	2400	2683
20	949	1342	1643	1897	2121	2324	2510	2683	3000
25	1061	1500	1837	2121	2372	2598	2806	3000	3354
32	1200	1697	2078	2400	2683	2939	3175	3394	3795
40	1342	1897	2324	2683	3000	3286	3550	3795	4243
50	1500	2121	2598	3000	3354	3674	3969	4243	4743
63	1684	2381	2916	3367	3765	4124	4455	4762	5324
75	1837	2598	3182	3674	4108	4500	4861	5196	5809
90	2012	2846	3486	4025	4500	4930	5324	5692	6364
110	2225	3146	3854	4450	4975	5450	5886	6293	7036
125	2372	3354	4108	4743	5303	5809	6275	6708	7500
140	2510	3550	4347	5020	5612	6148	6641	7099	7937
160	2683	3795	4648	5367	6000	6573	7099	7589	8485
180	2846	4025	4930	5692	6364	6971	7530	8050	9000
200	3000	4243	5196	6000	6708	7348	7937	8485	9487
225	3182	4500	5511	6364	7115	7794	8419	9000	10062
250	3354	4743	5809	6708	7500	8216	8874	9487	10607
280	3550	5020	6148	7099	7937	8695	9391	10040	11225
315	3765	5324	6521	7530	8419	9222	9961	10649	11906
355	3997	5652	6923	7994	8937	9790	10575	11305	12639
400	4243	6000	7348	8485	9487	10392	11225	12000	13416
450	4500	6364	7794	9000	10062	11023	11906	12728	14230
500	4743	6708	8216	9487	10607	11619	12550	13416	15000
560	5020	7099	8695	10040	11225	12296	13282	14199	15875
630	5324	7530	9222	10649	11906	13042	14087	15060	16837

Due to the low material specific proportional action factor k of PE-HD (k = 26) in comparison to PP (k = 30), the in the table contained minimum straight lengths can be reduced by 13 %.

The minimum straight length for PE is therefore calculated as follows:

$$L_{s(PEHD)} = 0{,}87 \cdot L_{s(PP)}$$

Calculation of buried piping systems

A stress and deformation proof according to ATV, instruction sheet A 127, has to be furnished for buried piping systems (e. g. drainage channels). But there can also serve other basis for calculation, such as OEVGW (guideline G 52) or results of research projects.

There is a software program for the surcharge calculation according to ATV 127 at disposal in our technical engineering department in order to furnish the demanded proof.

Please fill in the following questionnaire as completely as possible. We will promptly prepare a corresponding statics after receipt of the questionnaire.

1. Generally	Project:					
	Site:					
	Principal:					
2. Details for pipe	Pipe material:			Pipe inside diameter:	[mm]	
	Pipe outside diameter:	[mm]		Wall thickness:	[mm]	
	Nominal width:	[mm]				
3. Soil		Zone	1	2	3	4
	Group	G (1,2,3,4)				
	Kind of soil	(gravel, sand, clay, loam)				
	Specific gravity	[kN/m³]				
	Proctor density	[%]				
	E-Modulus of the soil E_B	[N/mm²]				
4. Installation	Dam ☐	Trench ☐				
	Gravel surcharge above pipe summit (min.2xda)	h = [m]		Width of trench	b= [m]	
				Gradient of slope	β= [°]	
5. Surcharge	Soil ☐	Waste ☐		Traffic load	without ☐	
	Surcharge height	h = [m]			LKW12 ☐	
	Specific gravity	γ_B = [kN/m³]			SLW30 ☐	
	Weight on surface	F = [kN/m²]			SLW60 ☐	
6. Operating conditions of the pipe	Unpressurized discharge piping system			Pressurized piping system		
	Operating temperature	T = [°C]		Operating temperature	T = [°C]	
	Entry cross section at drainage systems	A_E = [%]		Operating pressure	p = [bar]	

Calculation of buried piping systems

Comments to some points of the questionnaire

1. Generally:
These general statements are only necessary to enable an easy assignment of the different projects.

2. Details for pipe:
The most important statement is the determining of the pipe material (polyethylene or polypropylene), as normally the pipe dimensions are given.

3. Soil / 4. Installation:
There are four different groups of soil

Group	Specific gravity	Angle of internal friction	Deformation modulus E_B in [N/mm²] at degree of compaction D_{Pr} in %					
	γ_B [kN/m³]	φ'	D_{Pr}					
			85	90	92	95	97	100
G1	20	35	2,0	6	9	16	23	40
G2	20	30	1,2	3	4	8	11	20
G3	20	25	0,8	2	3	5	8	13
G4	20	20	0,6	1,5	2	4	6	10

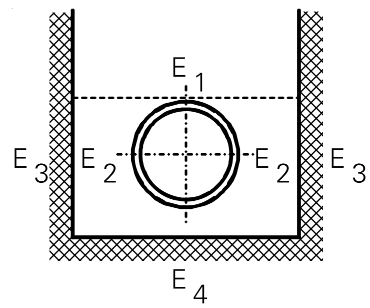
The at the calculation applied deformation modulus of the soil has to be distinguished by the following zones:

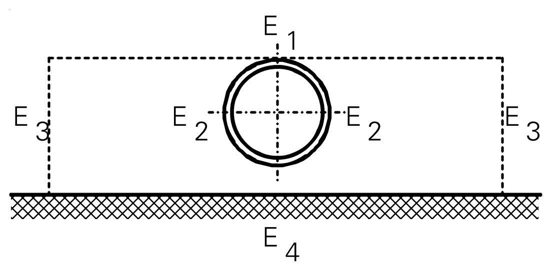
E_1 .... Surcharge above pipe summit
E_2 .... Conduit zone at the side of the pipe
E_3 .... Adjoining soil beside the conduit zone
E_4 .... Soil below the pipe (site soil)

5. Surcharge:The surcharge height is at the trench embedding condition the installation depth of the pipe (referring to the pipe summit) and at the dam embedding condition the waste surcharge.

6. Operating conditions of the pipe: You only have to fill in the corresponding operating parameter for each application.

Dam embedding condition





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 recommanded 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 is neccessary.

The used machines and appliances must correspond to the standards of the DVS 2208 part 1. For the welding of plastics in the workshop the standards of the instructions from the DVS 1905 part 1 and part 2 are valid.

Measures before the welding operation

The welding area has to be protected from unfavourable weather conditions (e. g. moisture, wind, intensive UV-radiation, temperatures below +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 pipe 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. In addition the pipe ends should be closed during the welding process.

PE- and PP-pipes from coils are oval immediately after the rolling action. 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 described AGRU welding instructions apply to the welding of semi-finished products, pipes and fittings out of the in the table contained thermoplastics.

With AGRU semi-finished products, the MFR value, of which does not fall into the here stated values, it is necessary to test the weldability by performing welding tests.

Material designation		Weldability
Polyethylene	PE 80, PE 100	MFR (190/5) = 0,3 - 1,7 [g/10min]
Polypropylene	PP-H, PP-R PP-H mit PP-R	MFR (190/5) = 0,4 - 1,5 [g/10min]
Special types	PE 80-el	with PE 80
	PP-R-el	with PP-H and PP-R
	PP-R-s-el	with PP-H and PP-R

Note:
Welding of PE80 with PE100 as well as PP-H with PP-R is permitted.

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.

Kind of joint	Ø 20 ... 63		Ø 63 ... 110		Ø 110 ... 225		Ø 225 ... 1400	
	< PN6	>= PN6	< PN6	>= PN6	< PN6	>= PN6	< PN6	>= PN6
Heating element butt welding (HS)	A B C	A - E	A B C	A - E	A B C	A - E[3]	A B C	A B C D
Non-contact butt welding (Infrared - IR)	A D	A D E	A	A D E	A	A D E		
Beadless butt welding (IS)	A B C	A B C	A B C	A B C	A B C[1]	A B C[1]		
Heating element socket welding		A B C D	A B C	A B C D				
Electric socket welding (hot wedge welding)		A B C D	A B C	A B C	B	A B	B[2]	B[2]
Hot gas welding	A - E	A - E	A - E	A - E	A - E			
Extrusion welding					A - D	A - D	A - D	A - D
Flange joint	A - E	A - E	A - E	A - E	A - E[3]	A - D	A - D[4]	A - D[4]
Union	A - E	A - E						

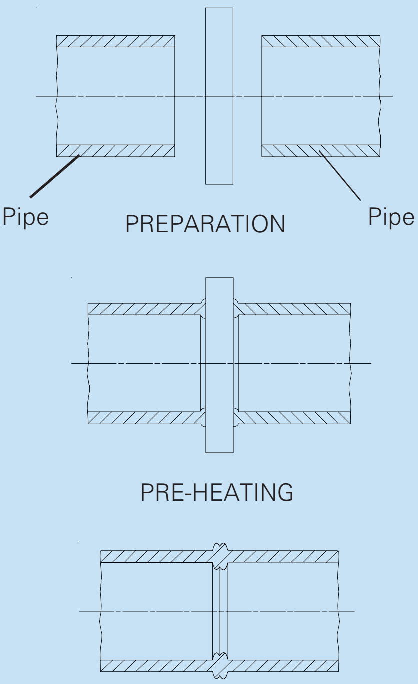
A ... PP-H100, PP-R80
B ... PE
C ... Special types (PE80-el, PP-H-s, PP-R-s-el)
D ... PVDF
E ... ECTFE
1) upto Ø 160
2) <PN6 upto Ø 600
3) upto Ø 160
4) upto Ø 315

Heating element butt welding

(following to DVS 2207, part 1 for PE-HD and part 11 for PP)

Welding method discription

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 pipe surface. 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 ocurs 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 aligned axial. The ligh longitudinal movement of the parts to be welded is to ensure for example through adjustable dollies or swinging hangings.

The areas to be welded should be cleaned immediately before the welding process with a clean, fat-free planing tool, 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]
$\leq$ 355	0,5
400 ... < 630	1,0
630 ... < 800	1,3
800 ... $\leq$ 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.
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.

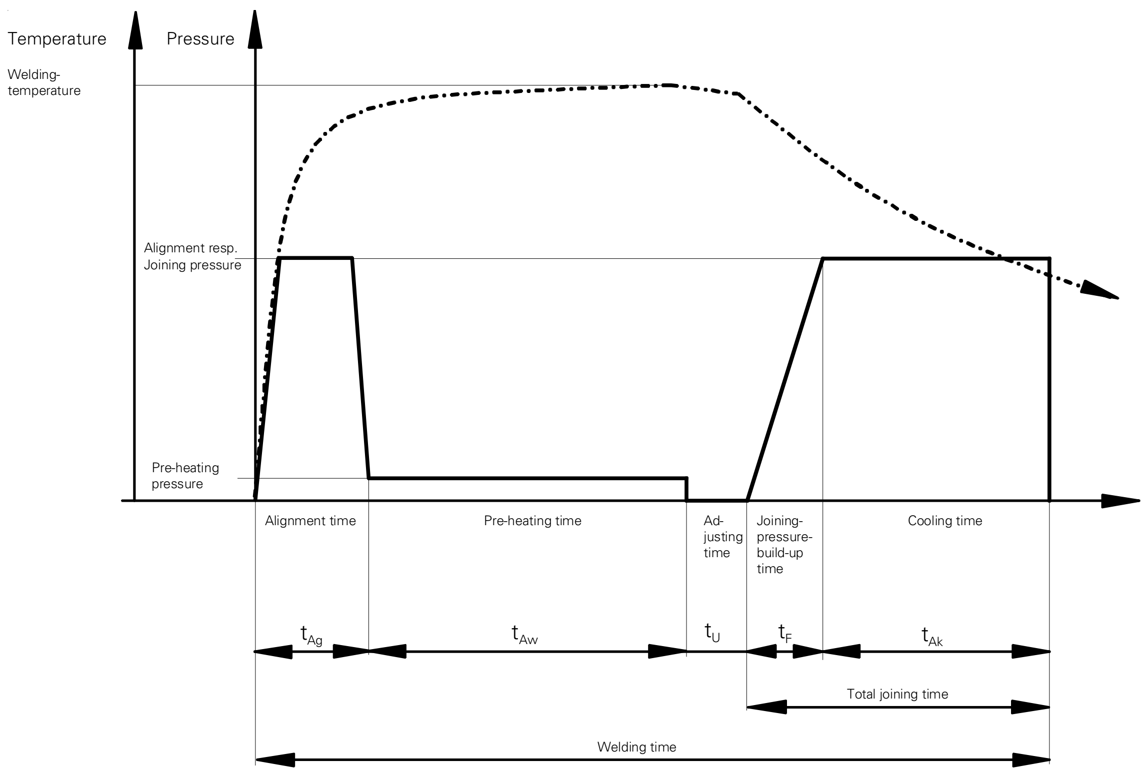
Heating element butt welding

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

	PE	PP	PVDF	ECTFE
Heating element temperature [°C]	200 up to 220	200 up to 220	232 up to 248	275 up to 285

The gradually sequences of the welding process



Heating element butt welding

Welding parameters

Reference values for heating element butt welding of PP, PE, PVDF and ECTFE 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} [s]	Adjusting time t_U [s]	Joining pressure build-up time t_F [s]	Cooling time t_{Ak} [min]
PP-H, PP-R, PP-H-s, PP-R-el, PP-R-s-el		P=0,10 N/mm²	P=0,01 N/mm²		P=0,10 N/mm²	
	 4,5	0,5	 135	5	6	6
	4,5 7,0	0,5	135 175	5 6	6 7	6 12
	7,0 12,0	1,0	175 245	6 7	7 11	12 20
	12,0 19,0	1,0	245 330	7 9	11 17	20 30
	19,0 26,0	1,5	330 400	9 11	17 22	30 40
	26,0 37,0	2,0	400 485	11 14	22 32	40 55
	37,0 50,0	2,5	485 560	14 17	32 43	55 70
PE 80, PE 100, PE-el		P=0,15 N/mm²	P≤0,02 N/mm²		P=0,15 N/mm²	
	 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
PVDF		P=0,10 N/mm²	P=0,01 N/mm²		P=0,10 N/mm²	
	1,9 3,5	 0,5	59 75	3	3 4	5,0 6,0
	3,5 5,5	 0,5	75 95	3	4 5	6,0 8,5
	5,5 10,0	0,5 1,0	95 140	4	5 7	8,5 14,0
	10,0 15,0	1,0 1,3	140 190	4	7 9	14,0 19,0
	15,0 20,0	1,3 1,7	190 240	5	9 11	19,0 25,0
	20,0 25,0	1,7 2,0	240 290	5	11 13	25,0 32,0
ECTFE		P=0,085 N/mm²	P=0,01 N/mm²		P=0,085 N/mm²	
	1,9 3,0	0,5	12 25	4	5	3 5
	3,0 5,3	0,5	25 40	4	5	5 7
	5,3 7,7	1,0	40 50	4	5	7 10

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:

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

or

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

Calculation of the welding force:

$$F = p_{spec} \cdot A_{Pipe}$$

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	PP	PVDF	ECTFE
Specific heating pressure [N/mm²]	0,15	0,10	0,10	0,08 up to 0.09

Pre-Heating

During the pre-heating process the areas must about onto the heating element 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 kept as short as possible, otherwise the plasticised areas will cool down and the welding seam quality would be influenced in a negative way.

Performing of pressure test

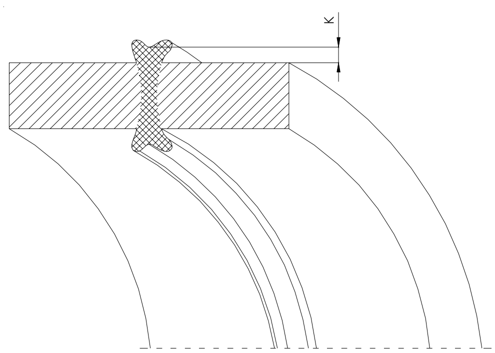
Before the pressure testing, all welding joints have to be completely cooled down (as a rule, 1 hour after the last welding process). The pressure test has to be performed according to the relevant standard regulations (e. g. DVS 2210 Part 1 - see table pressure test).
The piping system has to be protected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

Joining

The areas to be welded should coincide by contact with a velocity of nearly zero. The required joining pressure will rise linear if possible.

During cooling the joining pressure must be maintained. A higher mechanical use is only after prolongation of the cooling permissible. Under factory circumstances and insignificant mechanical use the cooling times can be remain under especially by parts with a thick wall during the clamp removal and storage. Assembly or mechanical treatment is allowed after the whole cooling.

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.



Pressure test acc. DVS® 2210-1 suppl. 2

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

Types of the internal pressure test

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

The results of the test have to be recorded. A continuous pressure and temperaturerecord have to be conducted.

Pre-test

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

Main-test

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

- changes in length
- tightness of the flange connections

Short-test

This kind of test is a special case because there is too short time that the pipe adjusts to the stress-strain balance.
Inadequacies can not be identified.

Topic and explanation		Pre-test	Main-test	short-test
Test Pressure pP	depends on the wall temperature and on the max. pressure of components	≤ $p_{P(zul)}$	≤ 0,85 . $p_{P(zul)}$	≤ 1,1 . $p_{P(zul)}$
Test Period	Pipes with or without branches and a total length of L ≤ 100 m 1)	≥ 3 h	≥ 3 h	≥ 1 h
	Pipes with or without branches with a total length of 100 m < L ≤ 500 m	≥ 6 h	≥ 6 h	≥ 3 h
	Pipes with or without branches with a total length of L > 500 m	The respective piping system has to be tested in sections, the testing length of L_P ≤ 500 m must be strictly adhered to.		
		≥ 6 h	≥ 6 h	≥ 3 h
Checks during the test	The check results, the test pressure and the temperature profile have to be recorded.	≥ 3 checks (adjusting (increase) the pressure to the testing pressure again)	≥ 2 checks (no adjusting (increase) to the testing pressure)	≥ 1 check (keep the testing pressure constant)
Material specific drecrease in pressure	Depends on the creep modul of the specific plastics material	PE: ≤ 1,0 bar/h	PE: ≤ 0,5 bar/h	For short term forces, no data regarding a decrease in pressure is available.
		PP 2)	PP 2)	
		PVDF,ECTFE 2)	PVDF,ECTFE 2)	
1) Does total L exceed the maximum length no more than 10%, the mentioned testing conditions can stay the same		Usually used		Special case (acceptance of the operator or the principal in necessary)

Advice

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

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

Details for the internal pressure test

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

Filling of the pipe
The medium for filling is water.
The origin of the filling has to be the lowest point of the pipe. When setting the fill quantity per time unit it has to be considered that the air can escape safely at the de-aeration points.
The following table contains guide values:

DN	V [l/s]
≤ 80	0,15
100	0,3
150	0,7
200	1,5
250	2,0
300	3,0
400	6,0
500	9,0

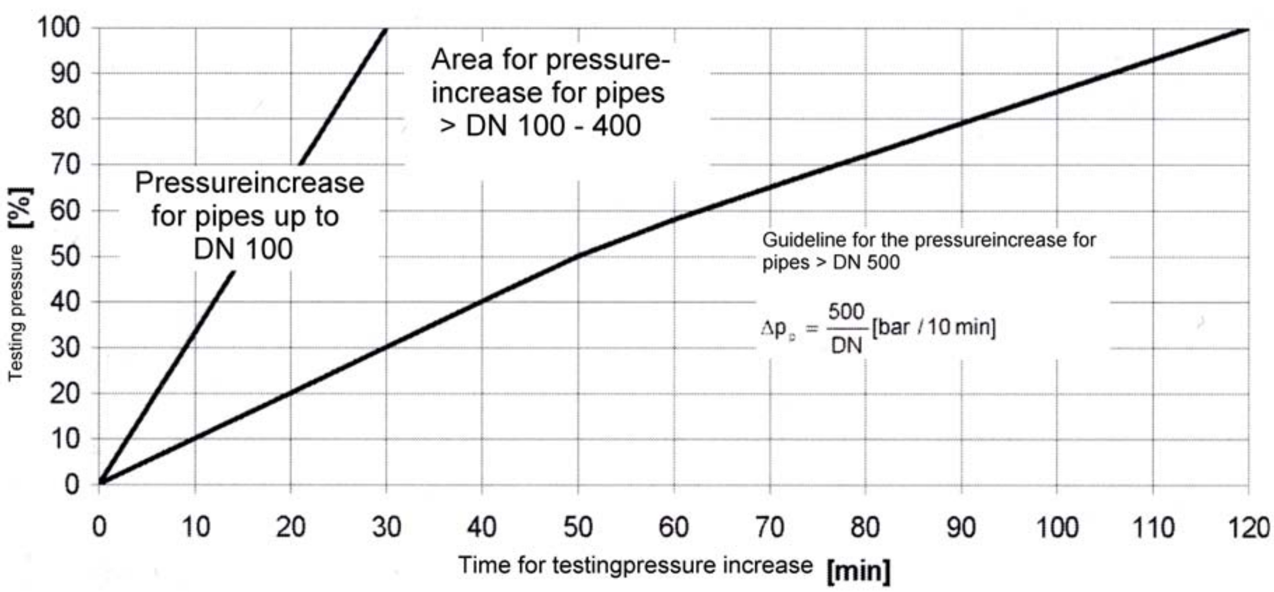
If the pipeline has more than one lowest point, it may be necessary to fill the pipe in sections.
The time between filling and testing the pipe has to be long enough for the de-aeration (approximate time ≥ 6 … 12h; it depends on the dimension of the pipe).

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

Applying the testing pressure

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

The following chart contains guide values:



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

Material Properties
Installation Guidelines
Calculation Guidelines
Connection Methods
Double Containment Piping
Approvals and Standards

Testing pressure and temperature

Evaluation of the testing pressure

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

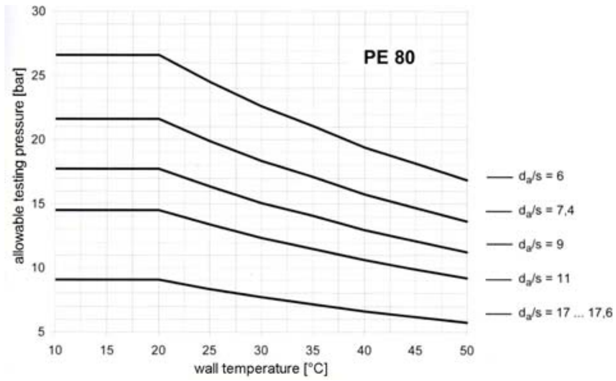
$$p_{P(zul)} = \frac{1}{\frac{od}{s}} \cdot \frac{20 \cdot \sigma_{v(T,100h)}}{S_P \cdot A_G} [bar]$$

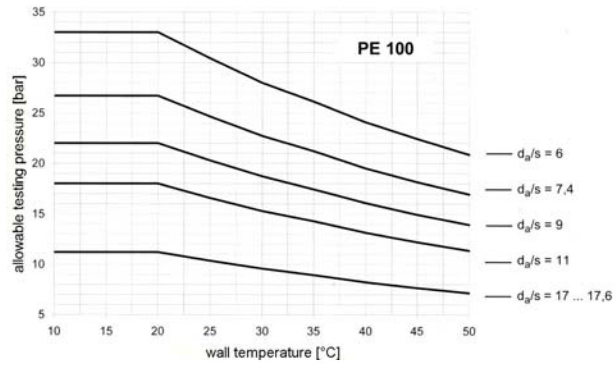
Od	[mm]	Outside Diameter
s	[mm]	wall thickness
$\delta_{v\ (T,\ 100h)}$	[N/mm²]	Reference stress for a wall temperature T_R at t=100h
s_P	[1]	Minimum safety distance to the creep strength
A_G	[1]	Manufacturing and design specific factor which reduces the allowable test pressure ($A_G \geq 1{,}0$)
d_a / s		~ SDR
p_B	[bar]	Operating pressure

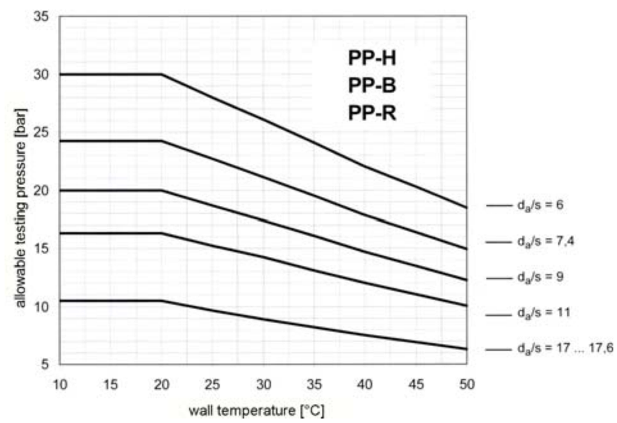
Determining a bigger safety distance as stated in the following table is possible and depends on the user.

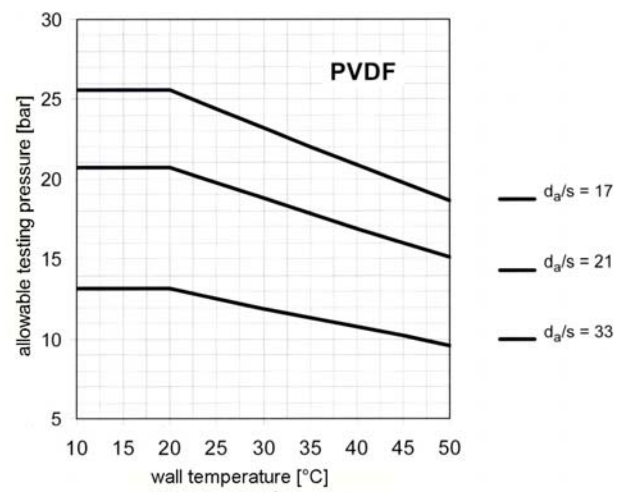
Material	PE	PP-H	PP-(B,R)	PVDF
S_p	1,25	1,8	1,4	1,4

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









Testtemperature (advices for walltemperature)

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

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

The wall temperature can be assumed as the arithmetic mean of T_i and T_R.

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

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

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

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

The measuring respectively the recording of the temperature in the inside of the pipeline (temperature of the test medium) demands the assembly of a gauge connection at the most disadvantageous point of the piping system. In case that it is ensured by proper arrangements, that the temperature of the pipe wall is never exceeding a pre-defined maximum value, it is not necessary to make the measurement of the medium temperature. For pipelines made out of thermoplastic materials with low impact strength (e.g. PP-H, PVC-U) the inside pressure test shall never be done at temperatures lower than 10°C.

Description of the pressure test according to DIN EN 805[1]

The pressure test according to DIN EN 805 is a test method, in which the tightness of the piping system is proven by the development of a contraction in the piping system.

The inside pressure test is again divided into a pre- and a main test. During the pre-test the test pressure shall be applied within 10 minutes, afterwards the test pressure has to be kept for 30 minutes (e.g. by further pumping of the test medium into the piping system).
The test pressures have to by calculated by using the formula at page 170.

After the time of 30 minutes the conditions shall be kept for one hour without any change of the conditions to enable a visco-elastic forming of the piping system caused by the inside pressure.

During the period of deformation a maximum decrease of 30% for the test pressure caused by the volume expansion is allowed, whereas the pressure decrease for piping systems made out of thermoplastic materials with not so high elasticity (e.g. PCV, PVDF) is expected to be lower (reference value: $\Delta p_p \leq 0{,}20 \cdot p_p$).

In case of a higher pressure decrease than the material specific reference values it can be assumed that the piping system is not tight. As far as possible the piping system has to be inspected for leakages and these deficiencies have to be remedied. After a relaxing period of at least 60 minutes ($p_p = 0$) the pre-test has to be repeated.

If the pre-conditions concerning the permitted pressure loss are fulfilled, the pre-test is followed immediately by the main test.

During the main test the following test steps have to be done:

- First a quick pressure drop of Δp_p = 10 to 15% of the actual pressure at the end of the pre-test has to be done.
- The dumped volume of water has to be measured and compared to the calculated volume.
- A contraction time of 30 minutes has to be kept after the pressure drop of 10-15%.
- The values of the pressure during the contraction time have to be checked and recorded exactly.

The piping system can be considered as a tight system, provided that during the contraction time no decreasing tendency is noticed, which means, that the pressure drop shows a tendency to $\Delta p_p = 0$.

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 163).

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 requires 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 reproducable. Time is manually controlled as a rule.

In order to ensure reproduceability, 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 lightweight 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.

Machines used in workshops have to meet the following requirements:

- Stable construction
- Universal basic construction (swivelling or retractable auxiliary tools and clamps)
- Quick-clamping device
- Maximum degree of mechanization
- Indication of pressure transmission (hydraulic/ welding pressure) on the rating plate
- Possibility to fix working diagrams in the operating area
- In case of big machines, an undercarriage with locking device (stable, adjustable in height, built-in level) is recommended.

Non-contact heated tool butt welding for PP, PVDF and ECTFE (IR-welding)

Welding method

The method is in accordance with approved standard butt fusion, where the components are not in contact with the heat source.
The heating of pipe ends is performed by radiant heat. The advantage of the non contact method is the minimal bead sizes and the elimination of possible contamination from the heating element (further detailed information can be taken from our technical brochure "SP Series").

Welding parameters

Reference values of welding parameters for the non-contact butt welding of PVDF- PP- PFA- and ECTFE- pipes and fittings need not to be stated separately as this data is stored in the machine for the relevant material and of the dimensions to be welded.

With AGRU IR-welding machines 70% lower weling times can be reached in comparison too standard but weling machines.

New generation of welding machines for IR-welding

SP-welding equipment

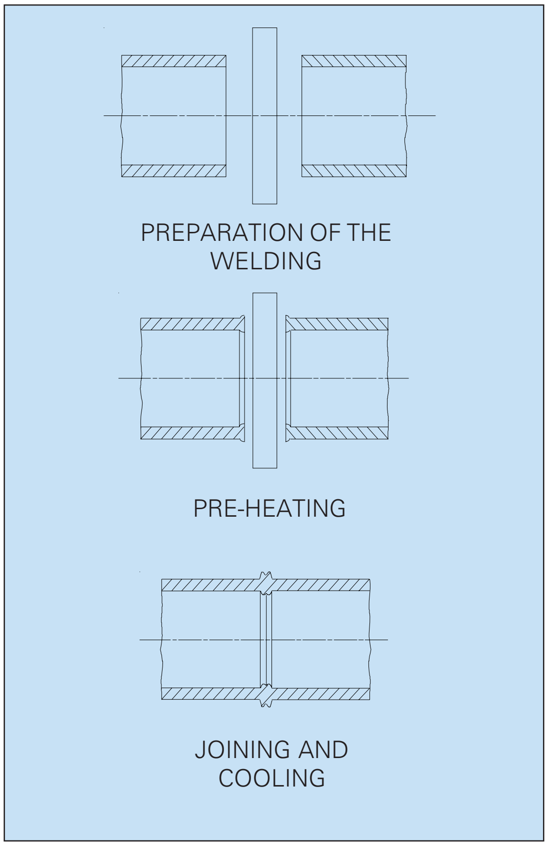
This new developed welding equipment operates fully automatic and can be used for different materials (PP, PVDF, ECTFE, PFA).

There are the following sizes of welding equipment available:

SP 110 S (OD 20mm up to OD 110mm)
SP 315 S (OD 110mm up to OD 315mm)

Pressure test see page 167-171

Schematic sketch of the welding process



Heating elemet socket welding

Heating element socket welding (following to DVS 2207, part 1 for PE-HD, part 11 for PP and part 15 for PVDF)

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.

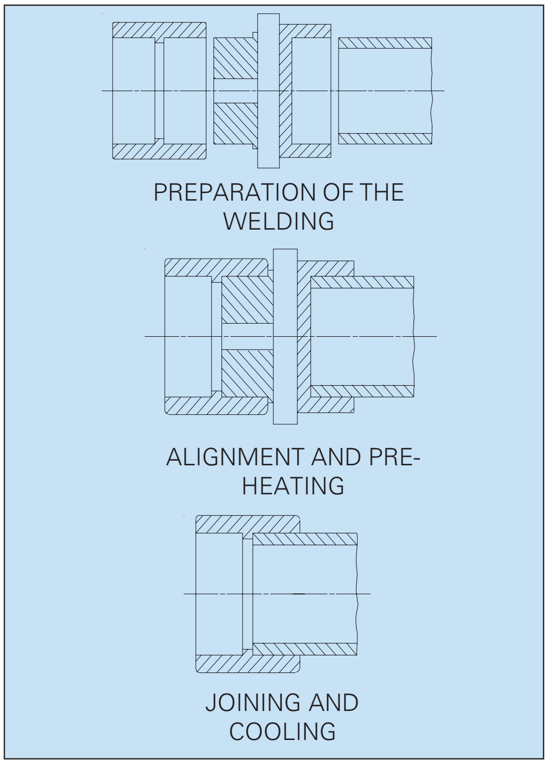
The dimensions of pipe end, heating element and fitting socket are coordinated so that a joining pressure builds up on joining (see schematic sketch).

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 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

Schematic sketch of the welding process



Welding temperature (T)

PP-H, PP-R 250 ÷ 270 °C
PE-HD 250 ÷ 270 °C
PVDF 250 ÷ 270 °C

Material type	Pipe outside diameter da [mm]	Pre-heating time t_{Aw} [sec] SDR 17,6; 17	Pre-heating time t_{Aw} [sec] SDR 11; 7,4; 6	Adjusting time t_U [sec]	Cooling time t_{Ak} fixed [sec]	Cooling time t_{Ak} overall [min]
PE 80, PE 100 PPH, PPR	16	-	5	4	6	2
	20	-	5	4	6	2
	25	[1]	7	4	10	2
	32	[1]	8	6	10	4
	40	[1]	12	6	20	4
	50	[1]	18	6	20	4
	63	[1](PE) ; 10 (PP)	24	8	30	6
	75	18 (PE) ; 15 (PP)	30	8	30	6
	90	26 (PE) ; 22 (PP)	40	8	40	6
	110	36 (PE) ; 30 (PP)	50	10	50	8
	125	46 (PE) ; 35 (PP)	60	10	60	8
		Pipe wall thickness [mm]	Pre-heating time [sec]			
PVDF	16	1,5	4	4	6	2
	20	1,9	6	4	6	2
	25	1,9	8	4	6	2
	32	2,4	10	4	12	4
	40	2,4	12	4	12	4
	50	3,0	18	4	12	4
	63	3,0	20	6	18	6
	75	3,0	22	6	18	6
	90	3,0	25	6	18	6
	110	3,0	30	6	24	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 cleaning agents (ethanol or similar).
If peeling is not necessary, work the pipe surface with a scraper knife and mark the depth (t) on pipe.

Pipe diameter	Pipe chamfer for		Insert length for	
	PEHD, PP	PVDF	PEHD, PP	PVDF
d [mm]	b [mm]	b [mm]	l [mm]	l [mm]
16	2	2	13	13
20	2	2	14	14
25	2	2	15	16
32	2	2	17	18
40	2	2	18	20
50	2	2	20	22
63	3	3	26	26
75	3	3	29	31
90	3	3	32	35
110	3	3	35	41

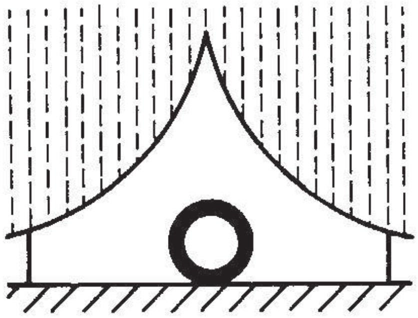
Preparations before welding

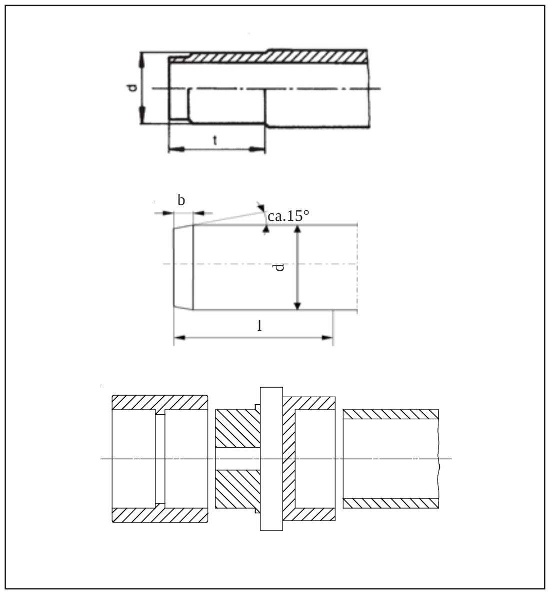
Check temperature of heating element (on heating spigot and on heating socket).
Thoroughly clean heating spigot and heating socket immediately before each welding process (with fluffless paper). At any rate, be careful that possibly clogging melt residues are removed.

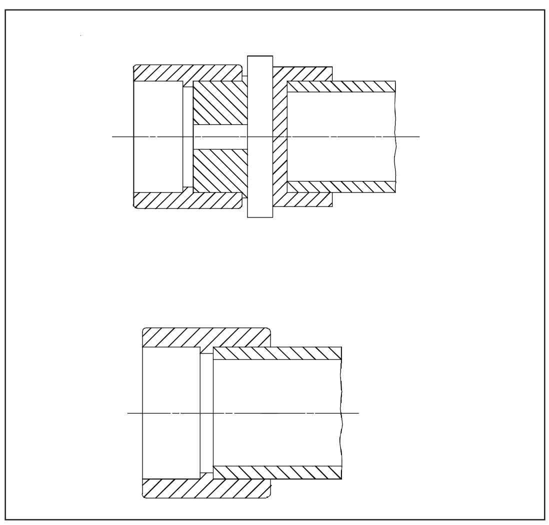
Performing of welding process

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.

On manual welding:
Adjust the parts and hold them fast under pressure for at least one minute. (see table: page 175:fixed cooling time)







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 - see table pressure test). 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 meeting 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)

Pressure test acc. DVS® 2210 part 1

please see page 167 - 171

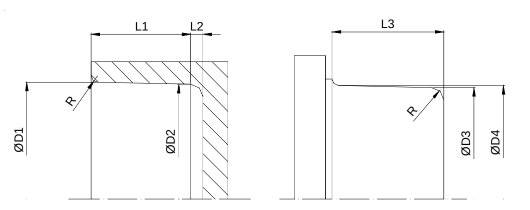
Heating element socket welding

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 2/4draft, document 172 E) apply to the dimensions of the heating tools.

Dimensions[1)] of heating elements for heating element socket welding fittings
Type B (with mechanical pipe working)



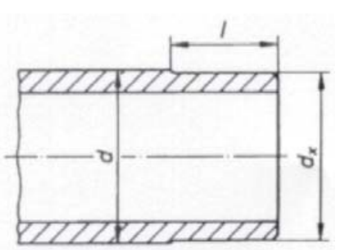
Pipe diameter [mm]	ØD1 [mm]	ØD2 [mm]	ØD3 [mm]	ØD4 [mm]	L1 [mm]	L2 [mm]	L3 [mm]	R [mm]
16	15,9	15,76	15,37	15,5	14	4	13	2,5
20	19,85	19,7	19,31	19,45	15	4	14	2,5
25	24,85	24,68	24,24	24,4	17	4	16	2,5
32	31,85	31,65	31,17	31,35	19,5	5	18	3,0
40	39,8	39,58	39,1	39,3	21,5	5	20	3,0
50	49,8	49,55	49,07	49,3	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

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 electo-fusion socket. A transformer for welding purposes supplies electric power.

The extansion of the plastified melt and the during the cooling developed shrinking stress produce the necessary welding pressure which guarantee an optimal welding.

The method distinguishes itself by an extra-low safety voltage as well as by high automatization.

Welding systems

For the welding of AGRU-E-fittings a universal welding machine should be used.
This welding device is a machine with bar code identification, it supervise all functions full automaticly during the welding process and stores them.

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

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

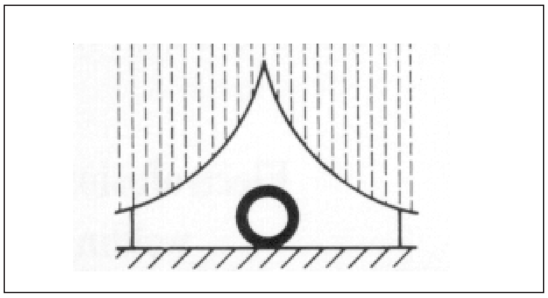
The welding parameters are specified by the bar code, which is directly affixed on the fitting.

For AGRU electro fusion fittings is valid:

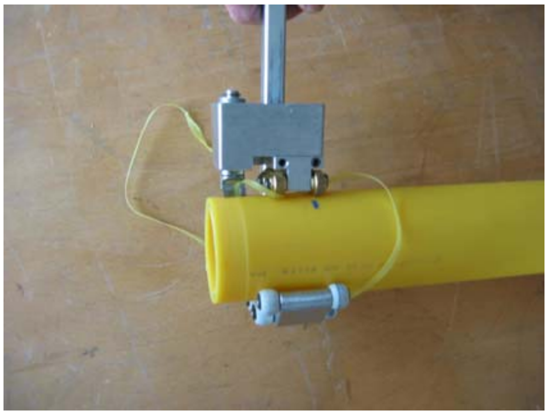
e-coupler	OD	weldable pipes / fittings							
		SDR 33	SDR 26	SDR 17,6	SDR 17	SDR 13,6	SDR 11	SDR 9	SDR 7,4
SDR 11	20	no	no	no	no	no	yes	yes	yes
SDR 11	25	no	no	no	no	no	yes	yes	yes
SDR 11	32	no	no	no	no	no	yes	yes	yes
SDR 11	40	no	no	yes	yes	yes	yes	yes	yes
SDR 11	50	no	no	yes	yes	yes	yes	yes	yes
SDR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

Electrofusion welding

Preparation of welding place



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



Preparations before welding

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 161)

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.

Unpack the E- fitting immediately before welding.

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

The welding areas have to be cleaned with PP- or PE-cleaner (or similar) and 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

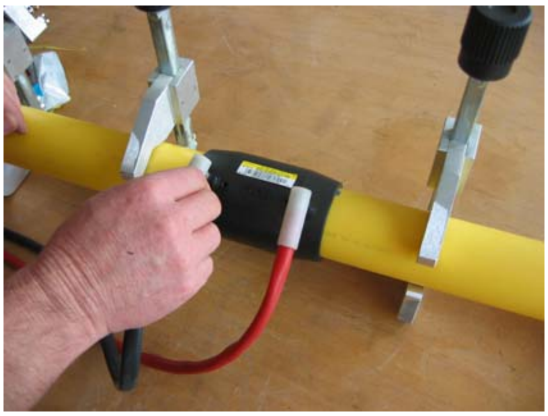
Processing guidelines

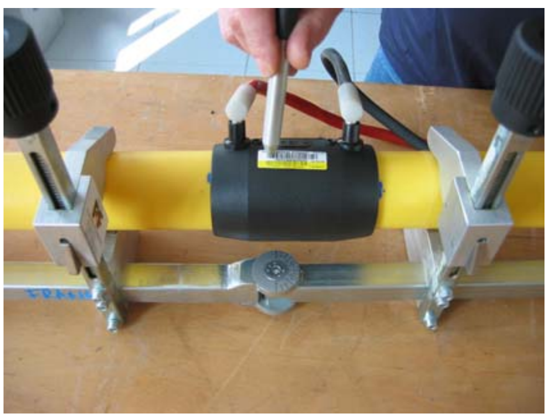
The second part which has to be welded with the socket (pipe or fitting) should be prepared too.
Insert the second pipe end (or fitting) into the socket and clamp both pipes into the holding device, so that no forces can raise between welding area and the pipe (fitting) and that the socket can be turned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

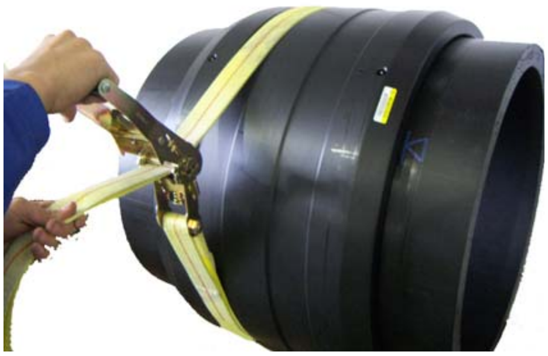
da 20 mm	-	63 mm	6 min
da 75 mm	-	125 mm	10 min
da 140 mm			15 min
da 160 mm	-	180 mm	20 min
da 200 mm	-	280 mm	30 min
da 315 mm	-	400 mm	45 min
da 450 mm	-	500 mm	60 min.

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 180 and 181.

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

After the insertation 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 184.

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 182 can be performed.

Tension belts should be removed afer finnished cooling time.

minimum cooling time:
da 560 mm - 710 mm 90 min.

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

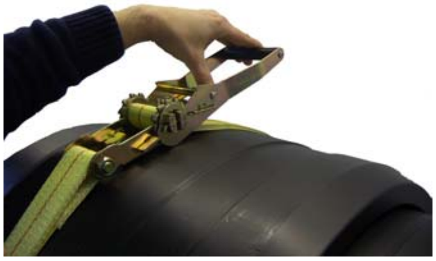
open the ratchet lever

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

Hot gas welding

(following to DVS 2207, part 3 for PP, PE-HD, PVDF and analogous for ECTFE)

Welding method

At hot gas welding, the edge areas and outer zones of the welding fillers are transformed into plastisized condition - as a rule by means of heated air - and joined under low pressure. The hot gas must be free of water, dust and oil.
This guideline applies to hot gas welding of pipes and sheets out of thermoplastics, such as PP and PE-HD. In general, material thickness of the semi-finished products to be welded ranges from 1 mm to 10 mm.
Fields of application of this welding method are: apparatus engineering, construction of vessels and piping systems.

Piping systems for gas supply and water supply must not be joined by hot gas welding!

Weldability of base material and welding fillers according to guideline DVS 2201, part 1, is taken for granted.

Another requirement for high quality welding processes is that the welding fillers are of the same kind and same type as far as possible. Condition and requirement of the welding fillers have to comply with the guideline DVS 2211.
The most common welding fillers are round rods with diameters of 3 mm and 4 mm. There are also used special profiles, such as oval, triangular and trefoil rods, as well as bands. In the following, the term "welding rods" is applied for the different welding fillers.

Welding parameter

Reference values at outside temperatures of about 20 °C (acc. to DVS 2207)

Material	Welding force [N]		Hot air temperature [1] [°C]	Air quantity [l/min]
	Rod Ø3mm	Rod Ø4mm		
PEHD, PEHD-el	10 ÷ 16	25 ÷ 35	300 ÷ 350	40 ÷ 60
PP-H, PP-B, PP-R PP-H-s PP-R-s-el	10 ÷ 16	25 ÷ 35	280 ÷ 330	40 ÷ 60
PVDF, PVDFflex	12 ÷ 17	25 ÷ 35	350 ÷ 400	40 ÷ 60
ECTFE	12 ÷ 17	25 ÷ 35	340 ÷ 350	48 ÷ 52

[1] measured in hot air stream approximately 5 mm in the nozzle.

Qualification of welder and requirement on welding devices

The plastics welder must have obtained the knowledge and skill required for the performing of welding processes. As a rule, this would mean that he is a qualified plastics worker and welder continuously practizing or displaying of long-time experience. Hot gas welding machines have to comply with the requirements according to guideline DVS 2208, part 2.

Welding of ECTFE

The choice of gas is a very important factor in ECTFE welding. It is not necessary to use nitrogen in ECTFE welding; good quality ECTFE welds can be obtained when a clean and dry source of air is used. Welding in nitrogen is recommended only when the welding facility lacks a clean and dry source of air.

Safety precaution

At ECTFE - melt temperatures of > 300°C hydrogen chloride and hydrofluorics are released. They could be toxically at higher concentrations and should not be breathened in.
The recommended load limit acc. to TWA for HCl is 5ppm, for HF 3ppm.
At breathing contact wit ECTFE-vapours, the person should be brought out in the fresh air and medical aid should be summoned without delay (danger of polymer-fever!).

The following safety measures should be considered:

- Please consider for good ventilating of the working place (otherwise please use breathing protections)
- Please use eye protections
- Please use hand protections

The drawing nozzle has to correspond with the respective cross section of the welding rod. In order to apply the required heating pressure on welding with welding rods of larger cross sections, an additional press handle may be required with this kind of nozzle. Special slotted nozzles enable the welding of bands.

Processing guidelines - Hot gas welding

Preparation of welding place

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

Install welding tent or similar device.

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

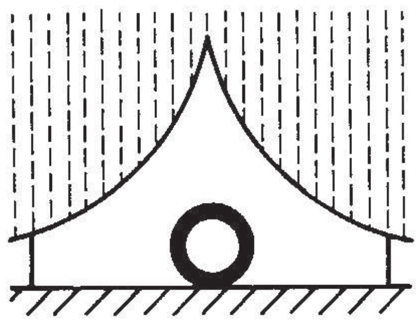
The adjusting surfaces and the adjacent areas have to be prepared adequately before welding (e. g. by scrapping). Furthermore, it is also recommendable to scrape the welding rods, it is, however, a must, when welding PP material. Parts that have been damaged by influences of weather conditions or chemicals have to be machined until an undamaged area appears.

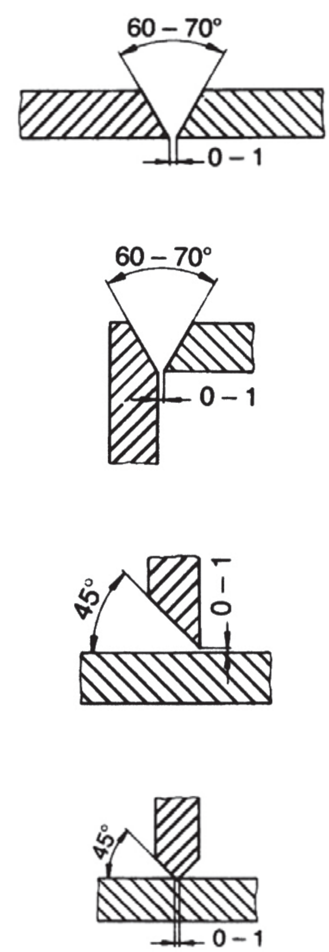
The forms of the welding seams on plastics components generally correspond with the forms of welding seams on metal parts.The guideline DVS 2205, parts 3 and 5, are valid with respect to the choice of welding seam forms on containers and apparatus. In particular, pay attention to the general principles for the formation of welding seams. The most important welding seam shapes are:
V-weld, double V-weld, HB-weld and K-weld.

With welding areas accessible from both sides, it is recommendable to make double-V-welds (sheet thickness of 4 mm and more). Generally do so when the thickness is 6 mm and more. The displacement of sheets may be minimized by changing the sides of welding.

Preparations for welding

Before starting the welding process, check the heated air temperature adjusted on the welding machine. Mea-surement is performed by means of a control thermocouple, inserted approximately 5 mm into the nozzle, and with rod-drawing nozzles in the opening of main nozzle. The diameter of the thermocouple must not exceed 1 mm. Air quantity is measured by means of a flow control instrument before the air stream enters into the welding machine.





Processing guidelines
Hot gas welding

Performing of welding process

The welder has to acquire the feeling for the speed and force he needs for welding by practising. The welding power may be determined by test welding on a weighing machine.
The welding rod is heated within the rod-drawing nozzle and pushed into the welding groove with its break-like extension mounted on the lower part of the nozzle. As a consequence of the forward movements of the nozzle, the welding rod is automatically being pushed on as a rule.
If necessary, the welding rod has to be pushed on manually in order to avoid stretching caused by friction within the nozzle.

Structure of welding seam

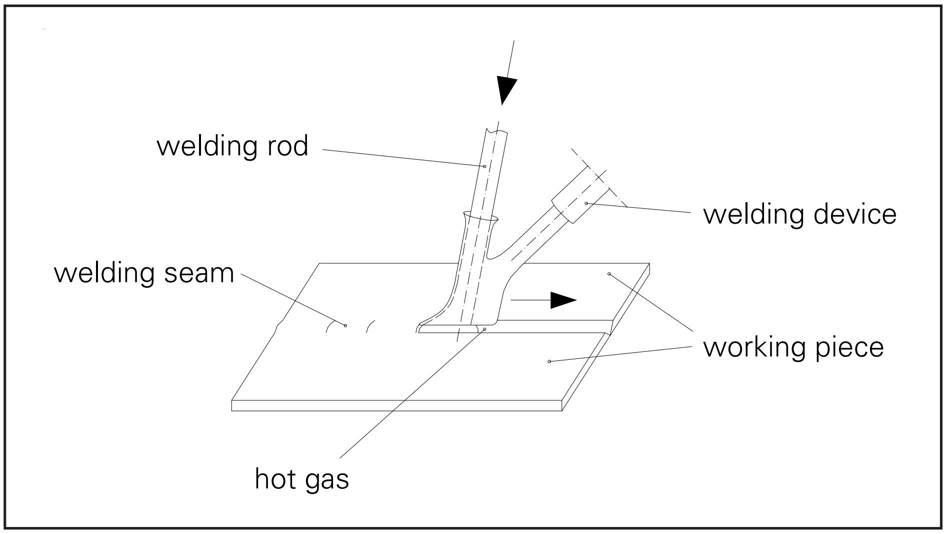
The first layer of the welding seam is welded with filler rod, diameter 3 mm (except for material thickness of 2 mm). Afterwards, the welding seam may be built up with welding rods of larger diameters until it will have completely been filled. Before welding with the next welding rod, the welding seam which has been formed with the preceeding welding rod, has to be adequately scrapped.

Additional machining of welding seam

Usually welding seams need no reworking however, if necessary, pay attention to the fact that the thickness of the base material must be maintained.

Visual control of welding seam

Welding seams are visually checked with a view to weld filling, surface conditions, thorough welding of welding root and displacement of joining parts.



Hot gas welding

Requirements on the welding device used for hot gas welding (following to DVS 2207-3)

Manual welding devices (with external air supply)

The devices comprise handle, heating, nozzle, air supply hose and electrical connecting cable.
Due to their construction properties, they are particularly suitable for longer lasting welding processes.

General requirements

- Safe fuctionality at a temperature application range between -5 to +60°C
- Safe storage within a temprature range of -5 to +60°C
- Adequate corrosion protection against moisture entering from the outside
- As light as possible
- Favourable position of the gravity center
- Functionally formed handle
- No preferred direction in relation to the supply lines and that the nozzle can be fixed in any position
- The functional elements are easily accessible
- The equipment must ensure that feed hoses and cables can be extended by the welder with the minimum of effort and do not kink or twist in proper operation
- Welding equipment can be stored safely when the welding work is finished or during interruptions
- Used nozzles are easy to remove and to fix in heated state
- Indefinitely variable power consumption
- If possible, handle with built-in control system
- Operating elements arranged in a way preventing unintentional changes
- Material of handle: break-proof, thermo-resistant, thermo-insulating, non-conducting
- Corrosion-proof hot gas supply pipes of low scaling
- Constant welding tempereture has to be achieved after a maximum of 15 minutes.

Safety requirements

The devices have to be safe with a view of all kind of personal injuries. In particular, the following requirements apply:

- Parts next to hands should not be heated to temperatures above 40°C, even after longer use.
- Protection against overheating (e. g. due to lack of air) of the device has to be present.
- Equipment surfaces presenting a burn hazard are to be kept as small as possible, or isolated and lebelled as required.
- Sharp edges on equipment and accessories are to be avoided.

Air supply

At hot gas welding, air is normally used which is supplied by a compressed air network, a compressor, a pressure gas bottle or a ventilator.
The air supplied has to clean, free of water and oil, as otherwise not only the quality of the welding seam but also the lifetime of the welding devices decreases. Therefore adequate oil and water separators have to be used.
The air volume supplied to the device has to be adjustable and has to be maintained constant, as it is a main factor influencing the temperature control of the device.

Welding devices (with built-in ventilator)

The devices comprise handle, built-in ventilator, heating, nozzle and electrical connecting cable.
Due to their constructional features, they can be used at sites where external air supply is not available.
On account of their dimensions and their weight, they are less suitable for longer lasting welding processe

Requirements on design

The ventilator has to supply the quantity of air required for welding various types of plastics to all nozzles (see DIN 16 960, part 1).
The electrical circuit has to ensure that the heating is only turned on when the ventilator is operating.
The noise level of the ventilator has to comply with the relevant stipulations.

Safety requirements

- The nozzles used for the particular devices have to be securely fastened and easily exchangeable even when heated.
- The material must be corrosion-proof and of low scaling.
- In order to prevent heat from dissipating, the surface of the nozzle has to be as smooth as possible, e. g. polished.
- For reducing friction, the inner surface of the slide rail of the drawing nozzles have to be polished. The same applies to the sliding surfaces of tacking nozzles.
- In order to avoid strong air vortexes at the outlet of the nozzle, the round nozzles have to be straight for at least 5 x d (d = outlet diameter of the nozzle) in front of the outlet.

Extrusion welding

(following to DVS 2207, part 4)

Welding method

Extrusion welding is used for joining thick-walled parts (construction of containers, apparatus engineering, piping systems), for joining of liners (for buildings, linings for ground work sites) and for special tasks.

This welding technique is characterized as follows:
- Welding process is performed with welding filler being pressed out of a compounding unit.
- The welding filler is homogenous and completely plastified.
- The joining surfaces have been heated up to welding temperature.
- Joining is performed under pressure.

Weldability of base material and welding filler

Semi-finished products and welding fillers have to be suitable for extrusion welding. Weldability of base material and welding fillers have to be in perfect processing condition. Assure weldability of parts to be welded according to DVS 2207, part 4. The welding filler has to be adjusted to processing with the particular extrusion welding device and to the type of material used for semi-finished product.The welding filler is being processed in form of pellets or rods. Pellets and welding rods of uncontrolled composition and unknown origin must not be processed. Do not use regenerated material for welding.
The welding filler has to be dry and clean (prevent moisture from falling upon cold pellets).

Qualification of welder and requirement on welding devices

The plastics welder must have obtained the knowledge and skill required for the performing of welding processes.
As a rule, this would mean that he is a qualified plastics worker and welder continuously practising or disposing of long-time experience.

For extrusion welding, several kinds of devices may be used (see DVS 2209, part 1). The most common device is a portable welding device consisting of a small extruder and a device for generating hot air. The welding pressure is applied onto the teflon nozzle, directly fastened at the extruder, which corresponds to the welding seam form.
Depending on the type of device, the maximum capacity of the welding fillers is about 4,5 kg/h.

Material	short	Masse-temperatur	Hotgas-temperature	Hotgas-quantity
Polyethylen high density	HD-PE	210 ... 230	250 ... 300	300
Polypropylen Typ 1,2,3	PP-H; PP-B; PP-R	210 ... 240	250 ... 300	300
Polyvinylidenf	PVDF	280 ... 350	280 ... 350	300

Processing guidelines - Extrusion 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)

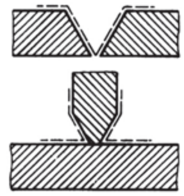
The adjusting surfaces and the adjacent areas have to be prepared adequately before welding (e. g. by scrapping). Parts that have been damaged by influences of weather conditions or chemicals have to be machined until an undamaged area appears. This has to be considered especially on performing repair works.
Do not use cleansing agents affecting plastics thus by causing them to swell.
In order to equalize higher differences in temperature between the different workpieces, the workpieces have to be stored long enough at the working place under the same conditions.

Welding seam forms

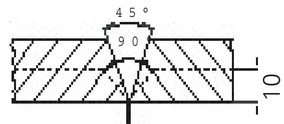
On choosing welding seam forms for containers and apparatus , in general observe the guideline DVS 2205, part 3 and 5. In particular, consider the general technical principles for welding seam formations quoted therein.

In general, single-layer seams are welded on extrusion welding. If on welding of thicker semi-finished products it is not possible to make DV-welds, also multilayer seams can be performed.

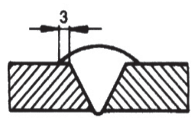
The welding seam should laterally extend by about 3 mm beyond the prepared welding groove.



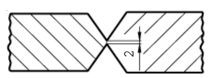
Welding seam forms for extrusion welding



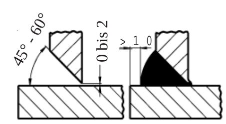
0 to 2
Prepared welding groove



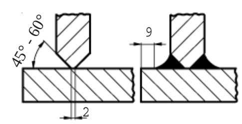
V-weld without sealing run



Double V-butt welding



T-joint with single bevel groove with fillet weld



T-joint with double bevel groove

Processing guidelines - Extrusion welding

Preparation of welding seam

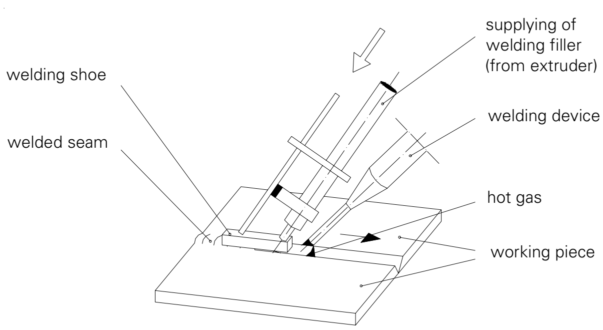
(at any rate immediately before starting the welding process)

Lap joint
In order to guarantee sufficient heating and thorough welding, it is necessary to provide an air gap depending on wall thickness (width of air gap should be 1 mm minimum).

Performing of welding process

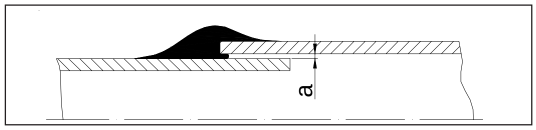
Due to the hot gas passing out of the nozzle of the welding device, the adjusting surfaces of the parts to be welded are heated up to welding temperature. The welding filler, continuously flowing out of the manually guided device, is pressed into the welding groove. The discharged material pushed the device ahead thus determining the welding speed. The heating of the adjusting surfaces must be coordinated with the welding speed.

Basically the welding seams have to executed in a way to assure that no re-working will be required. If necessary, it should, however, be performed only after acceptance so that eventual welding faults can be discovered on visual inspection. On performing re-working, avoid the build-up of notches.

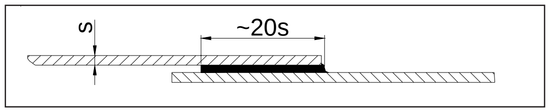


Visual control of welding seam

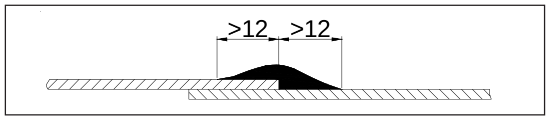
On visual inspection, surface conditions of the welding seam, proper performance as to drawings as well as evenness are evaluated.



Lap joint with fillet weld



Lap joint with lap weld
(for liners with a thickness of up to 3,5 mm)



Lap joint with extrusion welding
(for liners/sheets with a thickness of up to 3,5 mm)

Welding shoes

hand welding extruder Type K1

Detachable joints

Flange connections 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 thereby occuring tensile stress has to be avoided under any circumstances.

Tightening of screws
The length of the screws has to be chosen this way that the screw thread possibly flushes with the nut. There have to be placed washers 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 www.agru.at).

Generally

It is recommend to brush over the thread, e. g. with molybdenum sulphide, so that the thread stays also at longer operation time easy-running.
For the selection of sealing material the chemical and thermal resistance has to be considered.

Unions of piping systems

If pipe joints out of thermoplastics are connected by means of unions, the following regulations have to be adhered to:
For avoiding 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 (common pipe wrenches should not be used).

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

Tip: thread seal only with Teflon, do not use hemp.

Adhesive joints

Adhesive joints with polyolefines are not applicable.

The hereby achieved strength values range extremely below the minimum requirements made to adhesive joints in practice.

General information

Advantages of double containment piping systems

- Application of highly corrosion resistant materials such as PE, PP or PVDF (ECTFE)
- Different combinations of media pipe and protective pipe
- Exact identification of the leak area by means of an electronic detection system therefore low repair expenses
- No succesive damages
- Assignment of the system in some protection areas - therefore higher operation flexibility

Application range of double containment piping systems

Buried:

- Buried conveying piping systems of ground water dangerous media through sensitive areas
- Sewage water systems in the industry
- In the landfill construction or in clarification plants for drainage water transport

Aboveground:

- Process systems for dangerous chemicals:
- in industrial plants
- in chemical manufacturing
- in the semiconductor production

The components of double containment piping systems :

Inside pipe:
The media is transported through the inside media pipe

Outside pipe:
The outside- or encasing pipe provides protection against the leaking of the media

The ring gap:
The gap between the inside and outside pipe. In the ring gap the leak detection takes place

Leak detection system:
The leak detection system consists of a supervising room (sleeve), controlling device (z.B. sensor) and an indicator

Available dimensions

In practice different pipe materials have be applied due to different operation conditions. At the double containment piping system the following possibilities can be performed:

	outside pipe (protective pipe)	inside pipe (media pipe)	welding
Standard	PP	PP	S
	PE	PE	S
	PE	PP	K
	PE	PVDF	K
	PP	PVDF	K
On demand	PVDF	PVDF	S
	PE	ECTFE	K
	PP	ECTFE	K
	PVDF	ECTFE	K
	ECTFE	ECTFE	S

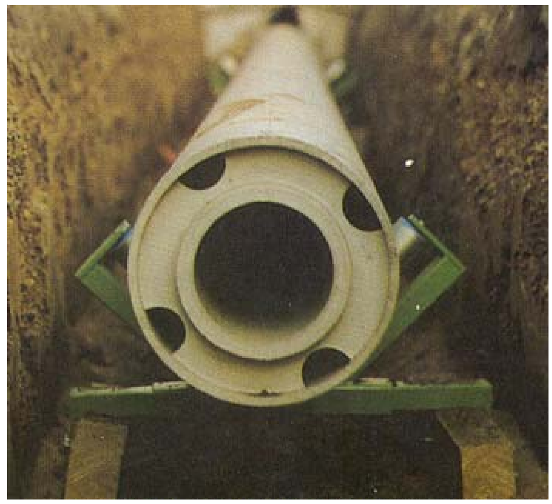
S = Simultaneous welding
K = Cascade welding

PE - PP

Standard dimension combinations for <u>cascade welding</u>
PE/PP - PE/PVDF - PP/PVDF - PE/ECTFE - PP/ECTFE

outside pipe		inside pipe	
d_1	SDR_1	d_2	SDR_2
90	17	32	11 (21)
125	17	63	11 (21)
160	17	90	11 (33)
200	17	110	11 (33)
280	17	160	11 (33)

PE - PVDF



PP - PP
Standard dimension combination for simultaneous welding PP/PP - PE/PE

outside pipe		inside pipe	
d_1	SDR_1	d_2	SDR_2
90	17	32	11
110	33	63	11
160	33	90	17
160	33	90	11
200	33	110	17
200	33	110	11
280	33	160	11
315	33	200	11
355	33	250	11

PE - PE

Special dimensions on request!

Connection method

The welding of a dual pipe can happen with different welding methods. There exists also the choice between simultaneous welding and cascade welding. The methode of the welding must be indicated in term of the order, because the offset of the inside pipe is adjusted by the welding method.

Simultaneous welding

With simultaneous welding the inside and outside pipe are welded at the same time. Here the dual pipe can be installed or welded like a single pipe but with different welding parameters.

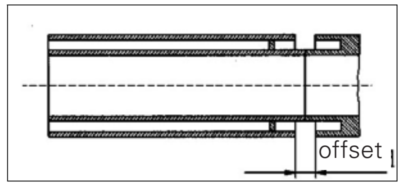
Advantages of simultaneous welding:

- Less time spent for a welding
- Easy and fast installation
- Use of the standard - heating element (not by leak detection cables)

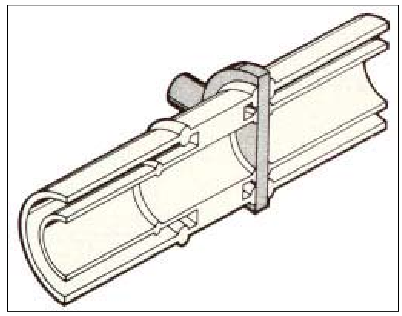
Disadvantages of a simultaneous welding:

- No visual controll of the inside pipe welding seam is possible
- Inside and outside pipe must be made of the same material.

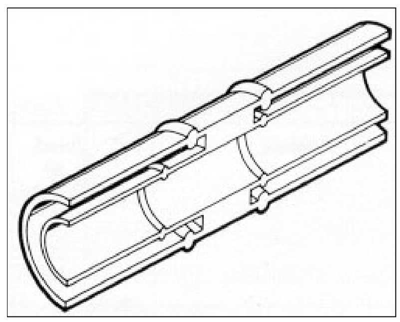
1.Step: Control of the offset on the inside pipe and planning of the welding surface



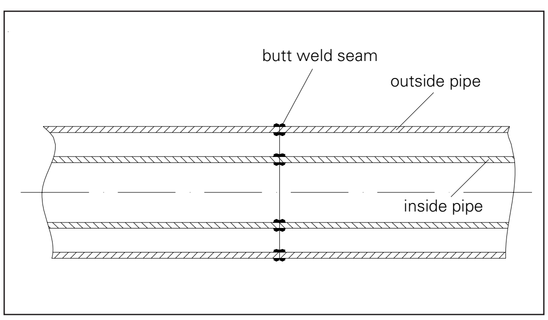
2.Step: Heating of the joining areas



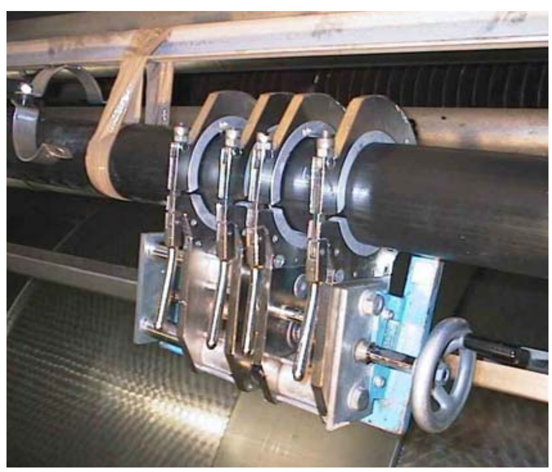
3.Step: Welding of inside and outside pipe



Simultaneous joining with butt welding:



Simultaneous welding of a PE - PE system



Connection method

Cascade welding

For the butt welding of the inside pipe the outside pipe is pulled back until the inside pipe is clamped into the clamps of the welding machine. The inside pipe is welded by heating element butt welding in accordance with the DVS guideline 2207.

The outside pipe can be joined with split heating element butt welding, with sleeve or with electrofusion welding. If a split heating element is used take care that a minimum ring gap between inside pipe and heating element of 10 mm is given. Further do not damage the inside pipe during the adjusting of the heating element. By the welding of the outside pipes with an electrofusion welding socket the inside stop in the middle of the socket should be removed before placement on the outside pipe, this will allow room for welding the inside pipe. After the welding of the inside pipe the loose outside pipe will be pulled on the to be welded pipe and will be welded on the circumference with electrofusion sockets. This welding is only possible with an outside pipe out of PEHD. A further possibility for the joining of the outside pipes is the welding with a sleeve. The procedure can be compared with the welding of electrofusion sockets. In this situation the sleeve is welded in place by hot gas or extrusion welding .

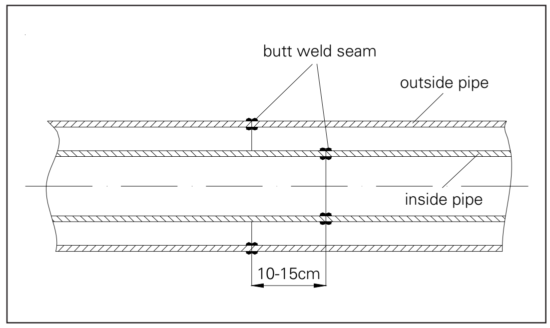
Advantages of the cascade welding:

- Easier installation of the leak detection cable
- The welding seam of the inside pipe can be checked visually
- This method can be applied for all material combinations

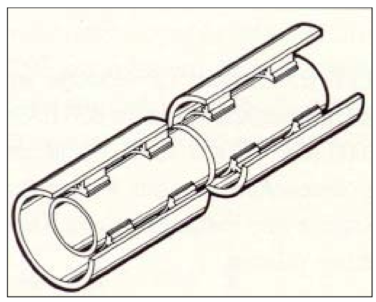
Disadvantages of the cascade welding:

- Higher time expenditure per welding
- Varied installation and so higher installation expenses

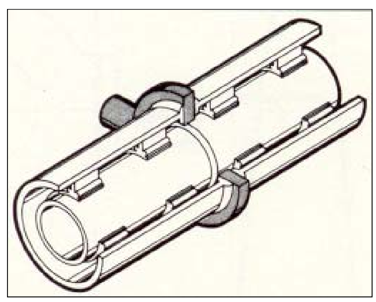
Cascade joining with butt welding



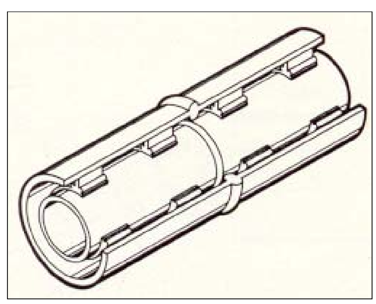
1.Step: Heating and welding of the inside pipe



2.Step: Heating of the outside pipe with a split heating element



3.Step: Welding of the outside pipe



Welding parameter

Welding parameter for PE/PE simultaneous welding

outside pipe			inside pipe			welding force	preheating time	cooling time	bead height outer pipe
d1 [mm]	SDR	s1 [mm]	d2 [mm]	SDR	s2 [mm]	F [kg]	tAw [sec.]	tAk [min]	[mm]
90	17	5,4	32	11	2,9	25	50	8	1
110	33	3,4	63	11	5,8	34	55	8	1
160	33	4,9	90	17	5,4	58	50	7	1,5
160	33	4,9	90	11	8,2	69	80	12	2
200	33	6,2	110	17	6,6	89	65	9	2
200	33	6,2	110	11	10	106	100	14	2,5
280	33	8,6	160	11	14,6	214	145	18	2,5
315	33	9,7	200	11	18,2	303	180	22	2,5
355	33	10,9	250	11	22,7	432	220	27	3

Welding parameter for PP/PP simultaneous welding

outside pipe			inside pipe			welding force	preheating time	cooling time	bead heigth outer pipe
d1 [mm]	SDR	s1 [mm]	d2 [mm]	SDR	s2 [mm]	F [kg]	tAw [sec.]	tAk [min]	[mm]
90	17	5,4	32	11	2,9	17	80	8	1
110	33	3,4	63	11	5,8	22	100	10	1
160	33	4,9	90	17	5,4	38	70	8	1,5
160	33	4,9	90	11	8,2	45	120	15	1,5
200	33	6,2	110	17	6,6	60	110	10	1,5
200	33	6,2	110	11	10	70	160	18	2
280	33	8,6	160	11	14,6	142	200	22	2,5
315	33	9,7	200	11	18,2	200	290	30	2,5
355	33	10,9	250	11	22,7	285	300	33	3

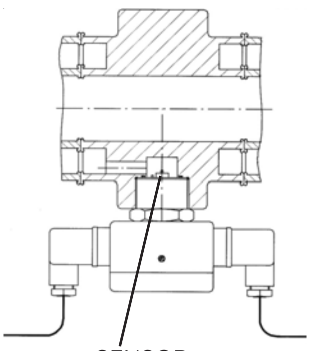
Leakage detection system

You need a **leak detection system** to supervise the transport of media in double containment piping systems. This is installed in or through the ring gap between the inside and outside pipe. If a leak should occur the operator immediately receives a message from the permanent leak detection system. The outside pipe protects the environment until a repair happens.

Today the following leak detection system in piping system are applied:

Sensors

In leak detection with sensors the sensors are installed on the lowest point of the pipeline system. In the case of a leaking the leaked medium will be advanced to the lowest point in the ring gap, where a sensor is situated. The sensors, which depend on different detection methods, can locate the position of the leak. This measurement ensures a constant control of the system, because the sensors are joined to a terminal, which makes supervising very easy. Through the application of fixed points the pipeline system can be split into separate safety zones. A further advantage is that in case of a leak the detection system can be renewed. Through the easy installation of the leak detection system it is one of the most widespread systems in practice.

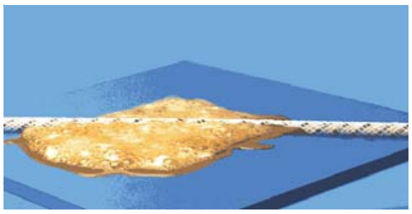


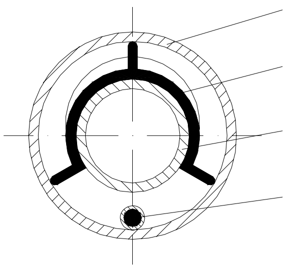
Visual leak detection

After leaking the medium can be seen through inspection glasses. These must be installed on all lowest points of the pipeline system. In case of a leak the leaked medium will advanceced to the lowest point and there it can be seen. The inspection glasses should have ports to make analysies of the medium in case of a leak. A constant control of the system by the visual method is not possible because the controls depends on the operator.
It is also possible to install a valve at the lowest point at the outside pipe of the double containment pipe for leak detection.

Leak detection cables

This special leak detection method was developed to detect and show the leak places . The cables are installed over the whole length in the ring gap of the piping system. The position of the leak can be located exactly with a system map.





Differential control
(Comparison inside pressure to ring gap pressure)

With differential pressure control the ring gap is supplied with under- or over pressure. By the overpressure method the gas flows out of the ring gap in the inside or media pipe during pressure loose in the ring gap, as a result of this an alarm is triggered by a pressure manometer. If a leak develops by the under pressure or vacuum control it will lead into a pressure loss in the media pipe following a pressure increase in the ring gap, which will also trigger an alarm. For the dimensions the stress of the different pressure in the ring gap should be noticed.

Design of the double containment piping system

Installation system

With the installation of the double containment piping system are in comparison with the installation of a single pipe possible changes in the length due to thermal expansion or contraction require special attention. The temperature changes of the inside and outside pipe can be different or even opposite through the distance between the pipes. This can lead to considerable length expansions of the pipes to one another. If it can not picked up constructive stress will be developed which is an additional demand on the pipe lines. One can distinguish between three different design systems:

Unimpeded heat expansion (flexible system)

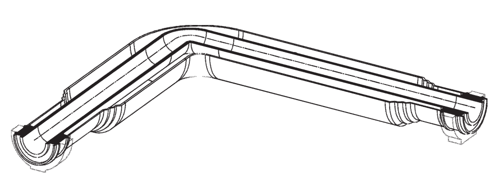
The inside and outside pipe are installed such that a length expansion from both pipes and even among each other can happen. In term of the planning we have to consider that the length expansion of the inside pipe takes place in the out-side pipe.

Advantages:

- Applicable for higher operating temperatures
- Low stress of the double containment piping system because of free expansion

Disadvantages:

- Higher expenses
- Need often much area because of the compensation elbow



System with impeded heat expansion

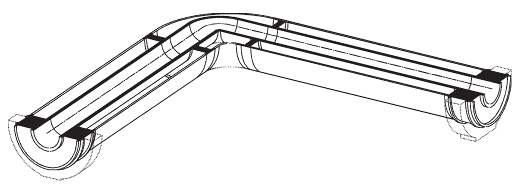
The inside and outside pipe are fixed together by dog bones. The length expansion of the whole double containment pipe line will be picked up through sufficient measures (compensator, straight). This method is only sensible when the inside an outside pipe are made out of the same material and few tempertrue changes between inside and outside pipe occur.

Advantages:

- low expenses
- usually low fixing expenses

Disadvantages:

- high stress in the double containment piping system
- need often much area because of the compensation elbow



Fixed system

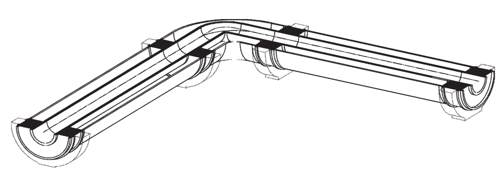
Inside, outside pipe and the surrounding are fixed together by dog bones on each direction change. A length expansion of the inside or outside pipe is not possible.

Advantages:

- low expensens
- need little area

Disadvantages:

- high dog bone forces (note the fixing demand)



Installation of the double containment system

Calculation

In order to be able to perform a complete and exact calculation and design of the piping system, we need to know the exact application and installation conditions of the respective project.

We have issued two questionnaires which should to be filled in by the customer and sent back to us. The questionnaires are available on demand. After the analysis of the questionnaire through our technical department you will receive a recommondation for the dimensions of the double containment piping system.

Questionnaire I

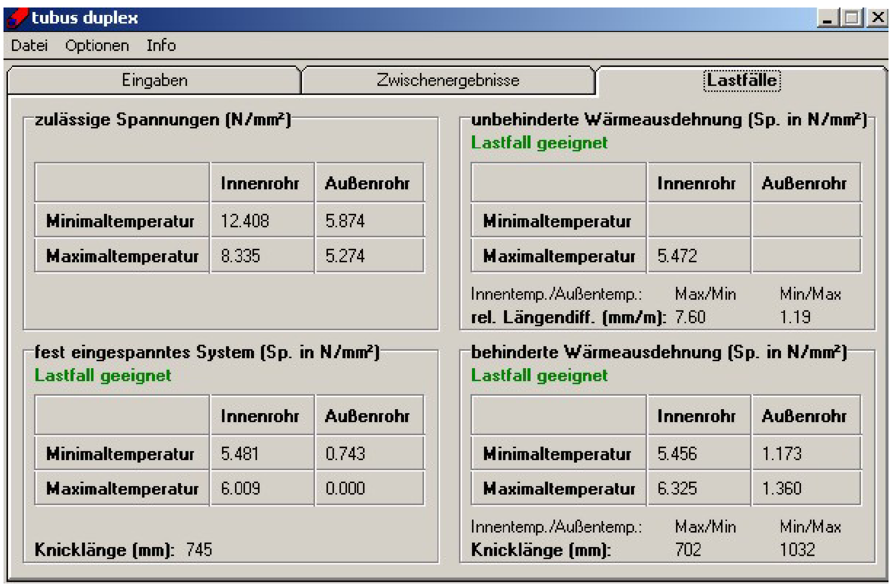
("Application and installation conditions") contains the dimensions, materials, pressure ratings, general application parameter and the leak detection system.

Please find the questionaire on the next page.

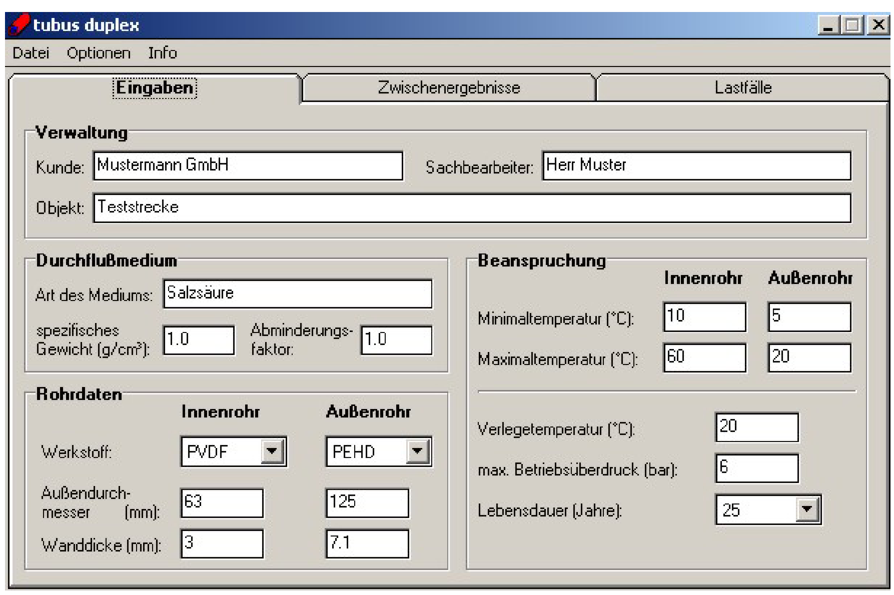
Questionnaire II

("Application conditions for buried piping systems") should be filled in if the piping system shall be installed underground and therefore a static calculation is necessary.

Please find the questionaire on page 159.



Excerpt from our calculation program for the double containment piping system



Excerpt from our calculation program for the double containment piping system

Double containment piping system

Questionnaire to calculate the double containment piping systems

Please send the filled questionnaire back to the indiquated address.

Company: ____________________________ Phone:____________________________________
Name: ____________________________ Telefax:____________________________________
Site: ____
Project: ____

Operating conditions
Flow medium[1]:____
Operating temperature:inside min. __________°C inside max. ______________________°C
Operating temperature:outside min. __________°C outside max. ______________________°C
Installation temperature:______________________°C Medium density: ________________kg / m³
max. operating over pressure: ____________________ bar required time to fail: ________years

Requested material combination:
Inside pipe **O** PEHD **O** PP **O** PVDF **O** ECTFE outside pipe **O** PEHD **O** PP **O** PVDF **O** ECTFE

Requested wall thickness combination and dimensions outside pipe / inside pipe:

Simultaneous welding					
outside pipe		**inside pipe**		**PE**	**PP**
d1	**SDR**	**d2**	**SDR**	**PE**	**PP**
90	17	32	11	☐	☐
110	33	63	11	☐	☐
160	33	90	17	☐	☐
160	33	90	11	☐	☐
200	33	110	17	☐	☐
200	33	110	11	☐	☐
280	33	160	11	☐	☐
315	33	200	11	☐	☐
355	33	250	11	☐	☐

cascade welding						
outside pipe		**inside pipe**		**PE**	**PE**	**PP**
d_1	**SDR_1**	**d_2**	**SDR_2**	**PP**	**PVDF**	**PVDF**
90	17	32	11 (21)	☐	☐	☐
125	17	63	11 (21)	☐	☐	☐
160	17	90	11 (33)	☐	☐	☐
200	17	110	11 (33)	☐	☐	☐
280	17	160	11 (33)	☐	☐	☐

☐ others: outside pipe d1_______ SDR_______ inside pipe d2_______ SDR_______

Installation

O aboveground system, plant
O aboveground system, outdoor in the shade
O with direct UV radiation
O buried piping system[2]

Leak detection system

O selective with sensors
O constant detection with leak detection cables
O visual control
O other leakd detection methods

Address:

AGRU Kunststofftechnik GmbH

Ing. Pesendorfer-Strasse 31 Phone : +43 7258 790 0
E-Mail: anwt@agru.at
A-4540 Bad Hall Telefax: +43 7258 790 430 Internet: http://www.agru.at

[1] For the material choice of the piping system is the exact combination of the medium necassery to control the chemical resistance.
[2] By buried systems please demand on our questionnaire „Application conditions for buried piping system".

Approvals

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

The systems out of PE, PP and PVDF are approved as per approval principles of DIBt and following registration numbers:

PE
Z-40.23.232
Z-40.23.231

PP
Z-40.23.234
Z-40.23.233

PVDF
Z-40.23.201
Z-40.23.202

The pipes and fittings out of PE, PP and PVDF are approved according European pressure equipment directive 97/23/EG for the production of pressure equipment.

PPH and PVDF - fittings and valves
TUEV0206966701

Fittings PE 100 and PE 80
TUEV0206966701

Fittings PP-H and PP-R
TUEV0206966701

Fittings PVDF
TUEV0206966701

Pipes PPH, PPR, PE 80, PE 100
TUEV0206966701

Further approvals:

PP-R-pipes
ON87272

PP-H-pipes
ON83054

PE-pipes and fittings
OENORM EN 12201

PE-pipes and fittings
OENORM EN 13244

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-Sued-Industrieservice
MPA-Darmstadt
SKZ-Wuerzburg
LKT-Wien
OKI-Wien

Standards

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

Hereafter a summary of the most important standards for PE, PP, PVDF and ECTFE.

OENORM B 3800
Behaviour of building materials and components in fire

OENORM B 5014, part 1
Sensory and chemical requirements and testing of materials in contact with drinking water

OENORM B 5174
Polypropylene pipes

OENORM EN 12201
Plastics piping systems for water supply - Polyethylene (PE)

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

OENORM EN ISO 1872
Plastics - Polyethylene (PE) moulding and extrusion materials

OENORM EN ISO 1873
Plastics - Polypropylene (PP) moulding and extrusion materials

OENORM EN ISO 15494
Plastics piping systems for industrial applications - Polybutene (PB), polyethylene (PE) and poly-propylene (PP) - Specifications for components and the system - Metric series (ISO 15494:2003)

DIN 4102
Fire behaviour of building materials and building components

DIN 8074/8075
High-density polyethylene pipes

DIN 8077/8078
Polypropylene pipes

DIN 16962 part 1 - part 13
Pipe joints and their elements for pressure pipes of polypropylene (PP)

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

ISO 4065
Thermoplastic pipes

ISO 10931 part 1 - part 5
Plastics piping systems for industrial applications - Polyvinylidene fluoride (PVDF)

Bestellbeispiel für AGRU Formteile

AGRU - CODE

- Material
- Teil Nr.
- Dimension
- Rohrreihe

XX . XXX . XXXX . XX

Bestellbeispiel:
PE 80 Bogen 90°, DA 63 mm, SDR 11
Code: 20.001.0063.11

Material-Code Nr.:
11 PP-R grau
12 PP-H grau
14 PP-R schwarz
15 PP weiss
16 PP natur
17 PP-s grau
19 PP-s-el schwarz
40 ECTFE natur
85 PVDF/PVDF

Order Sample for AGRU fittings

AGRU - CODE

- material
- part no.
- dimension
- pipe series

XX . XXX . XXXX . XX

Order Sample:
PE 80 bend 90°, OD 63 mm, SDR 11
Code: 20.001.0063.11

Samples of Material-Code No.:
11 PP-R grey
12 PP-H grey
14 PP-R black
15 PP white
16 PP natural
17 PP-s grey
19 PP-s-el black
20 PE 80 black
25 PE 100 black
85 PVDF/PVDF

Bestellbeispiel für AGRU Platten

AGRU - CODE

- Material
- Teil Nr.
- Dimension
- Rohrreihe

XX . XXX . XXXX . XX

Bestellbeispiel:
PVDF Platte, 2000 x 1000 mm, 2 mm dick
Code: 30.600.2010.02

Material-Code Nr.:
11 PP-R grau
12 PP-H grau
14 PP-R schwarz
15 PP weiss
16 PP natur
17 PP-s grau
19 PP-s-el schwarz
40 ECTFE natur
85 PVDF/PVDF

Order Sample for AGRU sheets

AGRU - CODE

- material
- part no.
- dimension
- pipe series

XX . XXX . XXXX . XX

Order Sample:
PVDF sheet, 2000 x 1000 mm, 2 mm thick
Code: 30.600.2010.02

Material-Code No.:
11 PP-R grey
12 PP-H grey
14 PP-R black
15 PP-H white
16 PP natural
17 PP-s grey
19 PP-s-el black
20 PE 80 black
85 PVDF/PVDF