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A Material properties

1 Material definition

- PVDF-UHP: Ultra high purity polyvinylidene fluoride natural
- PP-Pure: High purity polypropylene random-copolymer (PP-R) grey
- Polypure: High purity polypropylene random-copolymer (PP-R) natural
- ECTFE: Ethylene chlorotrifluorethylene natural
- PVDF-Vent: Polyvinylidene fluoride natural

2 PVDF-UHP

2.1 General properties

PVDF-UHP is an extremely pure polymer and contains no UV stabilisers, thermostabilisers, softeners, lubricants or flame-retardant additives. It is particularly suitable for the production, distribution and storage of ultra pure media in the semiconductor and life science industry.

PVDF-UHP pipes and components exhibit low leach out and easily comply with SEMI F-57 specification. PVDF-UHP components are capable to maintain a level of resistivity of deionised ultra pure water above 18 MΩ·cm [>0.055 μS/cm].

2.2 Material grade

PVDF-UHP is obtained by the polymerisation of vinylidene fluoride and corresponds to the following chemical structure:

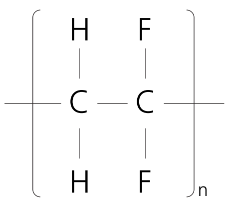


Figure A.1: Chemical structure of PVDF-UHP.

The two main processes to produce PVDF-UHP are:

- The emulsion polymerisation process
  PVDF type I according to ASTM D 3222
- The suspension polymerisation process
  PVDF type II according to ASTM D 3222

PVDF-UHP material produced through the suspension polymerisation process offers fewer structural defects, resulting in higher crystallinity as well as better mechanical properties and long-term behavior.

AGRU processes only suspension PVDF in order to provide the best possible product quality.

2.3 Fire resistance

PVDF-UHP is a halogen containing polymer which offers an excellent fire protection without flame retardant additives. During combustion of PVDF-UHP only a slight amount of smoke development arises. With a low oxygen index, PVDF-UHP received the highest flammability classification V0 according to UL-94.

AGRU PVDF sheets, pipes and fittings are specification tested for the use as clean room materials in accordance with FM approvals test standard 4910.

2.4 FDA conformity

PVDF-UHP is physiologically harmless and non-toxic and conforms to FDA regulations as outlined in Title 21, Chapter 1, Part 177-2510 (contact with food).

2.5 Advantages of PVDF-UHP

- Wide application temperature range
  (-20 °C to +140 °C / -4 °F to +284 °F)
- High heat deflection temperature
- Very good chemical resistance, even at high temperatures
- Good resistance against UV and gamma (γ) radiation
- Pure material without additives
- Very good surface quality
- High ageing resistance
- Good thermal stability
- Excellent abrasion resistance
- Very good anti-friction properties
- Good mechanical properties
- Excellent insulation characteristics
- Flame retardant

- Physiologically non-toxic
- Excellent weldability

2.6 Energy-rich radiation

The gamma (γ) ray effects on PVDF-UHP are significantly lower than in many other halogen polymers (e.g. PFA, PTFE, PVC). It is resistant to highly energetic radiation. This makes PVDF-UHP suitable for the use in the nuclear industry. The cross-linking of the polymer begins with 100 kilogray.

2.7 UV radiation

Suspension grade PVDF-UHP contains a high percentage of fluorine. The bond between the highly electronegative fluoride and carbon atom is extremely strong with a dissociation energy of 460 kJ/mol.

Therefore, PVDF-UHP is resistant to ambient UV radiation (>232 nm). In connection with UV sterilisers it is recommended to use light traps to eliminate problems in terms of stress cracking.

2.8 Material properties

The figures given below are common values for PVDF-UHP material.

	Properties	Condition	Standard	Units	Values
Physical	Specific density	23 °C (73.4 °F)	ISO 1183	g / cm³	1.78
	Melt flow rate (MFR)	230 °C/5 kg	ISO 1133	g / 10 min	6 - 24
Mechanical	Tensile stress at yield	50 mm/min	ISO 527	MPa	50
	Elongation at yield	50 mm/min	ISO 527	%	9
	Elongation at break	50 mm/min	ISO 527	%	80
	Impact strength unnotched	23 °C (73.4 °F)	ISO 179	kJ / m²	124
	Impact strength notched	23 °C (73.4 °F)	ISO 179	kJ / m²	11
	Ball indentation hardness according to Rockwell	23 °C (73.4 °F)	ISO 2039-1	MPa	80
	Flexural strength	23 °C (73.4 °F)	ISO 178	MPa	80
	Modulus of elasticity		ISO 527	MPa	2000
Thermal	Vicat softening point	VST/B/50	ISO 306	°C °F	140 284
	Heat deflection temperature	HDT/B	ISO 75	°C °F	145 293
	Linear thermal expansion coefficient		DIN 53752	$K^{-1} \times 10^{-4}$	1.2
	Thermal conductivity	20 °C (68 °F)	DIN 52612	W / (m × K)	0.20
	Flammability		UL94	-	V-0
Electrical	Specific volume resistance		DIN 53482	Ω · cm	$\geq 10^{13}$
	Specific surface resistance		DIN 53482	Ω	$\geq 10^{12}$
	Relative dielectric constant	1 MHz	DIN 53483	-	7.25
	Dielectric strength		DIN 53481	kV / mm	22
	Physiologically nontoxic		EEC 90/128		yes
	FDA				yes
	NSF 51				yes
	NSF 61				yes
	USP class VI				yes
	UV resistance				yes
	Colour				natural

Table A.1: Material properties of PVDF-UHP.

2.9 Hydrostatic strength graph for pipes out of PVDF-UHP

(according to EN ISO 10931:2005 (D) annex A)

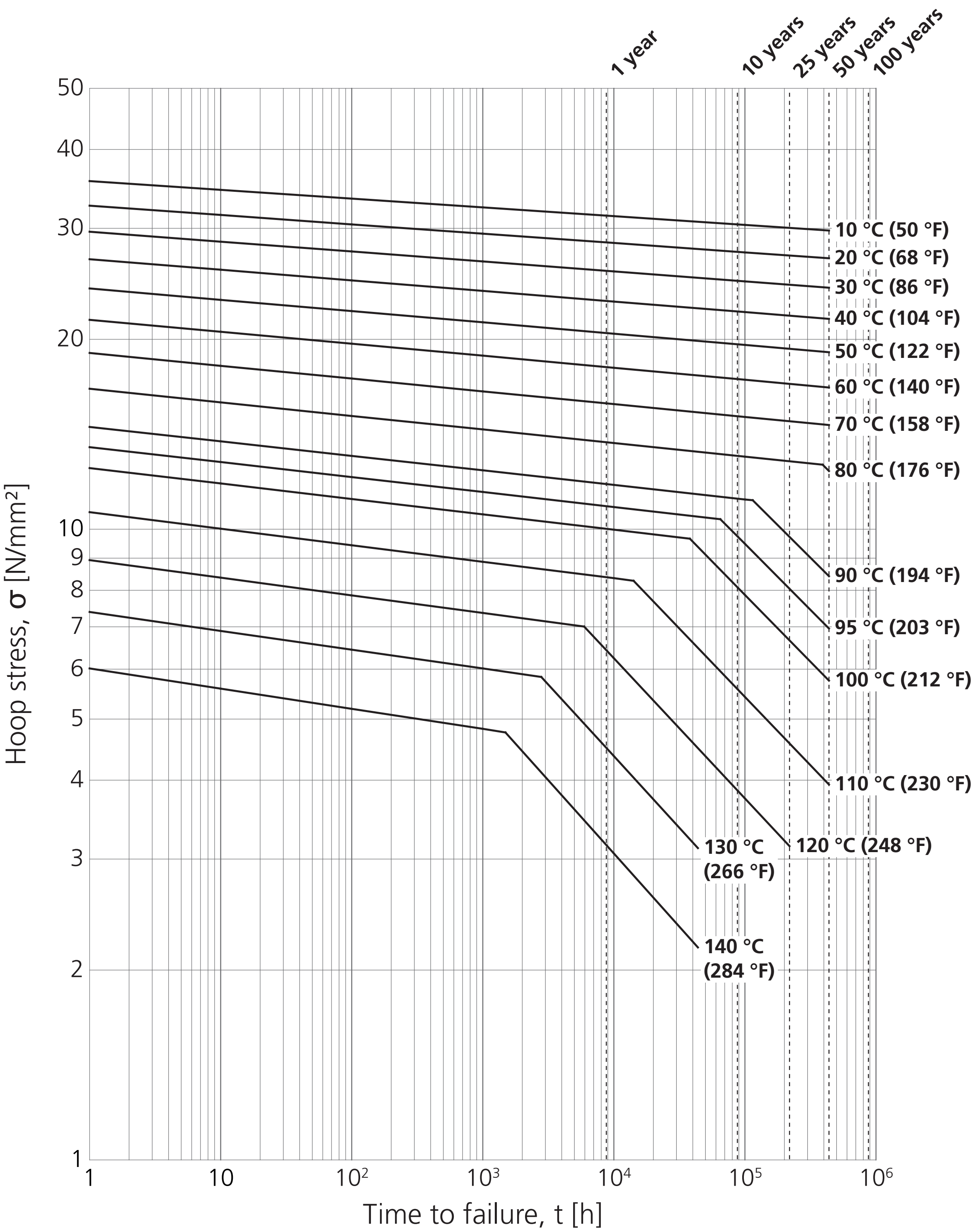


Figure A.2: Hydrostatic strength graph for PVDF-UHP pipes.

2.10 Permissible component operating pressure p_B for PVDF-UHP

(according to EN ISO 10931:2005 (D) annex A)

Temperature		Operating period	Permissible operating pressure PVDF-UHP			
			SDR 33 ISO-S 16		SDR 21 ISO-S 10	
[°C]	[°F]	[yr]	[bar]	[psi]	[bar]	[psi]
10	50	1	12.2	177	19.6	284
		5	12.0	174	19.1	277
		10	11.8	171	19.0	276
		25	11.7	170	18.7	271
		50	11.6	168	18.5	268
20	68	1	11.1	161	17.8	258
		5	10.8	157	17.3	251
		10	10.7	155	17.2	249
		25	10.6	154	16.9	245
		50	10.5	152	16.8	244
30	86	1	10.0	145	16.0	232
		5	9.7	141	15.6	226
		10	9.6	139	15.4	223
		25	9.5	138	15.2	220
		50	9.4	136	15.0	218
40	104	1	8.9	129	14.3	207
		5	8.7	126	14.0	203
		10	8.6	125	13.8	200
		25	8.5	123	13.6	197
		50	8.4	122	13.4	194
50	122	1	8.0	116	12.7	184
		5	7.7	112	12.4	180
		10	7.6	110	12.2	177
		25	7.5	109	12.0	174
		50	7.4	107	11.9	173
60	140	1	7.0	102	11.3	164
		5	6.8	99	10.9	158
		10	6.7	97	10.8	157
		25	6.6	96	10.6	154
		50	6.5	94	10.4	151
70	158	1	6.1	89	9.8	142
		5	5.9	86	9.5	138
		10	5.9	86	9.4	136
		25	5.7	87	9.2	133
		50	5.7	83	9.1	132
80	176	1	5.3	77	8.5	123
		5	5.1	74	8.2	119
		10	5.1	74	8.1	118
		25	5.0	73	8.0	116
		50	4.8	70	7.7	112
90	194	1	4.6	67	7.3	106
		5	4.4	64	7.1	103
		10	4.3	62	6.9	100
		25	3.8	55	6.0	87
		50	3.2	46	5.2	75
95	203	1	4.2	61	6.8	99
		5	4.0	58	6.5	94
		10	3.8	55	6.0	87
		25	3.1	45	5.0	73
		50	2.7	39	4.3	62

Table A.2: Maximum operating pressure of PVDF-UHP.

Temperature		Operating period	Permissible operating pressure PVDF-UHP			
			SDR 33 ISO-S 16		SDR 21 ISO-S 10	
[°C]	[°F]	[yr]	[bar]	[psi]	[bar]	[psi]
100	212	1	3.9	57	6.2	90
		5	3.6	52	5.8	84
		10	3.1	45	5.0	73
		25	2.6	38	4.1	59
		50	2.2	32	3.6	52
110	230	1	3.2	46	5.2	75
		5	2.5	36	4.0	58
		10	2.1	30	3.4	49
		25	1.7	25	2.8	41
		50	1.5	22	2.4	35
120	248	1	2.5	36	4.0	58
		5	1.7	25	2.8	41
		10	1.5	22	2.4	35
		25	1.2	17	1.9	28
130	266	1	1.7	25	2.8	41
		5	1.2	17	1.9	28
140	284	1	1.2	17	1.9	28
		5	0.8	12	1.3	19

The given values are only valid for water. They were determined from the creep curve taking into account a safety coefficient of C = 1.6 required by ISO/DIS 12162:2008.

For the calculation of the operating pressure in above ground piping systems it is recommended to multiply the value in the table with a system reduction coefficient f_s = 0.8 (This value contains installation influences such as welded joint, flange or also bending loads).

These operating pressures have to be reduced by the corresponding reducing coefficients (see Chapter D Section 7.2) for every application.

At higher temperatures, a discolouration of the material can occur. This has no influence on the mechanical, thermal, purity or electrical properties.

For more information on chemical resistance refer to the chemical resistance table on www.agru.at or contact anwt@agru.at.

2.11 Permissible buckling pressure PVDF-UHP

Temperature		Operating period	Permissible buckling pressure PVDF-UHP			
			SDR 33 ISO-S 16		SDR 21 ISO-S 10	
[°C]	[°F]	[yr]	[bar]	[psi]	[bar]	[psi]
20	68	1	0.28	4.0	1.18	17.10
		10	0.26	3.7	1.08	15.60
		25	0.20	2.9	1.04	15.00
30	86	1	0.26	3.7	1.05	15.20
		10	0.23	3.3	0.95	13.70
		25	0.23	3.3	0.92	13.30
40	104	1	0.23	3.3	0.93	13.40
		10	0.21	3.0	0.85	12.30
		25	0.20	2.9	0.85	12.30
50	122	1	0.20	2.9	0.82	11.80
		10	0.19	2.7	0.74	10.70
		25	0.17	2.4	0.70	10.10
60	140	1	0.17	2.4	0.70	10.10
		10	0.16	2.3	0.63	9.10
		25	0.15	2.1	0.60	8.70
70	158	1	0.15	2.1	0.60	8.70
		10	0.13	1.8	0.53	7.60
		25	0.12	1.7	0.50	7.20
80	176	1	0.13	1.8	0.52	7.50
		10	0.11	1.5	0.45	6.50
		25	0.10	1.4	0.42	6.00
90	194	1	0.11	1.5	0.43	6.20
		10	0.09	1.3	0.37	5.30
		25	0.08	1.1	0.35	5.00
100	212	1	0.09	1.3	0.36	5.20
		10	0.08	1.1	0.32	4.60
		25	0.07	1.0	0.29	4.20
110	230	1	0.07	1.0	0.30	4.30
		10	0.06	0.8	0.26	3.70
		25	0.06	0.8	0.23	3.30
120	248	1	0.06	0.8	0.26	3.70
		10	0.06	0.8	0.24	3.40
		25	0.05	0.7	0.21	3.00

Table A.3: Buckling pressure of PVDF-UHP.

The permissible buckling pressure stated in the table was determined based on a safety coefficient of C = 2.0.

These buckling pressures have to be reduced by the corresponding reducing coefficients for aggressive chemicals (f_{CR}).

Buckling loads can be caused by external pressure, e.g. soil and ground water pressure or internal vacuum. The values given in the table are stated for the relative buckling pressure.

2.12 Creep modulus curves for PVDF-UHP

(according to DVS 2205-1:2002 (D))

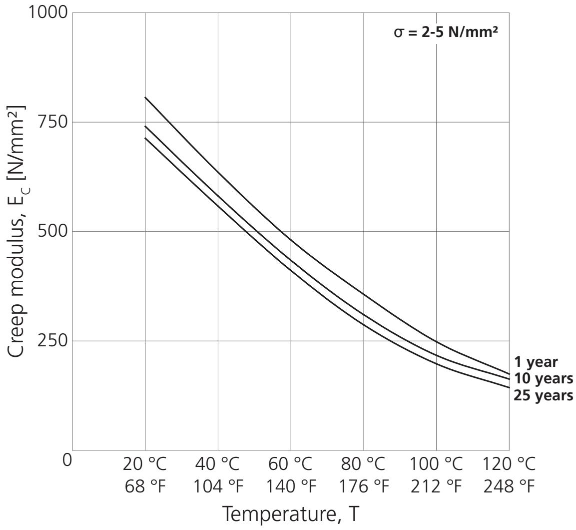


Figure A.3: Creep modulus curves of PVDF-UHP.

2.12.1 Reduction of the creep modulus

The creep modulus stated in the diagram has to be reduced by a safety coefficient of ≥2 for stability calculations.

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

3 PP-Pure and Polypure

3.1 General properties

The PP-Pure (high purity PP grey) and Polypure (high purity PP natural) piping systems are made out of specially selected PP-R material (polypropylene random-copolymer). These are thermoplastic materials which distinguish themselves with a low specific weight and also by excellent processibility, weldability and formability. These materials contain additives (e.g. stabilisers) but no plasticisers.

3.2 Material grade

By copolymerisation with ethylene, special properties are achieved as in PP-Pure and Polypure, which results 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 (polypropylene homopolymer). Therefore, PP-Pure and Polypure are especially suitable for applications in the chemical and semiconductor industry for UPW systems, where great demands are made on the chemical resistance.

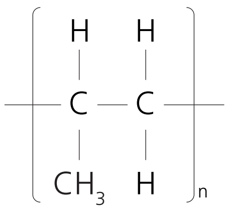


Figure A.4: Chemical structure of PP-Pure and Polypure.

PP-Pure is also being a substitute for PVDF in less critical UPW systems.

In comparison to other thermoplastics such as PVC, PP-Pure and Polypure show a thermal stability up to 100 °C / 212 °F (short-time up to 120 °C / 248 °F for pressureless applications).

3.3 Suitability for food and life science

With respect to its composition, PP-Pure and Polypure comply with the relevant food stuff regulations (according to ÖNORM B 5014 part 1, FDA, BGA, KTW guidelines).

3.4 Advantages of PP-Pure and Polypure

- Low specific weight of 0.91 g/cm³ (PVC 1.40 g/cm³)
- High creep resistance
- Excellent chemical resistance
- High resistance to aging
- Good weldability
- Excellent abrasion resistance
- Smooth inside surface
- No deposits and no overgrowth
- Less frictional resistance
- Non-conductive
- Good insulating characteristics

3.5 Energy-rich radiation

At an absorbed dose of $<10^4$ gray polypropylene piping systems can be applied without essential resistance decreasing.

At energy rays above 10^4 gray it may come to a temporary resistance increase due to a cross-linking of the molecular structure. But at durable radiation strain, it comes to a rupture of the molecular chains and therefore damages the material to a serious resistance decrease.

3.6 UV radiation

PP-Pure and Polypure piping systems 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 recommended.

However, for PP-Pure, it is possible to compensate for the damage of the surface by increasing the wall thickness, as the damage only occurs on the surface. This additional thickness should not be less than 2 mm and as a result, a maximum operating life of 10 years is expected (according to DVS 2210-1:1997(D)).

As polypropylene does not normally have UV stable colour pigments, there may be a change of colour (fading) as a result of long-term exposure.

3.7 Discolouration of Polypure

At higher temperatures, a discolouration of the material can occur. This has no influence on the mechanical, thermal, purity or electrical properties. Also when products are stored for a longer period a slight discolouration can appear.

3.8 Material properties

The figures given below are common values for PP-Pure and Polypure material.

	Properties	Condition	Standard	Units	Values
Physical	Density	23 °C (73.4 °F)	ISO 1183	g / cm³	0.91
	Melt flow rate	230 °C/5 kg	ISO 1133	g / 10 min	1.25
		190 °C/5 kg			0.5
Mechanical	Tensile stress at yield	50 mm/min	ISO 527	MPa	25
	Elongation at yield	50 mm/min	ISO 527	%	12
	Elongation at break	50 mm/min	ISO 527	%	>300
	Impact strength unnotched	23 °C (73.4 °F)	ISO 179/1eU	kJ / m²	no break
		0 °C (32 °F)			no break
		-20 °C (-4 °F)			40
	Impact strength notched	23 °C (73,4 °F)	ISO 179/1eA	kJ / m²	20
		0 °C (32 °F)			3.5
		-20 °C (-4 °F)			2.0
	Ball indentation hardness according to Rockwell		ISO 2039-1	MPa	45
	Flexural strength (3.5% flexural stress)		ISO 178	MPa	20
	Modulus of elasticity		ISO 527	MPa	900
Thermal	Vicat softening point	VST/B/50	ISO 306	°C °F	65 149
	Heat deflection temperature	HDT/B	ISO 75	°C °F	70 158
	Linear thermal expansion coefficient		DIN 53752	$K^{-1} \times 10^{-4}$	1.5
	Thermal conductivity	20 °C (68 °F)	DIN 52612	W / (m × K)	0.24
	Flammability		UL94 DIN 4102	-	94-HB B2
Electrical	Specific volume resistance		VDE 0303	Ω · cm	$> 10^{16}$
	Specific surface resistance		VDE 0303	Ω	$> 10^{13}$
	Dielectric constant	1 MHz	DIN 53483	-	2.3
	Dielectric strength		VDE 0303	kV / mm	70

Table A.4: Material properties of PP-Pure and Polypure (part 1).

	Properties	Condition	Standard	Units	Values
	Physiologically nontoxic		EEC 90/128		yes
	FDA				yes
	USP class VI				yes
	UV resistance				no
	Colour	PP-Pure			grey RAL 7032
		Polypure			natural

Table A.5: Material properties of PP-Pure and Polypure (part 2).

3.9 Hydrostatic strength graph for pipes out of PP-Pure and Polypure

(according to EN ISO 15494:2003 (D) annex C)

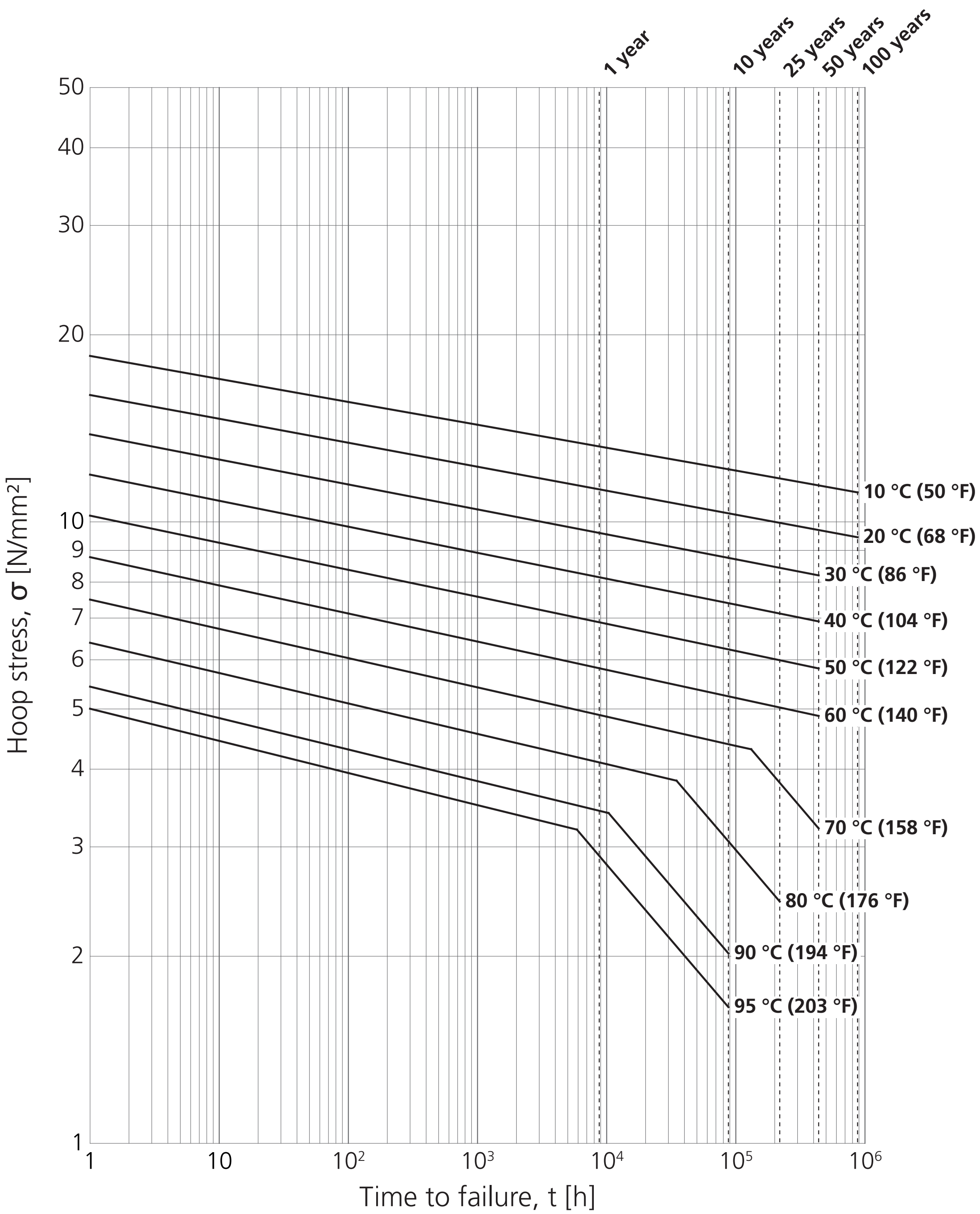


Figure A.5: Hydrostatic strength graph for PP-Pure and Polypure pipes.

3.10 Permissible component operating pressure p_B for PP-Pure and Polypure

(according to EN ISO 15494:2003 (D) annex C)

Temperature		Operating period	Permissible operating pressure SDR 11 ISO-S 5	
[°C]	[°F]	[yr]	[bar]	[psi]
10	50	1	21.1	306
		5	19.9	289
		10	19.4	281
		25	18.7	271
		50	18.3	265
		100	17.8	258
20	68	1	18.0	261
		5	16.9	245
		10	16.5	239
		25	15.9	231
		50	15.5	225
		100	15.1	219
30	86	1	15.3	222
		5	14.4	209
		10	14.0	203
		25	13.5	196
		50	13.1	190
40	104	1	13.0	189
		5	12.1	176
		10	11.8	171
		25	11.3	164
		50	11.0	160
50	122	1	11.0	160
		5	10.2	148
		10	9.9	144
		25	9.5	138
		50	9.3	135
60	140	1	9.3	135
		5	8.6	125
		10	8.3	120
		25	8.0	116
		50	7.7	112
70	158	1	7.8	113
		5	7.2	104
		10	7.0	102
		25	6.0	87
		50	5.1	74
80	176	1	6.5	94
		5	5.8	84
		10	4.9	71
		25	3.9	57
90	194	1	5.4	78
		5	3.8	55
		10	3.2	46
95	203	1	4.6	67
		5	3.1	45

Table A.6: Maximum operating pressure of PP-Pure and Polypure.

The given values are only valid for water. They were determined from the creep curve taking into account a safety coefficient of C = 1.25 required by ISO/DIS 12162:2008.

For the calculation of the operating pressure in above ground piping systems it is recommended to multiply the value in the table with a system reduction coefficient f_s = 0.8 (This value contains installation influences such as welded joint, flange or also bending loads).

These operating pressures have to be reduced by the corresponding reducing coefficients (see Chapter D Section 7.2) for every application.

For more information on chemical resistance refer to the chemical resistance table on www.agru.at or contact anwt@agru.at.

3.11 Permissible buckling pressure PP-Pure and Polypure

Temperature		Operating period	Permissible buckling pressure SDR 11 ISO-S 5	
[°C]	[°F]	[yr]	[bar]	[psi]
20	68	1	3.80	55
		10	3.35	49
		25	3.25	47
30	86	1	3.30	48
		10	2.95	43
		25	2.85	41
40	104	1	2.85	41
		10	2.65	38
		25	2.55	37
50	122	1	2.45	36
		10	2.30	33
		25	2.20	32
60	140	1	2.15	31
		10	2.00	29
		25	1.95	28
70	158	1	1.90	28
		10	1.70	25
		25	1.65	24
80	176	1	1.60	23
		10	1.45	21
95	203	1	1.25	18
		10	1.05	15

Table A.7: Buckling pressure PP-Pure & Polypure.

The permissible buckling pressure stated in the table was determined based on a safety coefficient of C = 2.0.

These buckling pressures have to be reduced by the corresponding reducing coefficients for aggressive chemicals (f_{CR}).

Buckling loads can be caused by external pressure, e.g. soil and ground water pressure or internal vacuum. The values given in the table are stated for the relative buckling pressure.

3.12 Creep modulus curves for PP-Pure and Polypure

(according to DVS 2205-1:2002 (D))

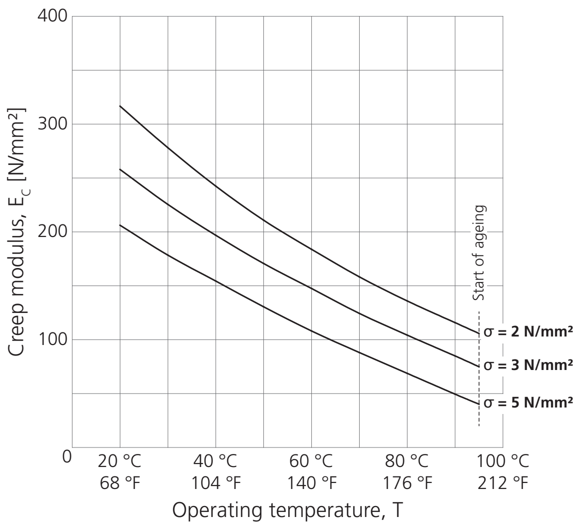


Figure A.6: Creep modulus of PP-Pure and Polypure for 1 year.

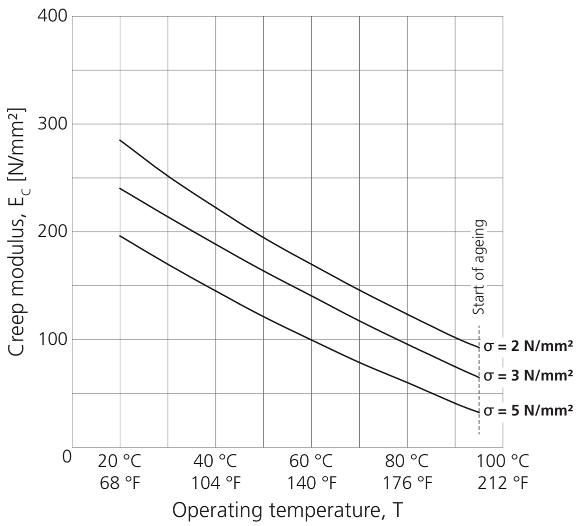


Figure A.7: Creep modulus of PP-Pure and Polypure for 10 years.

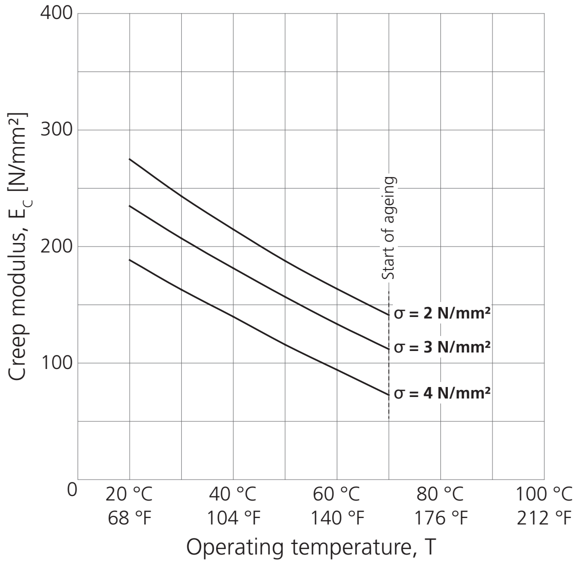


Figure A.8: Creep modulus of PP-Pure and Polypure for 25 years.

3.12.1 Reduction of the creep modulus

The creep modulus stated in the diagram has to be reduced by a safety coefficient of ≥2 for stability calculations.

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

4 ECTFE

4.1 General properties

ECTFE (known as HALAR®) provides excellent chemical resistance and high mechanical strength even at high temperatures. These characteristics enable the use of ECTFE as a cost-effective solution for many applications with ultra pure media.

4.2 Material grade

ECTFE is an incomparable material. Its exceptional combination of properties is based on the unique chemical structure. It is an alternating copolymer between ethylene and chlorotrifluorethylene.

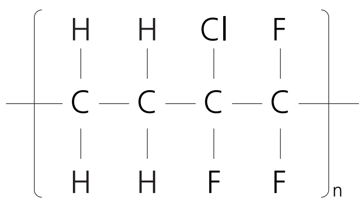


Figure A.9: Chemical structure of ECTFE.

Furthermore ECTFE has an inherent resistance to lots of aggressive chemicals even corrosive acids, alkalis and solvents as well as in contact with chlorine. It can withstand pH values from 0 to 14. There are only few chemicals, by which ECTFE is affected, for example hot amines, sodium and potassium.

4.3 Suitability for food and life science

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

4.4 Fire resistance

ECTFE has a very good flammability resistance (UL 94-V0) and a very low smoke generation of LOI >52 %.

4.5 Surface quality

ECTFE is distinguished from all other fluoropolymers by its exceptional surface smoothness which precludes the shedding of particles and avoids particle trapping. ECTFE surface exhibits a low incidence of microbial bio-fouling, making it ideal for the use in UPW applications.

4.6 Advantages of ECTFE

- Wide temperature application range (thermal resistance from (-76 °C to +150 °C / -104.8 °F to 302 °F)
- Good resistance to UV and γ radiation, therefore favourable ageing resistance
- Flame retardant (UL 94-V0 material)
- Oxygen index >52 %
- Extremely good chemical resistance to most technical acids, alkalis and solvents as well as in contact with chlorine
- Excellent insulating properties in connection with very good electrical values
- Physiologically non-toxic
- Exceptional surface smoothness
- Excellent impact strength
- Excellent tensile strength
- Highest creep modulus
- Extremely low permeability
- Excellent abrasion resistance

4.7 Energy-rich radiation

ECTFE has an extraordinary inherent resistance to many sources of radiation up to 2 megagray.

4.8 UV radiation

ECTFE shows only a slight change of the properties or appearance while weathering in the sunlight. Accelerated weathering tests showed a remarkable stability of the polymers, particularly the elongation at break, which is a good indicator for the polymer decomposition.

4.9 Material properties

The figures given below are common values for ECTFE material.

	Properties	Condition	Standard	Units	Values
Physical	Density	23 °C (73.4 °F)	ISO 1183	g / cm³	1.68
	Melt flow rate	275 °C / 2.16 kg	ISO 1133	g / 10 min	0.8 - 1.3
Mechanical	Tensile stress at yield	50 mm/min	ISO 527	MPa	30 - 32
	Elongation at yield	50 mm/min	ISO 527	%	3-5
	Elongation at break	50 mm/min	ISO 527	%	250 - 300
	Impact strength unnotched	23 °C (73.4 °F)	ISO 179	kJ / m²	no break
		-30 °C (-22 °F)			-
	Impact strength notched	23 °C (73.4 °F)	ISO 179	kJ / m²	no break
		0 °C (32 °F)			-
		-30 °C (-22 °F)			-
	Shore D hardness	2 mm	ASTM D2240		70 - 75
	Flexural strength	23 °C (73.4 °F)	ISO 178	MPa	45 - 55
	Modulus of elasticity	23 °C (73.4 °F)	ISO 527	MPa	1600 - 1800
	Abrasion resistance		TABER	mg / 1000 cycles	5
Thermal	Vicat softening point	VST/B/50	ISO 306	°C °F	n.a.
	Heat deflection temperature	HDT/B	ISO 75	°C °F	90 194
	Linear thermal expansion coefficient	-30 to 50 °C -22 to 122 °F	DIN 53752	$K^{-1} \times 10^{-4}$	0.8
	Linear thermal expansion coefficient	50 to 85 °C 122 to 185 °F	DIN 53752	$K^{-1} \times 10^{-4}$	1.0
	Linear thermal expansion coefficient	85 to 125 °C 185 to 365 °F	DIN 53752	$K^{-1} \times 10^{-4}$	1.35
	Thermal conductivity	20 °C (68 °F)	DIN 52612	W / (m × K)	0.15
	Flammability		UL94	-	V-0

Table A.8: Material properties ECTFE (part 1).

	Properties	Condition	Standard	Units	Values
Electrical	Specific volume resistance		VDE 0303	$\Omega \cdot cm$	$>1 \cdot 10^{16}$
	Specific surface resistance		VDE 0303	Ω	10^{14}
	Dielectric constant	1 MHz	DIN 53483	-	2.6
	Dielectric strength		ASTM D149	kV / mm	15
	Physiologically nontoxic	EEC 90/128			yes
	FDA				n.a.
	NSF 61				yes
	USP class VI				yes
	UV resistance				yes
	Colour				natural

Table A.9: Material properties ECTFE (part 2).

4.10 Hydrostatic strength graph for pipes out of ECTFE

(according to DVS 2205-1 supplement 4:2012 (D) yellow print)

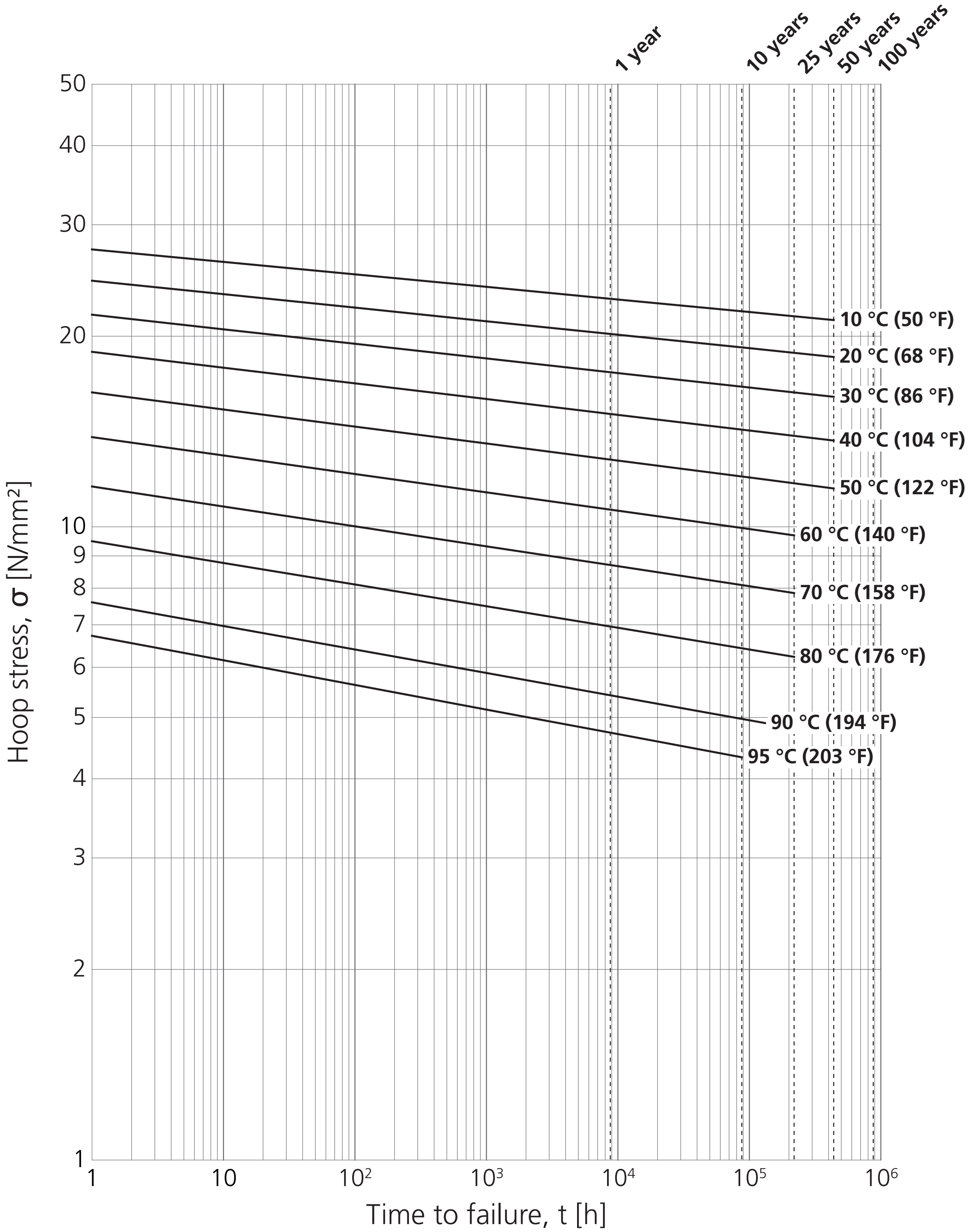


Figure A.10: Hydrostatic strength graph for ECTFE pipes.

4.11 Permissible component operating pressure p_B for ECTFE

(according to DVS 2205-1 supplement 4:2012 (D) yellow print)

Temperature [°C]	Temperature [°F]	Operating period [yr]	Permissible component operating pressure ECTFE, SDR 21 ISO-S 10 [bar]	Permissible component operating pressure ECTFE, SDR 21 ISO-S 10 [psi]
10	50	1	14.3	207
		5	13.8	200
		10	13.6	197
		25	13.4	194
		50	13.2	191
20	68	1	12.6	183
		5	12.1	175
		10	12.0	174
		25	11.7	170
		50	11.6	168
30	86	1	10.9	158
		5	10.5	152
		10	10.4	151
		25	10.1	146
		50	10.0	145
40	104	1	9.4	136
		5	9.0	131
		10	8.9	129
		25	8.7	126
		50	8.5	123
50	122	1	7.9	115
		5	7.6	110
		10	7.5	109
		25	7.3	106
		50	7.1	103
60	140	1	6.6	96
		5	6.3	91
		10	6.2	90
		25	6.0	87
70	158	1	5.4	78
		5	5.1	74
		10	5.0	73
		25	4.9	71
80	176	1	4.3	62
		5	4.1	59
		10	4.0	58
		25	3.9	57
90	194	1	3.3	48
		5	3.1	45
		10	3.1	45
		15	3.0	44
95	203	1	2.9	42
		5	2.7	39
		10	2.7	39

Table A.10: Maximum operating pressure of ECTFE.

For pressure values at higher temperatures please contact anwt@agru.at.

4.12 Permissible component operating pressure p_B for ECTFE-Vent

(according to DVS 2205-1 supplement 4:2012 (D) yellow print)

Temperature [°C]	Temperature [°F]	Operating period [yr]	OD 110 mm OD 4" s = 3 mm [bar]	OD 110 mm OD 4" s = 3 mm [psi]	OD 160 mm OD 6" s = 3 mm [bar]	OD 160 mm OD 6" s = 3 mm [psi]
10	50	1	8.0	116	5.4	78
		5	7.7	112	5.3	77
		10	7.6	110	5.2	75
		25	7.5	109	5.1	74
		50	7.4	107	5.0	73
20	68	1	7.0	102	4.8	70
		5	6.8	99	4.6	67
		10	6.7	97	4.5	65
		25	6.6	96	4.5	65
		50	6.5	94	4.4	64
30	86	1	6.1	88	4.1	59
		5	5.9	86	4.0	58
		10	5.8	84	3.9	57
		25	5.7	83	3.8	55
		50	5.6	81	3.8	55
40	104	1	5.2	75	3.6	52
		5	5.0	73	3.4	49
		10	4.9	71	3.4	49
		25	4.8	70	3.3	48
		50	4.8	70	3.2	46
50	122	1	4.4	64	3.0	44
		5	4.2	61	2.9	42
		10	4.2	61	2.8	41
		25	4.1	59	2.8	41
		50	4.0	58	2.7	39
60	140	1	3.7	54	2.5	36
		5	3.5	51	2.4	35
		10	3.4	49	2.3	33
		25	3.4	49	2.3	33
70	158	1	3.0	44	2.0	29
		5	2.9	42	1.9	28
		10	2.8	41	1.9	28
		25	2.7	39	1.8	26
80	176	1	2.4	35	1.6	23
		5	2.3	33	1.5	22
		10	2.2	32	1.5	22
		25	2.1	30	1.4	20
90	194	1	1.9	28	1.2	17
		5	1.7	25	1.2	17
		10	1.7	25	1.1	16
		15	1.7	25	1.1	16
95	203	1	1.6	23	1.1	16
		5	1.5	22	1.0	15
		10	1.5	22	1.0	15

Table A.11: Maximum operating pressure of ECTFE-Vent.

For pressure values at higher temperatures please contact anwt@agru.at.

The given values are valid for water. They were determined from the creep curve taking into account a safety coefficient of C = 1.6.

For the calculation of the operating pressure in above ground piping systems it is recommended to multiply the values in the table with a system reduction coefficient fs = 0.8 (This value contains installation influences such as welded joint, flange or also bending loads).

These operating pressures have to be reduced by the corresponding reducing coefficients (see Chapter D Section 7.2) for every application.

For more information on chemical resistance refer to the chemical resistance table on www.agru.at or contact anwt@agru.at.

4.13 Creep modulus curves for ECTFE

(according to information by Solvay Solexis and DVS 2205-1 supplement 4:2012 (D) yellow print)

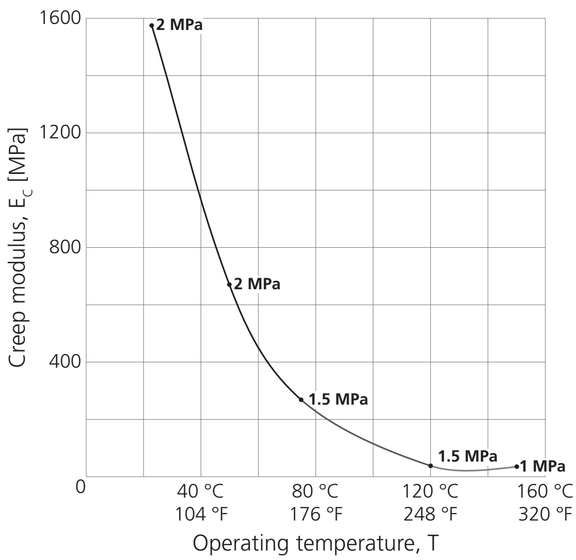


Figure A.11: Creep modulus of ECTFE (100h).

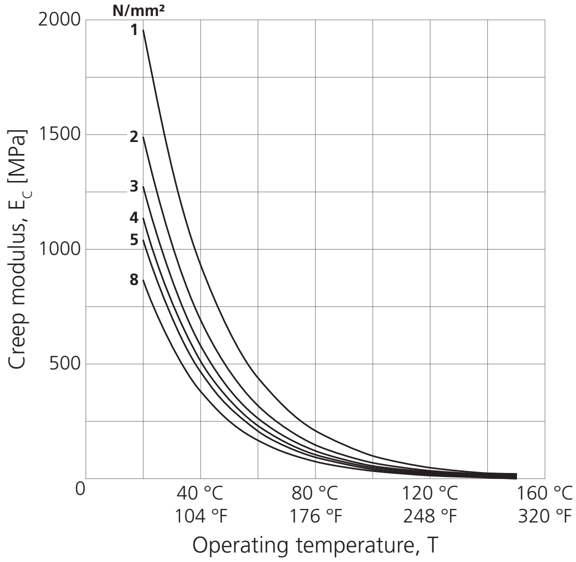


Figure A.12: Creep modulus of ECTFE for 1 year.

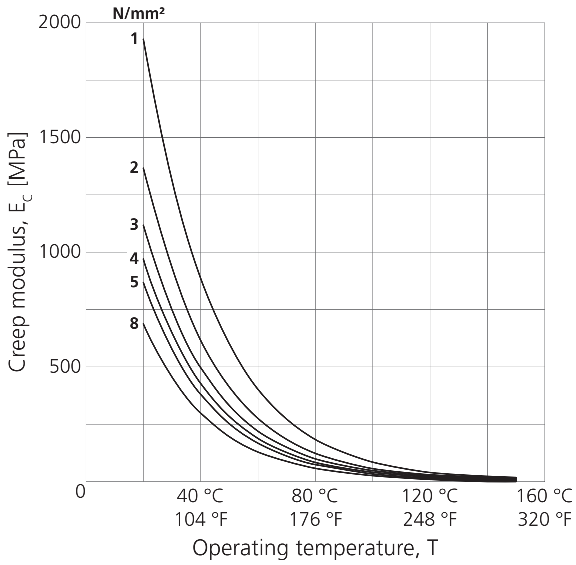


Figure A.13: Creep modulus of ECTFE for 10 year.

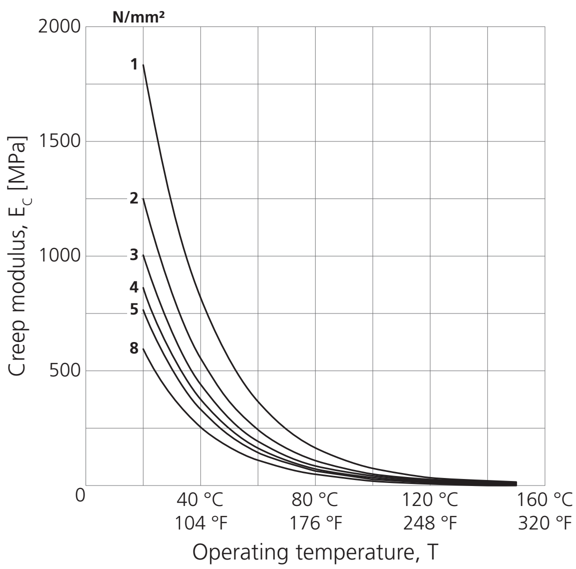


Figure A.14: Creep modulus of ECTFE for 25 year.

4.13.1 Reduction of the creep modulus

In the stated diagram the calculated creep modulus has to be reduced by a safety coefficient of ≥2.0 for stability calculations.

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

5 PVDF-Vent

5.1 General properties

This system is a unique solution for corrosive gases in the semiconductor, pharmaceutical and chemical industry. The superior chemical resistance of this product allows the transport of corrosive gases even at elevated and high temperatures.

In the semiconductor industry more than 200 different chemicals and gases are used per day. These chemicals are used for different applications including:

- Epitaxy
- Cleaning
- Photolithography
- Etching
- Polishing

The exhaust duct handles gases from almost all of the aggressive chemicals used. The high chemical resistance of the PVDF exhaust system means that it can be applied in the area of solvent, acid and basis exhaust systems.

5.2 Material grade

PVDF is obtained by the polymerisation of vinylidene fluoride and corresponds to the following chemical structure:

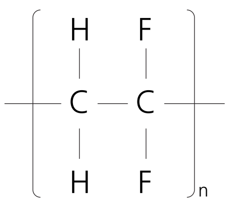


Figure A.15: Chemical structure of PVDF-Vent.

5.3 Fire resistance

PVDF-Vent is a halogen containing polymer which offers an excellent fire protection without flame retardant additives. During combustion of PVDF-Vent only a slight amount of smoke development arises. With a low oxygen index, PVDF-Vent received the highest flammability classification V0 according to UL-94.

5.4 Advantages of PVDF

- Wide application temperature range (-20 °C to +140 °C / -4 °F to +284 °F)
- High heat deflection temperature
- Very good chemical resistance, even at high temperatures
- Good resistance against UV and gamma (γ) radiation
- Very good surface quality
- High ageing resistance
- Good thermal stability
- Excellent abrasion resistance
- Very good anti-friction properties
- Good mechanical properties
- Excellent insulation characteristics
- Flame retardant
- AGRUVENT PVDF products are indicated as FM approval listed 4910 cleanroom material
- Good and simple processability
- Low permeability
- Fast and easy installation
- Connections are done by leak proof heat fusion or detachable joints
- Light weight / reduced investment for support system
- High lifetime / durability

5.5 Material properties

The figures given below are common values for PVDF-Vent material.

	Properties	Condition	Standard	Units	Values
Physical	Specific density	23 °C (73.4 °F)	ISO 1183	g / cm³	1.78
	Melt flow rate (MFR)	230 °C/5 kg	ISO 1133	g / 10 min	6 - 24
Mechanical	Tensile stress at yield	50 mm/min	ISO 527	MPa	50
	Elongation at yield	50 mm/min	ISO 527	%	9
	Elongation at break	50 mm/min	ISO 527	%	80
	Impact strength unnotched	23 °C (73.4 °F)	ISO 179	kJ / m²	124
	Impact strength notched	23 °C (73.4 °F)	ISO 179	kJ / m²	11
	Ball indentation hardness according to Rockwell	23 °C (73.4 °F)	ISO 2039-1	MPa	80
	Flexural strength	23 °C (73.4 °F)	ISO 178	MPa	80
	Modulus of elasticity		ISO 527	MPa	2000
Thermal	Vicat softening point	VST/B/50	ISO 306	°C °F	140 284
	Heat deflection temperature	HDT/B	ISO 75	°C °F	145 293
	Linear thermal expansion coefficient		DIN 53752	$K^{-1} \times 10^{-4}$	1.2
	Thermal conductivity	20 °C (68 °F)	DIN 52612	W / (m × K)	0.20
	Flammability		UL94	-	V-0
Electrical	Specific volume resistance		DIN 53482	Ω · cm	$\geq 10^{13}$
	Specific surface resistance		DIN 53482	Ω	$\geq 10^{12}$
	Relative dielectric constant	1 MHz	DIN 53483	-	7.25
	Dielectric strength		DIN 53481	kV / mm	22
	Physiologically nontoxic		EEC 90/128		yes
	UV resistance				yes
	Colour				natural

Table A.12: Material properties of PVDF-Vent.

5.6 Permissible buckling pressure PVDF-Vent

Temperature [°C]	Temperature [°F]	Operating period [yr]	OD 63 mm OD 2″ s = 2.5 mm [Pa]	OD 63 mm OD 2″ s = 2.5 mm [psi]	OD 110 mm OD 4″ s = 3 mm [Pa]	OD 110 mm OD 4″ s = 3 mm [psi]	OD 140 mm OD 5″ s = 3 mm [Pa]	OD 140 mm OD 5″ s = 3 mm [psi]	OD 160 mm OD 6″ s = 3 mm [Pa]	OD 160 mm OD 6″ s = 3 mm [psi]	OD 200 mm OD 8″ s = 3 mm [Pa]	OD 200 mm OD 8″ s = 3 mm [psi]
20	68	1	66485	9.64	20768	3.01	9894	1.43	6574	0.95	3328	0.48
		10	61052	8.85	19070	2.76	9085	1.31	6037	0.87	3056	0.44
		25	58814	8.53	18371	2.66	8752	1.26	5816	0.84	2944	0.42
30	86	1	59453	8.62	18571	2.69	8848	1.28	5879	0.85	2976	0.43
		10	53700	7.78	16774	2.43	7991	1.15	5310	0.77	2688	0.38
		25	52102	7.55	16275	2.36	7754	1.12	5152	0.74	2608	0.37
40	104	1	52421	7.60	16374	2.37	7801	1.13	5183	0.75	2624	0.38
		10	47946	6.95	14977	2.17	7135	1.03	4741	0.68	2400	0.34
		25	46028	6.67	14378	2.08	6850	0.99	4551	0.66	2304	0.33
50	122	1	46028	6.67	14378	2.08	6850	0.99	4551	0.66	2304	0.33
		10	41553	6.02	12980	1.88	6184	0.89	4109	0.59	2080	0.30
		25	39636	5.74	12381	1.79	5898	0.85	3919	0.56	1984	0.28
60	140	1	39636	5.74	12381	1.79	5898	0.85	3919	0.56	1984	0.28
		10	35800	5.19	11183	1.62	5328	0.77	3540	0.51	1792	0.25
		25	33882	4.91	10583	1.53	5042	0.73	3350	0.48	1696	0.24
70	158	1	33882	4.91	10583	1.53	5042	0.73	3350	0.48	1696	0.24
		10	30046	4.35	9385	1.36	4471	0.64	2971	0.43	1504	0.21
		25	28128	4.07	8786	1.27	4186	0.60	2781	0.40	1408	0.20
80	176	1	29407	4.26	9186	1.33	4376	0.63	2908	0.42	1472	0.21
		10	25571	3.70	7988	1.15	3805	0.55	2529	0.36	1280	0.18
		25	23653	3.43	7388	1.07	3520	0.51	2339	0.33	1184	0.17
90	194	1	24293	3.52	7588	1.10	3615	0.52	2402	0.34	1216	0.17
		10	21096	3.05	6590	0.95	3139	0.45	2086	0.30	1056	0.15
		25	19498	2.82	6090	0.88	2902	0.42	1928	0.27	976	0.14
100	212	1	20457	2.96	6390	0.92	3044	0.44	2023	0.29	1024	0.14
		10	17900	2.59	5591	0.81	2664	0.38	1770	0.25	896	0.12
		25	16302	2.36	5092	0.73	2426	0.35	1612	0.23	816	0.11
110	230	1	16941	2.45	5292	0.76	2521	0.36	1675	0.24	848	0.12
		10	14704	2.13	4593	0.66	2188	0.31	1454	0.21	736	0.10
		25	13105	1.90	4094	0.59	1950	0.28	1296	0.18	656	0.09
120	248	1	14384	2.08	4493	0.65	2141	0.31	1422	0.20	720	0.10
		10	13425	1.94	4193	0.60	1998	0.28	1327	0.19	672	0.09
		25	11827	1.71	3694	0.53	1760	0.25	1169	0.16	592	0.08

Table A.13: Permissible buckling pressure of PVDF-Vent (part 1).

1 bar = 100,000 Pa

The permissible buckling pressure stated in the table was determined based on a safety coefficient of C = 2.0.

These buckling pressures have to be reduced by the corresponding reducing coefficients for aggressive chemicals (f_{CR}).

Buckling loads can be caused by external pressure, e.g. soil and ground water pressure or internal vacuum. The values given in the table are stated for the relative buckling pressure.

Temperature		Operating period	Permissible buckling pressure PVDF-Vent							
			OD 250 mm OD 10"		OD 315 mm OD 12"		OD 355 mm OD 14"		OD 400 mm OD 16"	
			s = 3 mm		s = 4 mm		s = 4 mm		s = 5 mm	
[°C]	[°F]	[yr]	[Pa]	[psi]	[Pa]	[psi]	[Pa]	[psi]	[Pa]	[psi]
20	68	1	1688	0.24	2005	0.29	1395	0.20	1911	0.27
		10	1550	0.22	1841	0.26	1281	0.18	1755	0.25
		25	1493	0.21	1773	0.25	1234	0.17	1691	0.24
30	86	1	1510	0.21	1793	0.26	1247	0.18	1709	0.24
		10	1364	0.19	1619	0.23	1126	0.16	1544	0.22
		25	1323	0.19	1571	0.22	1093	0.15	1498	0.21
40	104	1	1331	0.19	1581	0.22	1100	0.15	1507	0.21
		10	1218	0.17	1446	0.20	1006	0.14	1378	0.19
		25	1169	0.16	1388	0.20	965	0.14	1323	0.19
50	122	1	1169	0.16	1388	0.20	965	0.14	1323	0.19
		10	1055	0.15	1253	0.18	872	0.12	1194	0.17
		25	1006	0.14	1195	0.17	831	0.12	1139	0.16
60	140	1	1006	0.14	1195	0.17	831	0.12	1139	0.16
		10	909	0.13	1080	0.15	751	0.10	1029	0.14
		25	860	0.12	1022	0.14	711	0.10	974	0.14
70	158	1	860	0.12	1022	0.14	711	0.10	974	0.14
		10	763	0.11	906	0.13	630	0.09	864	0.12
		25	714	0.10	848	0.12	590	0.08	809	0.11
80	176	1	747	0.10	887	0.12	617	0.08	845	0.12
		10	649	0.09	771	0.11	536	0.07	735	0.10
		25	601	0.08	713	0.10	496	0.07	680	0.09
90	194	1	617	0.08	733	0.10	510	0.07	698	0.10
		10	536	0.07	636	0.09	442	0.06	606	0.08
		25	495	0.07	588	0.08	409	0.05	560	0.08
100	212	1	519	0.07	617	0.08	429	0.06	588	0.08
		10	455	0.06	540	0.07	375	0.05	515	0.07
		25	414	0.06	492	0.07	342	0.04	469	0.06
110	230	1	430	0.06	511	0.07	355	0.05	487	0.07
		10	373	0.05	443	0.06	308	0.04	423	0.06
		25	333	0.04	395	0.05	275	0.03	377	0.05
120	248	1	365	0.05	434	0.06	302	0.04	413	0.05
		10	341	0.04	405	0.05	282	0.04	386	0.05
		25	300	0.04	357	0.05	248	0.03	340	0.04

Table A.14: Permissible buckling pressure of PVDF-Vent (part 2).

1 bar = 100,000 Pa

The permissible buckling pressure stated in the table was determined based on a safety coefficient of C = 2.0.

These buckling pressures have to be reduced by the corresponding reducing coefficients for aggressive chemicals (f_{CR}).

Buckling loads can be caused by external pressure, e.g. soil and ground water pressure or internal vacuum. The values given in the table are stated for the relative buckling pressure.

6 Leach out behaviour

Many factors of an UPW piping system can influence the quality of the water. This article aims to stress the effect of leach out rate on UPW quality and the many myths and misconceptions about test methodology.

Over the past 20 years AGRU has concentrated its efforts in testing and verifying the leach out behaviour of different materials. In addition extensive studies at various labs and institutes have been conducted to verify the influence of leach out due to such factors as manufacturing processes, installation techniques and testing methods. These studies which continue to go on verify that leach out testing is greatly influenced by:

- Sample preparation
- Sample design/volume
- Sample method
- Testing environment
- Analytical interpretation
- Test temperature

Existing industry testing standards and specifications do not provide test data that allows for comparative analysis to be conducted. For this reason, users should request detailed information about the test procedures and samples set up before comparing published test data.

If the test conditions are similar, the test provides comparative data to verify the quality levels of products and materials. In practical installations, the leach out behaviour is much lower than static leach out behaviour shows, since leach out is influenced by the surface contact time of the UPW. The surface contact time in a dynamic system is dependant upon the volume of water and therefore, pipe dimension and velocity are major factors.

6.1 SEMI Standard

SEMI is the global industry association serving the manufacturing supply chain for the microelectronics and nanoelectronics industries. The SEMI standard F57-0312 specifies the purity requirements and the mechanical requirements for ultra high purity polymers and references for qualification test methods.

6.1.1 Static leach out test

Static leach out tests provide valuable information on a material's purity. Static tests provide a worst case scenario since the test water is stagnant during the entire test. These tests are useful in comparing materials, but do not simulate an actual installation. When comparing this data to other materials, ensure the test methods and result units are identical. Results will vary based on the test method.

The leach out test consists of the following steps. After pre-cleaning suitable polymer test samples according to SEMI F40-0699E are filled with UPW (ultra pure water). After the defined soak time (7 days at 85 °C ±5 °C / 185 °F ±41 °F) the UPW is analysed. The detected compounds are calculated to µg/m² of inner surface of the test sample and compared with the SEMI F57-0312 document.

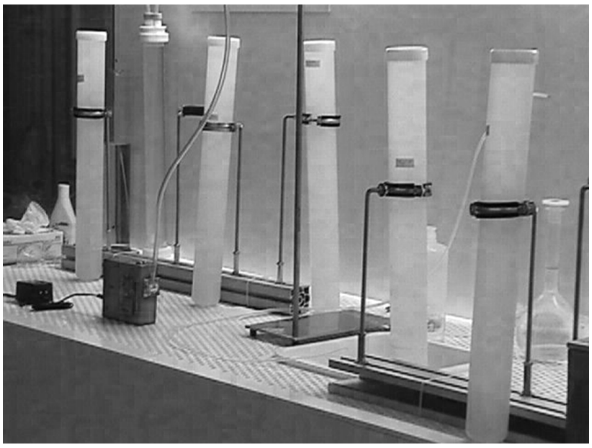


Figure A.16: Sample set-up.

To avoid any environmental contamination, the laboratory environment is airborne molecular contamination (AMC) controlled. During the whole preparation process, the flushing, the filling and the measuring process, the polymer components never leave the ISO class 5 clean room environment according to EN ISO 14644-1:1999 (D).

For latest values of the leach out test please contact anwt@agru.at.

7 Product surface roughness

Surface roughness can have a significant influence upon the quality of the conveyed media.

The smooth surface of AGRU UHP components are achieved by applying specially designed and designated manufacturing equipment and tooling. The use of mirror finished tools made of special material for injection moulding and extrusion have a significant influence upon the surface quality of final products. AGRU constantly monitors the surface quality during production of UHP components, whereby the surface roughness (R_a values) and micropores are measured. These tests, which are performed on a statistical basis, are providing an excellent indication on the quality of the manufacturing process.

The surface quality has been significantly improved for the PVDF-UHP material grade.

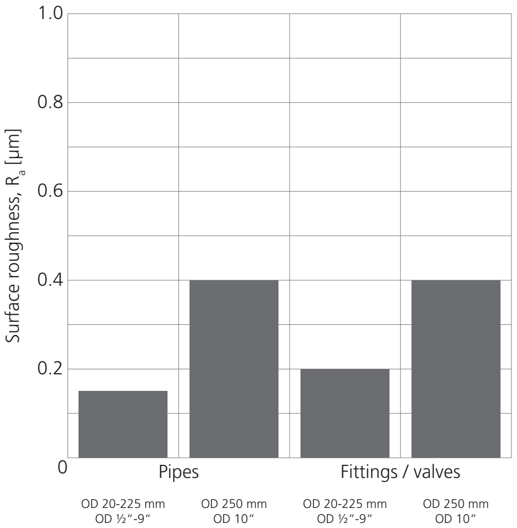


Figure A.17: Surface specification for PVDF-UHP products.

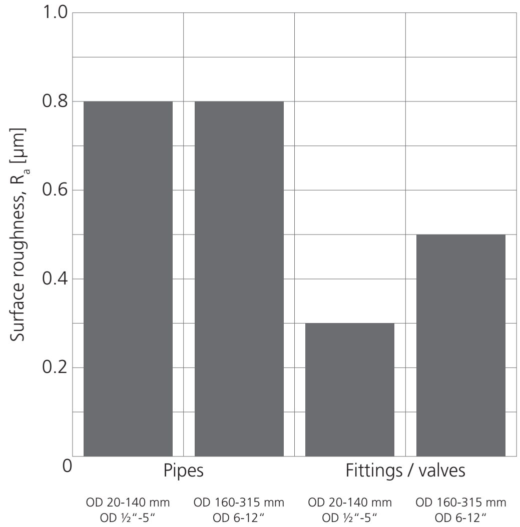


Figure A.18: Surface specification for PP-Pure products.

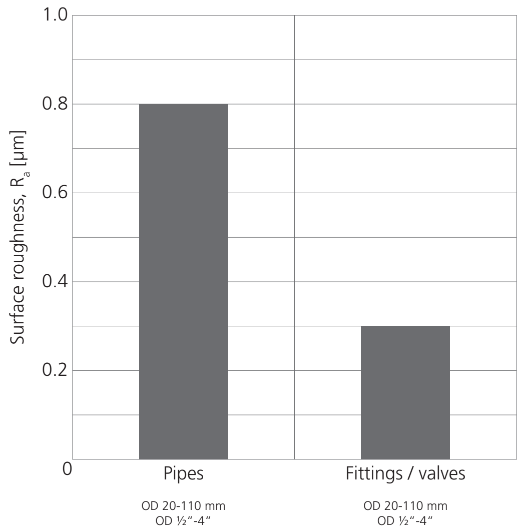


Figure A.19: Surface specification for Polypure products.

Beside this consistent control, surface analyses in accordance with SEMATECH 92010952B-STD and interferential microscopy are performed by independent laboratories.

	PVDF-UHP	PP-Pure
	OD 63 mm OD 2"	OD 63 mm OD 2"
	SDR 21	SDR 11
Z_{max} [nm]	818	1134
RMS [nm]	100	103
R_a [nm]	79	79
SA-Index	17	22

Table A.15: Surface roughness reference values.[1)]

1) PVDF: M+W Zander Report No. 020115be
PP-Pure: M+W Zander Report No. 031010ae

B Production and packaging

1 Production

1.1 Pipe production

1.1.1 PVDF-UHP

AGRU PVDF-UHP piping is produced from ultra pure virgin PVDF raw material. The dimensional range from 20 mm to 315 mm (½" to 12") are manufactured in cleanroom ISO class 5, on dedicated extrusion equipment. Pressure range: SDR 21 and SDR 33. The extrusion lines are especially equipped and adapted for the production of UHP components in cleanroom area.

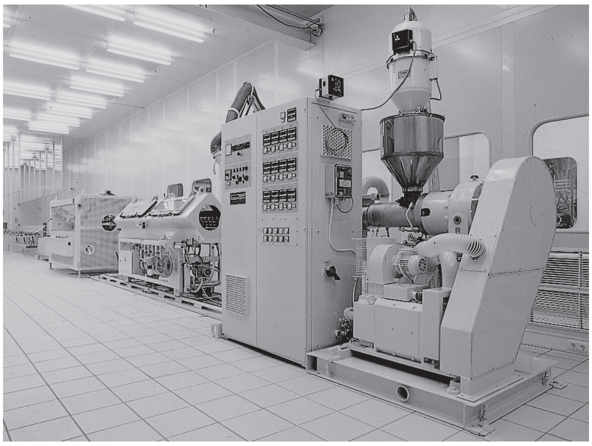


Figure B.1: Pipe extruder.

1.1.2 PP-Pure and Polypure

AGRU PP-Pure and Polypure pipes are made out of virgin PP-R raw material on specifically designated production lines. The manufacturing for the dimensional range 20 mm to 315 mm (½" to 12") in SDR 11 is performed under clean environment, whereby a laminar flow box ISO class 6 is integrated in the production line.

1.1.3 ECTFE

AGRU ECTFE pipes are produced from virgin ECTFE raw material. The pipes are available in two pressure classes. The pressure pipes SDR 21 from 20 mm to 110 mm (½" to 4") and the ventilation pipes are available in the dimensions 110 mm (4") and 160 mm (6").

1.2 Fitting and valve production

Fitting and valve production techniques and facilities are dependent on the materials to be moulded. PVDF-UHP and ECTFE fittings and valves are produced on dedicated moulding machines using virgin material in a cleanroom ISO class 5 environment. The material specialised moulds are utilised to provide the required surface quality.

PP-Pure and Polypure fittings and valves are manufactured out of PP-R raw material in a clean environment on designated moulding equipment.

Figure B.2: Moulding machine for fittings.

Machining of injection moulded components is necessary to remove sprues and finish the sealing surfaces on items such as unions or stub ends.

After machining, all UHP fittings and valves are cleaned in an automated cleaning facility. The cleaning process is performed in a cleanroom ISO class 5 environment. The process is fully automated.

In the cleaning facility, the fittings and valves are rinsed for minimum 60 minutes with UPW (quality: TOC <10 ppb, conductivity >18 MΩ at an elevated temperature >70 °C (158 °F)). After drying with hot clean air and a 100 % inspection, the valves are assembled. All fittings and valves are double packed under a cleanroom environment ISO class 5.

2 Packaging

2.1 Packaging of pipes

All PVDF-UHP pipes are immediately packaged after production in a cleanroom environment ISO class 5. Pipes are sealed on both ends with a PE film and closed with PE caps. The pipe is then sleeved into a PE bag and heat sealed on both ends. Finally the packed pipes are put into a rigid PE tube, which is non-particle generating and resistant to moisture and impacts for transport and shipment.

Figure B.3: PVDF-UHP pipe packaging.

PP-Pure pipes are packed immediately after the production under laminar flow box ISO class 6 environment. The pipe ends are capped and sleeved into a transparent PE bag and heat sealed on both ends. Additionally, the pipes are sleeved in a second PE bag with following quantities (see Table B.1) and the bag is heat sealded again on both sides.

Polypure pipes are packed immediately after the production under laminar flow box ISO class 6 environment. The pipe ends are capped and sleeved into a transparent PE bag according packaging unit (see Table B.1) and heat sealed on both ends.

ECTFE pipes are packed immediately after the production in a clean environment. The pipe ends are capped and sleeved in transparent PE bag according to the packaging unit (see Table B.1) and heat sealed on both sides. The dimensions 110 mm (4") or bigger are additionally put into a rigid PE protection tube.

Dimension		Quantity
[mm]	[inch]	[pcs]
20	½"	5
25	¾"	4
32	1"	3
40 - 315	1 ¼" - 12"	1

Table B.1: Packaging units for PVDF-UHP, PP-Pure, Polypure and ECTFE.

2.2 Packaging of fittings and valves

The PVDF-UHP, PP-Pure, Polypure and ECTFE diaphragm and T-diaphragm valves are cleaned and assembled in cleanroom ISO class 5 environment. To guarantee a 100 % leak-proof valve, they are assembled according to the internal procedures and torque values and kept in the cleanroom for minimum 24 hours. The valves are then checked again and the bonnet bolts are retorqued. Packaging is done as following:

- PVDF-UHP:
  After production and machining, the fittings/valves are 100 % inspected and cleaned/rinsed with UPW water. All fittings/valves are packed in a ISO class 5 cleanroom area. Fittings/valves are double packed in PE bags. The first bag is purged with nitrogen. Finally, the packed fittings/valves are put into cardboard boxes for transport.

Figure B.4: Cleanroom assembly and packaging for fittings/valves.

Production and packaging

- PP-Pure:
  After production and machining of the injection gates, the fittings/valves are 100 % inspected and cleaned/rinsed with UPW water. All fittings/valves are packed in a ISO class 5 cleanroom area. Fittings/valves are double packed in PE bags. The first bag is purged with nitrogen. Finally, the packed fittings/valves are put into cardboard boxes for transport.
- Polypure:
  After production and machining of the injection gates, the fittings/valves are 100 % inspected and cleaned/rinsed with UPW water. In a ISO class 5 cleanroom area, all fittings and valves are single packed in PE bags. Finally, the packed fittings/valves are put into cardboard boxes for transport.
- ECTFE:
  Fittings and valves are single packed in PE bags. Fittings and valves are finally put in cardboard boxes for transport.

Figure B.5: PVDF-UHP fitting packaging.

C Applications

Applications

1 Overview

The PURAD system is applicable in many areas and has been successfully utilised for more than 20 years.

- **Microelectronic industry:**
  - Semiconductor factories (logic, DRAM, flash, MEMS, ...)
  - Display factories (LCD, PDP, TFT, LED, OLED, ...)
  - Solar cell production fabs (PV, ...)
  - LED, OLED production facilities
  - Printed circuit board production (PCB)

- **Life science industry:**
  - Pharmaceutical industry
  - Biotechnology laboratories
  - Research facilities
  - Hospitals
  - Dialysis laboratories

- **Food and beverage industry**

- **Dairies**

- **Ultra pure and pure water systems** in power plants and other industries (e.g. petrochemical industry, …)

- **High purity chemical distribution piping**

Figure C.1: Polypure application.

Figure C.2: PVDF-UHP application.

Figure C.3: PVDF-UHP application.

Figure C.4: PP-Pure application.

2 Most popular applications

The following tables show an overview of various applications for PURAD piping systems.

Microelectronic industry	PVDF-UHP	PP-Pure	Polypure	ECTFE	PVDF-Vent
UPW plant interconnection piping	•	•	•		
Cold UPW supply line	•	•			
Hot UPW supply line	•			•	
Hot / cold UPW return line	•	•			
CMP slurry systems		•	•		
Hook up installations	•	•	•		
Reclaim systems		•			
Chemical distribution systems	•	•	•	•	
Pipes in wet stations and process equipment	•	•	•	•	
Ventilation piping systems					•
Exhaust piping systems				•	•

Table C.1: Microelectronic industry applications.

Life science	PVDF-UHP	PP-Pure	Polypure	ECTFE	PVDF-Vent
PW systems (purified water)	•	•	•		
hPW, WFI systems (water for injection)	•				
DI water supply lines	•	•	•		
Clean in place systems	•	•	•	•	
Ventilation piping systems					•
Exhaust piping systems				•	•

Table C.2: Life science applications.

Food and beverage industry	PVDF-UHP	PP-Pure	Polypure	ECTFE	PVDF-Vent
Process piping systems	•	•	•	•	
PW systems (purified water)	•	•	•		

Table C.3: Food and beverage industry applications.

Dairy industry	PVDF-UHP	PP-Pure	Polypure	ECTFE	PVDF-Vent
Transport line for milk	•	•	•		

Table C.4: Dairy industry applications.

D Design and calculation guide

1 High purity system design

The critical factor in a high purity system is to design it in a continuous loop without dead legs in order to avoid the possibility of microorganismic growth. PVDF-UHP, PP-Pure, Polypure and ECTFE are ideally suitable for pure water as they have extremely smooth surfaces that reduce particle generation and inhibit sites for bacteria to adhere to and proliferate.

In designing a thermoplastic high purity water system the following issues need to be considered:

- System selction
- Pipeline materials
- Operating parameters
- System sizing
- Thermal expansion and contraction
- Minimise dead leg areas

1.1 System selction

There should be only a minimum of welds and fittings. In unavoidably low pipeline sections install drain valves.

Unless otherwise agreed, install valves in all elevated or low pipeline sections. Ventilating valves and drain valves should be furnished with a plug or cap on the discharge side.

The number of detachable connections (flanges, screwed connections) should be minimised. Welded connections are preferable to detachable connections.

Apply cleaned flange gaskets (e.g. cleaned and packed Seal Clean ePTFE gaskets), realising an efficient sealing appropriate for plastic with low torque value.

The system should be protected from backflow/back strokes.

Pay attention to a vibration-reduced installation of the pumps.

1.2 Pipeline materials

PVDF is the premier material for high purity water systems. PVDF has been used in ultra pure water systems for over 25 years because it is superior to materials such as stainless steel or PVC. PVDF combines an excellent surface quality with low extractables to provide the highest quality piping material for the application. In addition to its purity attributes, PVDF is also available in a variety of components and welding methods that are perfectly suitable for UPW applications. PVDF is a crystalline material that can withstand high pressures.

For applications less stringent in water quality level, polypropylene is an excellent alternative. PP offers excellent surface smoothness as well as low extractable levels. Polypropylene systems are thermally fused together, eliminating the use of glues, that leach into the water system for an extended period of time. PP can easily be welded, making joints simple and reliable.

The third alternative is ECTFE. This material, also known as Halar®, provides a superior surface even compared to PVDF. Its extraction levels are also similar to that of PVDF. Halar® is a very ductile material, making its use and welded connections extremely reliable. ECTFE shows a remarkable hardiness and excellent chemical resistance to most organic and inorganic chemicals (pH 0 to 14) as well as solvents.

For more information on chemical resistance refer to the chemical resistance table on www.agru.at or contact anwt@agru.at.

1.3 Operating parameters

Thermoplastic piping systems can be selected by knowing the following operating parameters.

- Continuous operating temperature
- Continuous operating pressure
- Media and concentration

Compare the actual conditions to the allowed ratings of the material being selected for the job. It is important to predict elevated temperatures, as thermoplastics have reduced pressure ratings at higher temperatures. Valves should be verified in terms of temperature and pressure separately from the piping system, as certain styles and brands of valves have lower ratings than the pipe system. Finally, if the media is not water, a chemical compatibility check should be conducted with the manufacturer. After verifying the standard operating conditions, it is necessary to examine other conditions that might affect the piping system. The following FAQs are an example of issues that need to be investigated prior to specifying a material.

- Will there be temperature peaks?
- Will there be pressure peaks?
- Will there be cleaning processes to which the piping will be exposed to?
  - If yes, what is the cleaning agent?
  - How high will the concentration be?
  - At which temperature will the cleaning be conducted?
- Will the system be exposed to sunlight or other sources of UV?

Each of the above questions should be answered and the desired material should be checked for suitability based on the above factors as well as any others that are specific for the system in question.

1.4 System sizing

It is well known that high purity water systems are designed to operate in a continuously flowing loop to prevent stagnant water in the system. Stagnant water can proliferate the growth of bacteria and bio-film. The pattern and design of the loop will vary depending on the facility requirements. The flow rate in the system is important in determining the pipe's size (diameter). In a pure water system, elevating flow velocities is recommended to reduce the possibility of bio adhesion to the pipe wall or welded surfaces. The flow should be set at a minimum of 0.5 to 1.0 m/s for the suction side and between 1.0 to 3.0 m/s for the pressure side.

Main lines are dimensioned for the water demand needed for the tool supply lines, the tools themselves and the return lines/bypasses at a minimum flow. The tool demand can be calculated by taking the average flow demanded and multiplying it by 1.2 to 1.8 to include the peak demand. This should be based on the tool manufacturer's parameters.

1.5 Thermal expansion and contraction

Typically PVDF-UHP, PP-Pure and Polypure systems are designed for ambient or cold DI water. In these cases, the systems operate continuously and are usually located inside buildings with a fairly constant temperature level. Thus, there is no need to compensate thermal expansions, although it is an important factor that should be reviewed on each and every installation design.

Hot DI systems normally operate at temperatures of 65 °C to 120 °C, depending on the water usage, and require a more complex design. PVDF and ECTFE piping systems can be used in hot water applications and applications where temperature changes are given. These systems require analysis of the thermal expansion effects. This chapter guides through the steps of calculating thermal expansions, anchor loads and expansion compensating devices.

In most cases the use of expansions, offsets and proper hanging techniques are all that is required to ensure a proper design.

Hot DI systems also reduce the rigidity of thermoplastic piping systems, which in turn decreases the support distance between pipe hangers. At smaller dimensions, it is recommended to use continuous support to increase the support distance.

Finally, the use of hangers as guides and anchors becomes important. Certain hangers should be used as guides to allow the pipe to move back and forth in line, while restrained fittings should be anchoring locations used to direct the expansion into the compensating device. The anchors and hangers should be designed to withstand the anchor load generated by the thermal expansion.

1.6 Minimise dead leg areas

The term dead leg refers to a stagnant zone of water in the system. Dead legs are normally formed in the branch of a tee that is closed off with a valve (see Figure D.1).

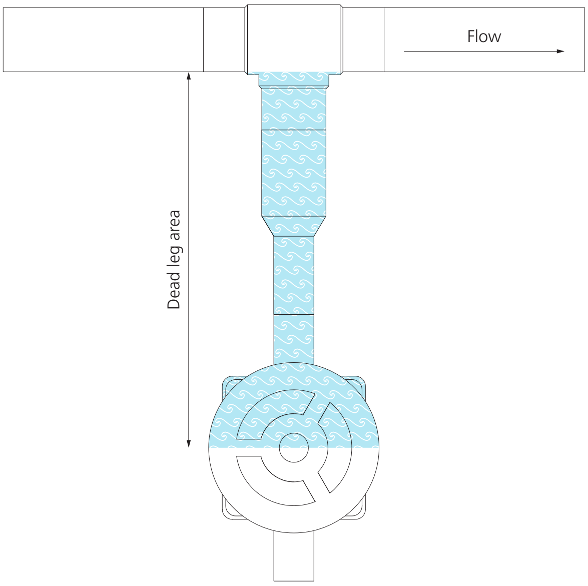


Figure D.1: Dead legs due to a not optimal design.

A rule of thumb in designing a system is to keep all dead legs to a maximum of 3 internal pipe diameters in length. The turbulent flow in the main line will create a significant amount of movement to keep the media in the dead leg moving and prevents bacteria from adhering to the pipe wall. However, the PURAD system allows designers to avoid dead legs altogether with the advent of T-diaphragm valves and zero dead leg fittings. T-valves (see Figure D.2) take the place of a tee, reducer, and diaphragm valve by combining all three in one component. T-valves reduce the quantity of welds in a system as well. By using a T-valve, branch lines can be shut off at any time without creating a dead leg and turned back on without an extensive flush procedure.

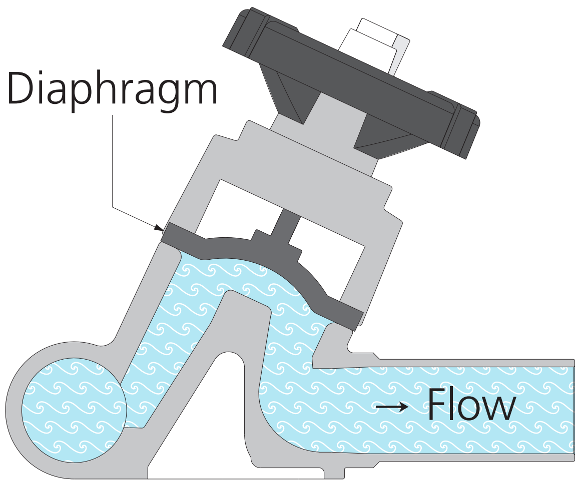


Figure D.2: T-valves reduce dead leg areas significantly.

1.7 AGRU CAD

The AGRU CAD offers a library of all AGRU products which can be used for most CAD software available on the market. 2D and 3D models are available in this edition.

The AGRU CAD can be requested as DVD, the files can be downloaded from our homepage www.agru.at.

This DVD contains the neutral formats DXF 2D and STEP 3D (depending on the manufacturer). Furthermore 66 different CAD formats can be downloaded from our online version.

Figure D.3: AGRU CAD (version E).

2 Sizing a thermoplastic piping system

2.1 SDR rating

The Standard Dimensional Ratio (SDR) is a ratio between the OD of the pipe and the wall thickness.

In general a plastic piping system is determined by the type of material, outside diameter and SDR rating.

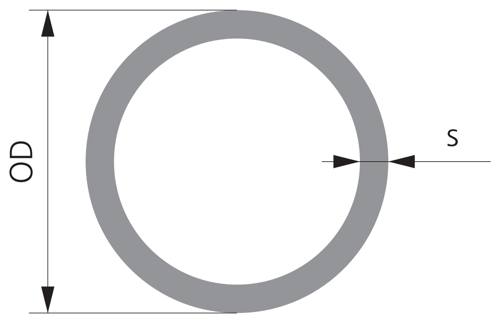


Figure D.4: Pipe dimensions.

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

Formula D.1: SDR.

OD outside diameter [mm]
s wall thickness [mm]
SDR standard dimension ratio [1]

2.2 ISO-S series

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

Formula D.2: ISO-S series.

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

3 Preliminary sizing

The first step in designing a piping system is to decide which diameter to use. If the required flow volume is known, the inside diameter can be calculated with Formula D.3 or Formula D.4. Reference values for the flow velocity are given in Section 4.3.

4 Hydraulic calculations

4.1 Volumetric flow rate

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

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

Formula D.3: Volumetric flow rate.

A free pipe cross section [mm^2]
$\dot{V}$ volumetric flow rate [m^3/h]
v flow velocity [m/s]

4.2 Mass flow rate

It is assumed that for gases and vapours the mass flow rate remains constant. Therefore the equation is as follows:

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

Formula D.4: Mass flow rate.

A free pipe cross section [mm^2]
$\dot{m}$ mass flow rate [kg/h]
ρ density of the medium [kg/m^3]
(dependent on pressure and temperature)
v flow velocity [m/s]

4.3 Inside diameter

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

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

Formula D.5: Inside diameter.

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

Formula D.6: Inside diameter.

ID inside diameter of pipe [mm]
Q_1 conveyed quantity [m^3/h]
Q_2 conveyed quantity [l/s]
v flow velocity [m/s]

Reference values for the calculation of flow velocities of fluids (DVS 2210-1:1997 (D)):

- 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 of gases (DVS 2210-1:1997 (D)):

- v ~ 10 - 30 m/s

4.4 Actual flow velocity

The determined inside diameter should be compared with the available inside diameter from the standard supply program of the piping material. The best suitable dimension should be selected. The actual flow velocity should be recalculated with the new inside diameter with Formula D.7 or Formula D.8 before determining the hydraulic pressure losses.

$$v = 354 \cdot \frac{Q_1}{ID^2}$$

Formula D.7: Actual flow velocity.

$$v = 1275 \cdot \frac{Q_2}{ID^2}$$

Formula D.8: Actual flow velocity.

5 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 inside surface
- Geometry of fittings, valves and finished joints or couplings
- Viscosity and density of the flowing medium
- Type of the flow (laminar or turbulent)

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

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

Formula D.9: Total pressure loss.

Δp_{ges} total pressure loss [bar]
Δp_R pressure loss of straight pipe sections [bar]
Δp_{RA} pressure loss of valves [bar]
Δp_{RF} pressure loss of fittings [bar]
Δp_{RV} pressure loss of joints [bar]

5.1 Pressure loss of straight pipe sections

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

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

Formula D.10: Pressure loss of straight pipe sections.

ID inside diameter of pipe [mm]
L length of piping system [m]
Δp_R pressure loss of straight pipe sections [bar]
λ pipe frictional index [1]
(in most cases $\lambda = 0.02$ is sufficient according to DVS 2210-1:1997 (D))
v flow velocity [m/s]
ρ medium density [kg/m³]

5.2 Pressure loss of fittings

There appear considerable losses regarding friction, deflection and unbonding.

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

Formula D.11: Pressure loss of fittings.

Δp_{RF} pressure loss of fittings [bar]
ζ_{RF} resistance coefficient for fittings [1]
(see Table D.1 and Table D.2)
v flow velocity [m/s]
ρ density of medium [kg/m³]

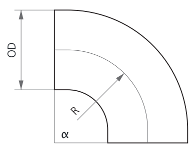
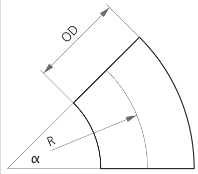
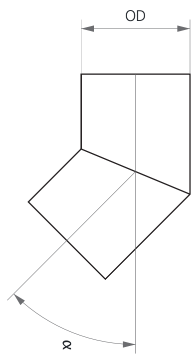
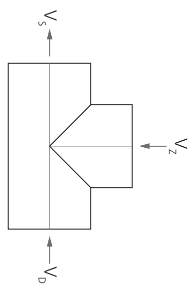
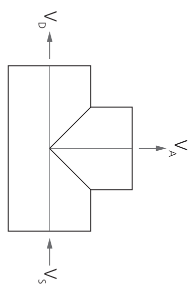
Fitting	Parameter	Resistance coefficient [1]		Design
Bend 90°	R	ζ		
moulded and sweep bend	1.0 × OD	0.51		
	1.5 × OD	0.41		
	2.0 × OD	0.34		
	4.0 × OD	0.23		
Bend 45°	R	ζ		
moulded and sweep bend	1.0 × OD	0.34		
	1.5 × OD	0.27		
	2.0 × OD	0.20		
	4.0 × OD	0.15		
Elbow	α	ζ		
moulded and segmented	45°	0.30		
	30°	0.14		
	20°	0.05		
	15°	0.05		
	10°	0.04		
Tee 90°	V_Z / V_S	ζ_Z	ζ_D	
moulded and segmented	0.0	-1.20	0.06	
	0.2	-0.40	0.20	
(flow merging)	0.4	0.10	0.30	
$V_S = V_D + V_Z$	0.6	0.50	0.40	
	0.8	0.70	0.50	
	1.0	0.90	0.60	
Tee 90°	V_A / V_S	ζ_A	ζ_S	
moulded and segmented	0.0	0.97	0.10	
	0.2	0.90	-0.10	
(flow separating)	0.4	0.90	-0.05	
$V_S = V_A + V_D$	0.6	0.97	0.10	
	0.8	1.10	0.20	
	1.0	1.30	0.35	

Table D.1: Resistance coefficients for fittings ζ_{RF} according to DVS 2210-1:1997 (D) table 9 (part 1).

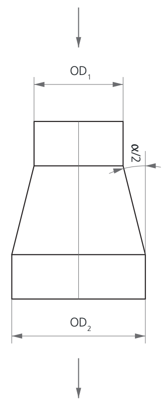
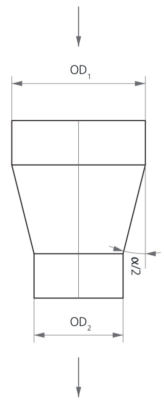
Fitting	Parameter	Resistance coefficient [1]			Design
Reducer	OD_1 / OD_2	4° > α < 8°	α = 16°	α = 24°	
moulded and machined	1.2	0.10	0.15	0.20	
	1.4	0.20	0.30	0.50	
	1.6	0.50	0.80	1.50	
(pipe expansion)	1.8	1.20	1.80	3.00	
	2.0	1.90	3.10	5.30	
ζ values based on λ = 0.025					
Reducer	OD_2 / OD_1	α = 4°	α = 8°	α = 20°	
moulded and machined	1.2	0.046	0.023	0.010	
	1.4	0.067	0.033	0.013	
	1.6	0.076	0.038	0.015	
(pipe constriction)	1.8	0.031	0.041	0.016	
	2.0	0.034	0.042	0.017	
ζ values based on λ = 0.025					

Table D.2: Resistance coefficients for fittings ζ_{RF} according to DVS 2210-1:1997 (D) table 9 (part 2).

V_A outgoing volume flow
V_D remaining volume flow
V_S total volume flow
V_Z additional volume flow
λ_R pipe friction coefficient [1]

Note

- Positive ζ values: pressure drop
- Negative ζ values: pressure rise

5.3 Pressure loss of valves

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

Formula D.12: Pressure loss of valves.

Δp_{RA} pressure loss of valves [bar]
ζ_{RA} resistance coefficient for valves [1] (see Table D.3)
v flow velocity [m/s]
ρ density of medium [kg/m³]

5.3.1 Correlation between K_V and ζ_{RA}

$$\zeta_{RA} = \frac{ID^4}{2.252 \cdot K_{V1}^2}$$

Formula D.13: Resistance coefficient ζ_{RA}.

$$\zeta_{RA} = \frac{ID^4}{625.44 \cdot K_{V2}^2}$$

Formula D.14: Resistance coefficient ζ_{RA}.

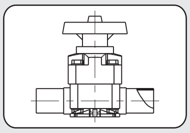
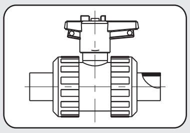
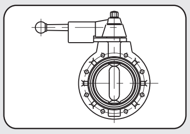
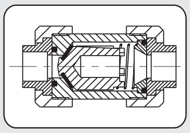
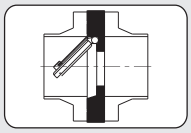
OD		Resistance coefficient ζ_{RA} [1]				
[mm]	[in]	Diaphragm valve	Ball valve	Butterfly valve	Check valve	Swing type check valve
						
32	1"	4.0	0.1 - 0.15	n.a.	2.5	n.a.
40	1¼"	4.2			2.4	1.6
50	1½"	4.4			2.3	1.5
63	2"	4.5		0.3 - 0.6	2.0	1.4
75	2½"	4.7			2.0	1.4
90	3"	4.8			2.0	1.3
110	4"	4.8	n.a.		n.a.	1.2
125	4½"	4.8				1.2
140	5"	4.5				1.0
160	6"	4.1				0.9
180	7"	n.a.				0.9
200	8"					0.8
225	9"					0.8

Table D.3: Resistance coefficients for valves ζ_{RA} according to DVS 2210-1:1997 (D) table 10.

Remark: The resistance coefficients are reference values and are suitable for approximate calculations of the pressure loss. For detailed pressure loss calculation of valves, the ζ_{RA} coefficient can be calculated by knowing the K_V value of the valve.

ID inside diameter [mm]
K_{V1} flow characteristics [l/min]
K_{V2} flow characteristics [m³/h]
ζ_{RA} resistance coefficient for valves [1]

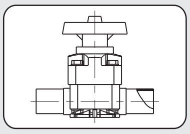
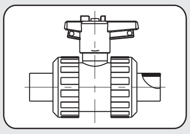
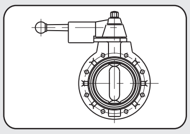
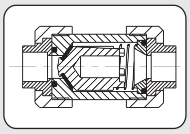
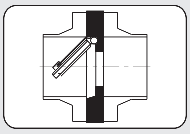
Selection criteria	Assessment				
	Diaphragm valve	Ball valve	Butterfly valve	Check valve	Swing type check valve
					
Flow resistance	high	low	moderate	high	moderate
Opening and closing times	medium	medium	medium	medium	medium
Actuation moment	low	high	moderate	n.a.	n.a.
Wear	moderate	low	moderate	moderate	moderate
Flow regulation	suitable	not very suitable	not very suitable	n.a.	n.a.

Table D.4: Selection criteria for valves according to DVS 2210-1:1997 (D) table 11.

5.4 Pressure loss of joints

It is impossible to give exact information, because types and qualities of joints (welds, unions, flange connections) vary.

It is recommended to calculate a resistance coefficient of ζ_{RV} = 0.1 per joint in a thermoplastic piping system, such as IR, butt and socket welding as well as flanges.

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

Formula D.15: Pressure loss of joints p_{RV}.

Δp_{RV} pressure loss of joints [bar]
ζ_{RV} resistance coefficient for joints [1] (0.1 per joint)
v flow velocity [m/s]
ρ density of medium [kg/m^3]

Once the pressure loss is determined, a pump can be sized to provide the proper flow rate and required pressure at the point of use

6 Flow characteristic (nomogram)

For rough determination of the flow velocity, pressure loss and conveying quantity serves this flow nomogram. At an average flow velocity a certain pipe length has to be added for fittings:

- Up to 20 m pipe length for each
  - Tee
  - Reducer
  - Elbow 90°
- About 10 m pipe length for each
  - Bend 90° (R = 1.0 × OD)
- About 5 m of pipe length for each
  - Bend 90° (R = 1.5 × OD)

This graph enables, based on two given parameters, the determination of the pressure loss. The pressure loss has to be multiplied with the pipe length.

6.1 Example

For the example a PVDF-UHP pipe OD 63 mm SDR 21 has been chosen. Thus the pipe has an inside diameter of ID 57 mm. Furthermore it was assumed that ν = 1.5 m/s.

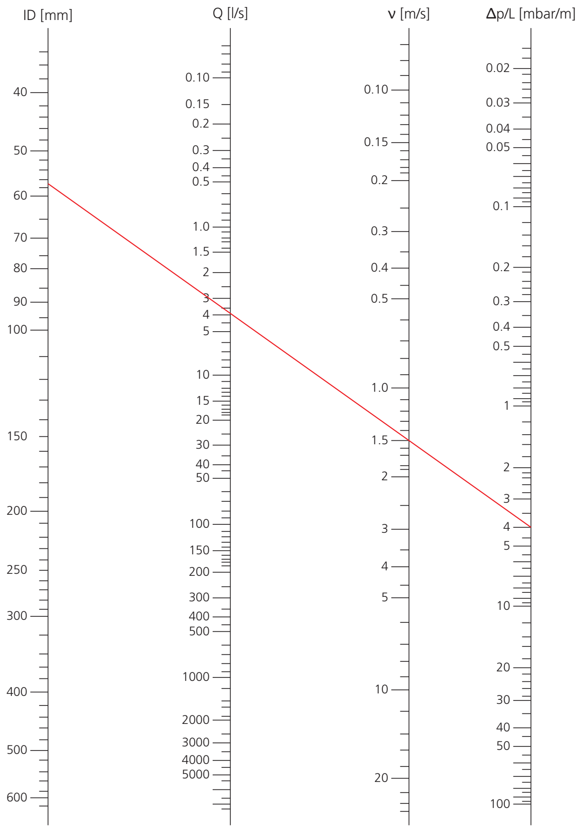


Figure D.5: Flow nomogram example.

After connecting the two value with a straight line the nomogram in our example shows the values for the conveyed quantity Q = 3.8 l/s and the pressure loss per meter pipe length Δp/L = 3.9 mbar/m.

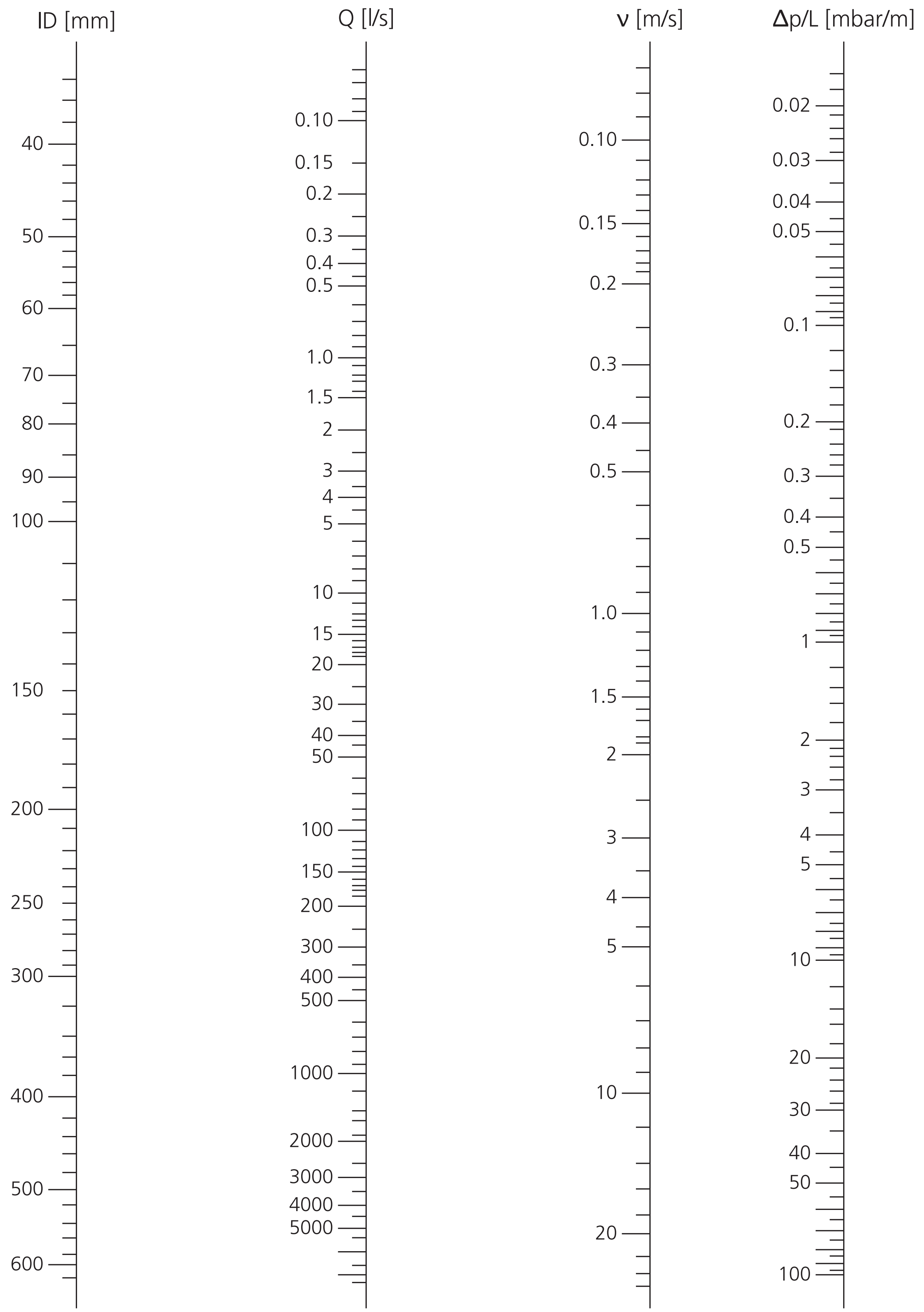


Figure D.6: Flow nomogram.

ID inside diameter of pipe [mm]
Q conveyed quantity [l/s]

Δp/L pressure loss per meter pipe length [mbar/m]
1 mbar = 0,001 bar
ν flow velocity [m/s]

7 Operating pressures

7.1 Component operating pressure

The component operating pressure for different temperatures and operating periods are given in Chapter A:

- PVDF-UHP see Table A.2
- PP-Pure and Polypure see Table A.6
- ECTFE see Table A.10 and Table A.11

For a detailed calculation of the component operating pressure the following formula can be used.

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

Formula D.16: Component operating pressure.

c_{min} minimum safety factor [1] (see Table D.5)
p_B component operating pressure [bar]
SDR standard dimension ratio [1]
σ_v reference stress [N/mm²] (see Figure A.2, Figure A.5 and Figure A.10)

Material	Minimum safety factor c_{min}
PP-Pure & Polypure	1.25
PVDF	1.6
ECTFE	1.6

Table D.5: Minimum safety factor c_{min} according to EN ISO 12162:2009 (D) valid for water and UPW.

For the calculation of the operating pressure in a above ground installed piping systems it is recommended to multiply the value in the table with a system reduction coefficient f_S = 0.8 (this value contains technical installation influences such as welded joints, flanges or also bending loads).

These operating pressures have to be reduced by the corresponding reducing coefficients (Section 7.2) for every application.

7.2 Operating pressure for water-dangerous media

In order to calculate the maximum permissible operating pressure for the conveying of water-dangerous fluids, the operating pressure as an initial value can be looked up in the relevant table for permissible system operating pressures (valid for water only).

Then, this operating pressure has to be reduced by the relevant reducing coefficients and the system reduction factor.The total safety coefficient is thereby in all cases at least 2.0.

$$p_A = \frac{p_B}{f_{AP} \cdot f_{CR} \cdot A_4}$$

Formula D.17: System operating pressure for water-dangerous media.

A_4 reduction factor for the specific strength of the material [1] (see Table D.6)
f_{AP} application factor [1] (see Table D.7)
f_{CR} chemical resistance factor [1] acording to DVS 2205-1:2002 (D)
p_A system operating pressure for water-dangerous media [bar]
p_B component operating pressure [bar]

Material	Reduction factor A_4			
	-10 °C +14 °F	+20 °C +68 °F	+40 °C +104 °F	+60 °C +140 °F
PP-Pure & Polypure	1.5	1.1	1.0	1.0
PVDF	1.6	1.4	1.2	1.0

Table D.6: Reduction factor A_4 according to DVS 2205-1:2002(D).

Material	Application factor f_{AP}
PP-Pure & Polypure	1.6
PVDF	1.25
ECTFE	1.25

Table D.7: Application factors f_{AP}.

8 External pressures (buckling pressures)

In certain cases, piping systems are exposed to external pressure:

- Installation in water or buried below groundwater
- Systems for vacuum, e.g. suction pipes

The buckling pressure for different temperatures and operating periods are given in Chapter A:

- PVDF-UHP see Table A.3
- PP-Pure and Polypure see Table A.7
- PVDF-Vent see Table A.13 and Table A.14

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

Formula D.18: Buckling pressure p_k.

The buckling stress can then be calculated as following:

$$\sigma_k = p_k \cdot \frac{OD - s}{2 \cdot s}$$

Formula D.19: Buckling stress σ_k.

E_C creep modulus for 25 years [N/mm²] (see Figure A.3, Figure A.8, Figure A.14)
OD outside diameter [mm]
p_k critical buckling pressure [bar]
s wall thickness [mm]
μ Poisson's ratio [1] (for thermoplastics generally 0.38)
σ_k buckling stress [N/mm²]

9 Pressure surges in piping systems

A change to the stationary conditions in a pipe system (e.g. when a quick-acting valve is actuated or when pumps are switched on) produces a pressure wave. Reflection at positions where there are changes in direction or cross-section leads to an increase in pressure, which may amount to many times the operating pressure (pressure surge). In order to roughly estimate whether a pipeline is at risk from pressure surges, it is possible to apply the following empirical relation according to DVS 2210-1:1997 (D):

$$K = \frac{L_R \cdot \nu}{\sqrt{H_P}}$$

Formula D.20: Pressure surges.

K pressure surge parameter [1]
L_R length of the pipeline [m]
ν flow velocity [m/s]
H_P delivery head of the pump [m]

Note: For K >70 and with simultaneous use of quick-acting valves, it is recommended to calculate the pressure surges separately. Pressure surge calculations must be made using special computation programs.

10 Calculations for pipe laying

10.1 Support distances

The support distances of thermoplastic piping systems should be determined giving consideration to the permissible bending stress and the limited deflection of the pipe section. For the calculation of the support distances, a maximum deflection of L_A/500 to L_A/750 has been taken as basis. Under consideration of the above deflection of a pipe section between the supporting points, the permissible supporting distance will be calculated with Formula D.21.

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

Formula D.21: Support distance.

E_C creep modulus for 25 years [N/mm²]
f_{LA} factor for the deflection (0,80 ÷ 0,92) [1]
J_R pipe moment of inertia [mm⁴]
L_A permissible support distance [mm]
q line load caused by pipe, filling and additional weight [N/mm]

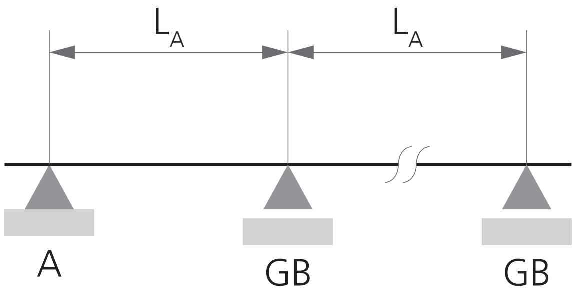


Figure D.7: Support distance.

A anchor / fixed point
GB guide bearing support

Please note that the factor f_{LA} is determined depending on the pipe outside diameter. There is the following relation valid:

$$\min \leftarrow OD \rightarrow \max$$
$$0.92 \leftarrow f_{LA} \rightarrow 0.80$$

Formula D.22: Deflection factor f_{LA}.

10.1.1 Support distances PVDF-UHP

according to DVS 2210-1:1997 (D), table 17

OD		Support distance L_A [mm]								
[mm]	[in]	20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	100 °C	120 °C
		68 °F	86 °F	104 °F	122 °F	140 °F	158 °F	176 °F	212 °F	248 °F
20	½"	850	800	750	750	700	650	600	500	450
25	¾"	950	900	850	800	750	700	675	600	500
32	1"	1100	1050	1000	950	900	850	800	700	600
40	1 ¼"	1200	1150	1100	1050	1000	950	900	750	650
50	1 ½"	1400	1350	1300	1200	1150	1100	1000	900	750
63	2"	1512	1458	1404	1350	1296	1242	1188	1026	864
75	2 ½"	1620	1566	1512	1458	1404	1350	1296	1134	918
90	3"	1728	1674	1620	1566	1512	1458	1404	1188	1026
110	4"	1944	1890	1836	1782	1674	1620	1566	1350	1188
125	4 ½"	2052	1998	1944	1836	1782	1728	1620	1458	1296
140	5"	2160	2106	2052	1944	1890	1836	1728	1566	1350
160	6"	2322	2268	2214	2106	1998	1944	1836	1674	1458
180	7"	2484	2376	2322	2214	2106	2052	1944	1728	1512
200	8"	2592	2538	2430	2322	2268	2160	2052	1836	1620
225	9"	2754	2700	2592	2484	2376	2268	2160	1944	1728
250	10"	2862	2808	2700	2592	2484	2376	2268	2052	1836
280	11"	3078	2970	2862	2754	2646	2538	2430	2160	1944
315	12"	3240	3186	3078	2970	2808	2700	2592	2322	2052

Table D.8: Support distances PVDF-UHP (SDR 21), valid for water only.

OD		Support distance L_A [mm]								
[mm]	[in]	20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	100 °C	120 °C
		68 °F	86 °F	104 °F	122 °F	140 °F	158 °F	176 °F	212 °F	248 °F
90	3"	1600	1550	1500	1450	1400	1350	1300	1100	950
110	4"	1800	1750	1700	1650	1550	1500	1450	1250	1100
125	4 ½"	1900	1850	1800	1700	1650	1600	1500	1350	1200
140	5"	2000	1950	1900	1800	1750	1700	1600	1450	1250
160	6"	2150	2100	2050	1950	1850	1800	1700	1550	1350
180	7"	2300	2200	2150	2050	1950	1900	1800	1600	1400
200	8"	2400	2350	2250	2150	2100	2000	1900	1700	1500
225	9"	2550	2500	2400	2300	2200	2100	2000	1800	1600
250	10"	2650	2600	2500	2400	2300	2200	2100	1900	1700
280	11"	2850	2750	2650	2550	2450	2350	2250	2000	1800
315	12"	3000	2950	2850	2750	2600	2500	2400	2150	1900

Table D.9: Support distances PVDF-UHP (SDR 33), valid for water only.

10.1.2 Support distances PP-Pure and Polypure

according to DVS 2210-1:1997 (D), table 14

OD		Support distance L_A [mm]						
[mm]	[in]	20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C
		68 °F	86 °F	104 °F	122 °F	140 °F	158 °F	176 °F
20	½"	525	506	488	469	450	431	413
25	¾"	600	581	563	544	525	506	488
32	1"	713	694	675	656	638	600	563
40	1 ¼"	825	806	788	750	713	694	656
50	1 ½"	938	919	900	863	825	788	750
63	2"	1088	1069	1050	1013	975	938	900
75	2 ½"	1163	1125	1088	1050	1013	975	938
90	3"	1238	1200	1163	1125	1088	1050	1013
110	4"	1388	1350	1313	1275	1200	1125	1050
125	4 ½"	1500	1463	1425	1350	1275	1200	1125
140	5"	1575	1538	1500	1425	1350	1275	1200
160	6"	1688	1650	1575	1500	1425	1350	1275
180	7"	1763	1725	1650	1575	1500	1425	1350
200	8"	1875	1800	1725	1650	1575	1500	1425
225	9"	1988	1913	1838	1763	1688	1613	1500
250	10"	2100	2025	1950	1875	1800	1725	1613
280	11"	2213	2138	2063	1988	1913	1838	1725
315	12"	2363	2288	2213	2138	2025	1950	1838

Table D.10: Support distances PP-Pure and Polypure (SDR 11), valid for water only.

10.1.3 Support distances ECTFE

OD		Support distance L_A [mm]									
[mm]	[in]	20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	90 °C	100 °C	120 °C
		68 °F	86 °F	104 °F	122 °F	140 °F	158 °F	176 °F	194 °F	212 °F	248 °F
20	½"	590	570	550	530	510	480	460	440	430	380
25	¾"	660	640	620	590	570	540	520	490	480	430
32	1"	780	750	720	690	660	630	610	580	560	500
50	1 ½"	1000	960	930	890	850	810	780	750	720	640
63	2"	1100	1060	1030	990	940	900	860	820	790	710
90	3"	1400	1350	1300	1250	1200	1140	1090	1050	1010	900
110	4"	1610	1550	1490	1440	1370	1310	1250	1200	1160	1040

Table D.11: Support distances ECTFE (SDR21), valid for water only.

OD		Support distance L_A [mm]									
[mm]	[in]	20°C	30°C	40°C	50°C	60°C	70°C	80°C	90°C	100°C	120°C
		68°F	86°F	104°F	122°F	140°F	158°F	176°F	194°F	212°F	248°F
110	4"	1380	1330	1290	1240	1180	1120	1080	1030	990	890
160	6"	1590	1530	1480	1420	1360	1290	1240	1190	1150	1030

Table D.12: Support distances ECTFE (ventilation), valid for water only.

10.1.4 Conversion factors for support distances

For gases and fluids with different densities, the conversion factors shown below should be used.

$$L = L_A \cdot f_1$$

Formula D.23: New support distance.

f_1 conversion factor [1] (see Table D.13)
L new support distance [mm]
L_A permissible support distance (see Table D.8 to Table D.12)

Material	SDR	Conversion factor f_1			
		Media density [g/cm³]			
		Gases	Water	Other media	
		<0.01	1.00	1.25	1.50
PP-Pure Polypure	11	1.30	1.0	0.96	0.92
PVDF-UHP	33	1.48	1.0	0.96	0.92
	21	1.36			
ECTFE	Vent	1.75	1.0	0.93	0.82
	21	1.26			

Table D.13: Conversion factor f_1.

10.2 Changes in length

Changes in length of a plastic piping systems are caused by changes in the operating or test process. The following influence factors are valid:

- Change in length by temperature fluctuation (most important to be considered in a piping design)
- Change in length by internal pressure
- Change in length by chemical effects

10.2.1 Changes in length by temperature fluctuation

If the piping system is exposed to different temperatures (operating temperature versus installation temperature) it changes its length according to the movement possibilities of the individual pipe sections. The distance between two anchors is regarded as one pipe section.

For the calculation of the change in length the following formula is applicable:

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

Figure D.8: Changes in length by temperature fluctuation.

L Pipe length [m]
α Linear expansion coefficient [mm/(m·K)]
ΔL_T Change in length by temperature [mm]
ΔT difference in temperature [K]

The maximum temperature change between the installation temperature and the operation temperature is the basis for the determination of ΔT (positive and negative temperature changes have to be evaluated).

	Linear expansion coefficient α [mm/(m·K)]
PP-Pure & Polypure	0.15
PVDF-UHP	0.12
ECTFE	0.08

Table D.14: Linear expansion coefficient α.

10.2.2 Changes in length by internal pressure

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

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

Formula D.24: Change in length by internal pressure.

L length of pipe section [mm]
p operating pressure [bar]
ΔL_P change in length by internal pressure [mm]
μ Poisson's ratio [1] (for thermoplastics generally 0.38)
E_C creep modulus for 100 minutes [N/mm²]
OD pipe outside diameter [mm]
ID pipe inside diameter [mm]

10.2.3 Changes in length by chemical effects

There may be a change in length (swelling) of thermoplastic piping system as well as an increase of the pipe diameter under influence of certain fluids (e.g. solvents). At the same time, there could be a reduction of the mechanical strength. To ensure a undisturbed operation of the piping systems conveying solvents, it is recommended to take a swelling factor into consideration at the design of the piping system.

$$f_{Ch} = 0.025 \div 0.040$$

Formula D.25: Swelling factor f_{Ch}.

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

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

Formula D.26: Changes in length by chemical influence.

f_{Ch} swelling factor [1]
L length of piping system [mm]
ΔL_{Ch} change in length by chemical effets [mm]

Remark: For application related calculations of thermoplastic piping systems exposed to solvents the f_{Ch} factor has to be determined by specific tests.

10.3 Minimum straight length

Changes in length are caused by changes in operating or ambient temperatures. In installations of piping systems above ground, attention must be paid to ensure 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, expansion loops have to be applied.

The minimum straight length is expressed by:

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

Formula D.27: Minimum straight length.

k material specific proportionality factor [1] (PP = 30; PVDF = 20)
L_S Minimum straight length [mm]
OD pipe outside diameter [mm]
ΔL change in length [mm]

If this cannot be realised, use compensators of low internal resistance. Depending on the construction, they may be applied as axial, lateral or angular compensators.

Between two anchors, 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.

Note: An installation temperature of 20 °C is the basis for the calculation of the k values. At lower 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, fume exhaust).

If possible, do not use any compensators in ultra high purity piping systems.

10.3.1 L expansion layout (change of direction)

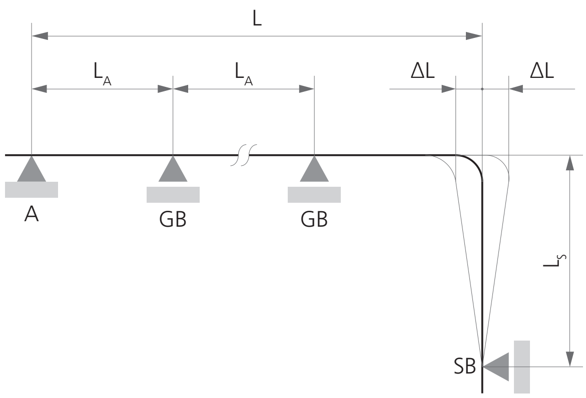


Figure D.9: L expansion layout.

A anchor / fixed point
SB slide bearing support
GB guide bearing support

10.3.2 U expansion layout (expansion loop)

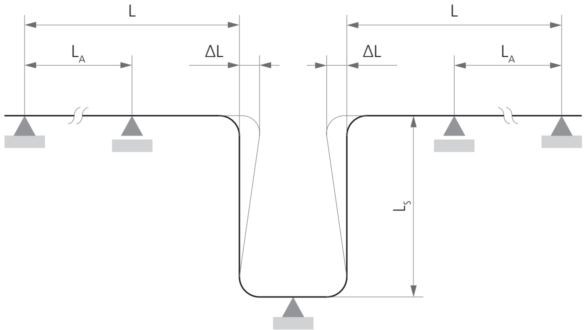


Figure D.10: U expansion layout.

A anchor / fixed point
GB guide bearing support

10.3.3 Z expansion layout (offset)

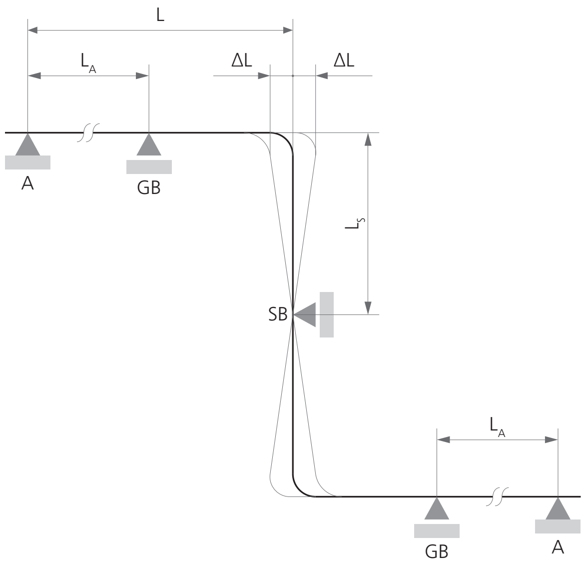


Figure D.11: Z expansion layout.

A anchor / fixed point
SB slide bearing support
GB guide bearing support

10.3.4 Straight lengths

Straight lengths L_S for pipes out of PP-Pure and Polypure depending on the change in length ΔL.

OD		Straight length L_S [mm]								
[mm]	[in]	Change in length ΔL = 50 mm	Change in length ΔL = 100 mm	Change in length ΔL = 150 mm	Change in length ΔL = 200 mm	Change in length ΔL = 250 mm	Change in length ΔL = 300 mm	Change in length ΔL = 350 mm	Change in length ΔL = 400 mm	Change in length ΔL = 500 mm
20	½"	949	1342	1643	1897	2121	2324	2510	2683	3000
25	¾"	1061	1500	1837	2121	2372	2598	2806	3000	3354
32	1"	1200	1697	2078	2400	2683	2939	3175	3394	3795
40	1 ¼"	1342	1897	2324	2683	3000	3286	3550	3795	4243
50	1 ½"	1500	2121	2598	3000	3354	3674	3969	4243	4743
63	2"	1684	2381	2916	3367	3765	4124	4455	4762	5324
75	2 ½"	1837	2598	3182	3674	4108	4500	4861	5196	5809
90	3"	2012	2846	3486	4025	4500	4930	5324	5692	6364
110	4"	2225	3146	3854	4450	4975	5450	5886	6293	7036
125	4 ½"	2372	3354	4108	4743	5303	5809	6275	6708	7500
140	5"	2510	3550	4347	5020	5612	6148	6641	7099	7937
160	6"	2683	3795	4648	5367	6000	6573	7099	7589	8485
180	7"	2846	4025	4930	5692	6364	6971	7530	8050	9000
200	8"	3000	4243	5196	6000	6708	7348	7937	8485	9487
225	9"	3182	4500	5511	6364	7115	7794	8419	9000	10062
250	10"	3354	4743	5809	6708	7500	8216	8874	9487	10607
280	11"	3550	5020	6148	7099	7937	8695	9391	10040	11225
315	12"	3765	5324	6521	7530	8419	9222	9961	10649	11906

Table D.15: Minimum straight length L_S for PP-Pure and Polypure.

OD		Straight length L_S [mm]								
[mm]	[in]	Change in length ΔL = 50 mm	Change in length ΔL = 100 mm	Change in length ΔL = 150 mm	Change in length ΔL = 200 mm	Change in length ΔL = 250 mm	Change in length ΔL = 300 mm	Change in length ΔL = 350 mm	Change in length ΔL = 400 mm	Change in length ΔL = 500 mm
20	½"	636	899	1101	1271	1421	1557	1682	1798	2010
25	¾"	711	1005	1231	1421	1589	1741	1880	2010	2247
32	1"	804	1137	1392	1608	1798	1969	2127	2274	2543
40	1 ¼"	899	1271	1557	1798	2010	2202	2379	2543	2843
50	1 ½"	1005	1421	1741	2010	2247	2462	2659	2843	3178
63	2"	1128	1595	1954	2256	2523	2763	2985	3191	3567
75	2 ½"	1231	1741	2132	2462	2752	3015	3257	3481	3892
90	3"	1348	1907	2336	2697	3015	3303	3567	3814	4264
110	4"	1491	2108	2582	2982	3333	3652	3944	4216	4714
125	4 ½"	1589	2247	2752	3178	3553	3892	4204	4494	5025
140	5"	1682	2379	2912	3363	3760	4119	4449	4756	5318
160	6"	1798	2543	3114	3596	4020	4404	4756	5085	5685
180	7"	1907	2697	3303	3814	4264	4671	5045	5394	6030
200	8"	2010	2843	3481	4020	4494	4923	5318	5685	6356
225	9"	2132	3015	3692	4264	4767	5222	5641	6030	6742
250	10"	2247	3178	3892	4494	5025	5505	5946	6356	7107
280	11"	2379	3363	4119	4756	5318	5826	6292	6727	7521
315	12"	2523	3567	4369	5045	5641	6179	6674	7135	7977

Table D.16: Minimum straight length L_S for PVDF-UHP.

10.4 Fixed system

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

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

- Anchor load
- Permissible guiding element distance under consideration of the critical buckling length
- Appearing tensile stresses
- Appearing compressive stresses

Do not install any high purity piping systems in a pre-stressed condition!

10.5 Anchor load

Anchor load should prevent a sliding or moving of the piping system in each direction. The anchor has to be dimensioned for all potential 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

Anchors which have not been determined should be chosen in a way as to make use of direction alterations in the course of the piping system for the absorption of the length alterations.

Figure D.12: Restrained fitting in PVDF-UHP.

Swinging clips or the clamping of the pipes are not appropriate to be used as anchors.

It is important to know that the anchor load is independent of the pipe length. The expansion in 1 meter of piping compared to the expansion of 100 meters of piping under the same operating conditions will generate the same force.

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

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

Formula D.28: Anchor load.

F_{FP} anchor load [N]
A_R pipe wall ring area [mm²]
E_C creep modulus for 100 minutes [N/mm²]
ϵ prevented length expansion [1]

Under consideration of the possible loads, ϵ has to be determined as mentioned below.

10.6 Support distances

If piping systems are installed where axial movement is not possible, attention must be paid to the critical buckling length for the operational safety. The calculated distance must provide a safety factor of 2.0 minimum.

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

$$L_A < L_F \Rightarrow L_A$$

Formula D.29: Selection of the support distance L_F.

For the calculated design of a fixed/restrained system the questionnaire (see Section 10.7) should be filled in and sent to anwt@agru.at.

10.7 Questionnaire for the layout of a fixed/restrained piping system

according to DVS 2210-1:1997 (D)

- Pipe material and dimension
  - Pipe material:
    ☐ PVDF-UHP
    ☐ PP-Pure
    ☐ Polypure
    ☐ ECTFE
  - Diameter: OD ____________________ mm
  - SDR: ____________________________
- Transported medium
  - Medium: __________________________
  - Concentration: __________________ mg/l
  - Concentration: __________________ %
  - In chemical solution with:
    1. Medium: ______________________
       Concentration: _________________ mg/l
       Concentration: _________________ %
    2. Medium: ______________________
       Concentration: _________________ mg/l
       Concentration: _________________ %
    3. Medium: ______________________
       Concentration: _________________ mg/l
       Concentration: _________________ %
    4. Medium: ______________________
       Concentration: _________________ mg/l
       Concentration: _________________ %
    5. Medium: ______________________
       Concentration: _________________ mg/l
       Concentration: _________________ %
- Conditions of the application
  - Medium temperature: _____________ °C
  - Temperature changes:
    ☐ yes
    ☐ no
  - Temperature range, if yes:
    - Minimum temperature: ___________ °C
    - Maximum temperature: ___________ °C
    - Installation temperature: _________ °C
  - Operating pressure: _______________ bar
  - Application location
    - Indoor:
      ☐ yes
      ☐ no
    - Outdoor:
      ☐ yes
      ☐ no
  - Insulation:
    ☐ yes
    ☐ no
  - Welding method: _________________
- Further information/details, which have to be considered for the piping layout:
  1. ______________________________
  2. ______________________________
  3. ______________________________
  4. ______________________________
  5. ______________________________

11 Unit systems

Quantity	SI - unit		ASTM - unit	
	Metre		Inch	
Length	1 m	1000 mm 100 cm 10 dm 0.001 km	1 in	0.083 ft 0.027 yd 1.578×10^{-5} mi 1.371×10^{-5} M
	1 m		39.369 in 3.281 ft 1.093 yd 0.621×10^{-3} mi 0.539×10^{-3} M	
	0.0254 m 0.3048 m 0.9144 m 1609.344 m 1852 m		1 in 1 ft 1 yd 1 mi 1 M	
	Square metre		Square inch	
Area	1 m^2	10^6 mm^2 10^4 cm^2 100 dm^2	1 in^2	6.94×10^{-3} ft^2 7.72×10^{-4} yd^2
	1 m^2		1550.003 in^2 10.764 ft^2 1.196 yd^2	
	6.45×10^{-4} m^2 0.093 m^2 0.836 m^2		1 in^2 1 ft^2 1 yd^2	
	Cubic metre		Cubic inch	
Volume	1m^3	10^9 mm^3 10^6 cm^3 10^3 dm^3	1 in^3	5.79×10^{-4} ft^3 2.14×10^{-5} yd^3
	1 m^3		61023.74 in^3 35.314 ft^3 1.308 yd^3	
	1.64×10^{-5} m^3 0.028 m^3 0.765 m^3		1 in^3 1 ft^3 1 yd^3	

Table D.17: Unit systems (part 1).

Quantity	SI - unit		ASTM - unit	
Force	Newton		Pound-force	
	1 N	1 kg×m/s² 0.102 kp	1 lbf	32.174 pdl 0.454 kp
	1 N		0.225 lbf 7.233 pdl	
	4.448 N 0.138 N		1 lbf 1 pdl	
	9,807 N	1 kp	2,205 lbf	
Pressure	Bar		PSI	
	1 bar	0.1 N/mm² 10^5 Pa 0.1 MPa 750.062 torr 0.987 atm 0.980 mWS 1.02 kp/cm²	1 psi	1 lbf/in²
	1 bar		14.504 psi 14.504 lbf/in²	
	0.069 bar	0.0069 N/mm² 6894.757 Pa 0.0069 MPa 51.715 torr 0.068 atm 0.0675 mWS	1 psi	
	0.98 bar	1 kp/cm²	14.214 psi	
Mechanical stress	Newton per square millimetre		PSI	
	1 N/mm²	0.102 kp/mm²	1 psi	1 lbf/in²
	1 N/mm²		145.0377 psi 145.0377 lbf/in²	
	0.0068947 N/mm²		1 psi	
	9.804 N/mm²	1 kp/mm²	142.14 psi	
Speed / velocity	Metre per second		Inch per second	
	1 m/s		1 in/s	0.083 ft/s
	1 m/s		39.370 in/s 3.281 ft/s	
	0.0254 m/s 0.3048 m/s		1 in/s 1 ft/s	

Table D.18: Unit systems (part 2).

Quantity	SI - unit		ASTM - unit	
Density	Gram per cubic centimetre		Pound per cubic inch	
	1 g/cm³	1000 kg/m³	1 lb/in³	1728 lb/ft³
	1 g/cm³		0.036 lb/in³ 62.428 lb/ft³	
	27.6799 g/cm³ 0.016 g/cm³		1 lb/in³ 1 lb/ft³	
Temperature	Degree Celsius		Degree Fahrenheit	
	1 °C	1 K	1 °F	
	T [°C] = (T [°F] - 32) × 5⁄9 T [K] = T [°C] + 273.15		T [°F] = T [°C] × 1.8 + 32 T [K] = (T [°F] + 459.67) × 5⁄9	

Table D.19: Unit systems (part 3).

E Installation guide

1 Transport and handling

When transporting and handling plastic pipes and fittings, the following guidelines have to be observed in order to avoid damages:

- For transport/support pipes along the full length, to prevent bending or deformation. Take pipes/fittings carefully from the transport vehicle. Do not throw the items.
- Protect the products from damage through nails, rivets etc. which may occur on the loading area.
- Impact and bending stresses at temperatures <0 °C have to be avoided.
- To prevent scratches, and damage to the pipes surface, do not drag them across the ground.

2 Storage

When storing pipes and fittings, the following guidelines should be observed to maintain quality:

- The storage area has to be even and free from waste, stones, screws, nails, moisture and any other conditions which may damage the pipe/fitting/valve.
- Do not stack pipes higher than 1 m (3 ft). Use wooden wedges on the outer pipes to prevent them rolling away. Smaller and ligther pipes should be stored on top of bigger ones.
- Pipes have to be stored evenly and without bending stress, if possible in a wooden frame. Pipes should be stored in their originally supply conditions.
- Natural and grey coloured products have to be protected from UV radiation at outdoor storage areas. In general, AGRU does not recommend to store PURAD products in outdoor areas.
- Cardboard boxes from fittings and/or valves should be removed prior to their use only.
- Used pipes should be cleaned and completely packed under cleanroom condition before taking them on stock for further usage.
- Waste disposal of protection tube, cardboard boxes and protection foil must be done in a proper manner and/or according to national guidelines.

Figure E.1: Horizontal pipe storage.

Figure E.2: Vertical pipe storage for large dimensions.

Figure E.3: Fitting storage.

3 High purity installation

Installing a high purity system properly requires pre-planning. The installation is more than the welding of components. It requires the proper environment, material inventory, welding equipment, tools and thorough training.

3.1 General rules of installation

The quality level of the materials should be maintained from delivery to the finished project.

No smoking or eating is allowed during work.

Incoming control of material and marking of quality level according to the user's standards of marking and labelling.

Do not touch the inner surface of any kind of piping component - not even with gloves.

3.2 Welding environment

AGRU does not set requirements for proper welding environments. As the installer, it is necessary to choose the environment based on the installation type, timing or quality goal. In all cases, the environment for welding should be monitored to ensure the temperature is within the range of 5 °C to 40 °C (41 °F to 105 °F). The humidity should not exceed 70 %. If using IR welding, wind/air movement must be avoided.

All PVDF-UHP, PP-Pure and Polypure components are manufactured and packaged in a cleanroom environment. Great care is taken to ensure that they arrive on the project site in protective packaging to maintain their purity. To be consistent, it is ideal to conduct welds in a clean or cleanroom environment. Particles, dust or dirt in the air will adhere to the pipe during the welding process. To reduce contamination in the system as many welds as possible should be conducted in a clean environment. A class ISO 5 or ISO 6 room is perfectly suitable. Portable style cleanrooms make for an efficient set-up when conducting all the welds on-site.

Within the clean zone it is recommended to build spool pieces. The size and configuration is dependent on the ability to safely transport it to the final destination. The ends of the spool pieces should be prepared for final connection once in the pipe rack. In smaller dimensions, OD 20 mm to OD 63 mm (½" - 2"), the ends should be fitted with unions or sanitary joint fittings to reduce welds in the pipe rack, as they are more difficult to perform.

In sizes larger than OD 63 mm (2") it is recommended to build spool pieces with flange connections. This prevents conducting difficult welds in tight locations. Flanged spool pieces also offer the benefit of changes later.

If welding in a cleanroom or clean environment, remove the outer bag in a staging area and store the fitting inside the cleanroom in the single bag until ready for use. It is recommended to store the fittings in plastic bins within the cleanroom and not to use a cardboard box inside a clean environment. Label bins with the fittings size and style.

Polypure fittings should be left in their bag and brought into the clean zone in packed condition. If for some reason the outside of the bag is contaminated, it should be wiped down with IPA prior to entering the clean zone. Valves should be handled in the same manner.

When ready to transport the pipe into the clean zone, open the outer cap on the HDPE protection tube of the PVDF-UHP pipes. Place the tube next to the clean zone entry and slide the pipe directly from the tube into the cleanroom. This will eliminate any need of wiping down the bag prior to entry. In the cleanroom, remove the single bag if ready for immediate usage. If stored in the clean environment, it is preferred to leave the pipe in its original packaging.

Place the double bagged PP-Pure pipe next to the clean zone entry. Open the second bag and slide the single bagged pipe into the cleanroom. Remove the single bag if ready for immediate usage.

Polypure pipes can remain in their shipping packaging until ready for use or transport into the fabrication cleanroom.

When ready for welding, remove all packaging and caps. Remember to save the caps for sealing the ends of prefabricated spool pieces.

3.3 Training

An ultra pure water or chemical system is a critical utility within a plant's operation. An unplanned shutdown can prove to be more costly than the water piping construction itself. One bad weld can cause hours of repair as well as significant revenue losses. For these reasons it is critical to receive training at the time of the job start-up and use certified personnel throughout the course of a project. Tool operation is only one of several factors in a thorough training course. Operators, inspectors and managers need to understand the physical nature of the material:

- How to properly handle it
- How to inspect welds
- How to identify potential problems
- How to properly maintain equipment
- How best to tie into a line and test it

All of the above topics are discussed during AGRU's certified training sessions. For the installation of a high purity system, the following training sessions are available:

- Tool operator training and certification
- Quality control inspection

4 Support guidelines

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

When laying pipes above ground expansions and contractions in both directions, radial and axial, must not be hindered. This means, installations with radial clearance, positions of compensation facilities, control of changes in length by reasonable arrangement of anchor points.

Supports have to be calculated to avoid pinpoint stresses, which 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°).

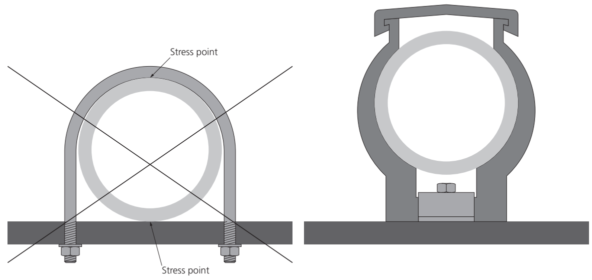


Figure E.4: Not recommended versus recommended pipe supports.

The surface qualities of the supports should help to avoid mechanical damage to the pipe surface.

Valves (in certain cases also tees) should basically be installed in a piping system as anchor points. Valve bodies with integrated support/fixed points are most advantegous to be used.

4.1 Pipe clip design

Support made of steel or thermoplastics are available for plastic pipes. Steel clips should be lined with a PE or rubber strip to prevent damage to the pipe wall. Otherwise the surface of the plastic pipes may be damaged. AGRU plastic pipe clips as well as pipe holders are very suitable for installations. They may be used with all materials, and have been specifically designed to allow for the tolerances of plastic pipes.

It is recommended for smaller pipe diameters (OD <63 mm), to use steel half-shells as support of the piping system in order to enlarge the support distances (see Figure E.5).

Figure E.5: Guide bearing pipe support with steel half-shell.

Pipes sizes OD 63 mm - 315 mm should be supported by means of pipe clips, which do not fix the pipe in the axial direction (see Figure E.6).

Figure E.6: Guide bearing pipe support with pipe clip.

For anchor points in the piping system, restraint fittings should be utilised together with suitable pipe clips (see Figure E.7).

The restrained fittings will prevent an axial movement, but will provide the required flexibility in radial direction (stress-free also during the application).

Figure E.7: Anchor point with a restrained fitting.

Figure E.8: Recommended pipe clip design.

F Connection technology

1 Connection technology

1.1 General information

Connection systems have to be designed to avoid any kind of stresses. Stresses which may arise from differences in temperature between installation and operation conditions must be kept as low as possible by taking appropriate measures as discribed in Chapter D.

Depending on the pipe dimension, following connection systems are applicable:

	20 mm - 63 mm (½" - 2")	75 mm - 90 mm (2 ½" - 3")	110 mm - 315 mm (4" - 12")	355 mm - 400 mm (14" - 16")
Infrared welding	✓	✓	✓	
Heating element butt welding	✓	✓	✓	✓
Beadless welding	✓			
Flange connection	✓	✓	✓	✓
Union connection	✓	✓		
Sanitary joint connection	✓			

Table F.1: Overview.

1.2 Welding personnel

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 welds can be tested and inspected by destructive and/or visual methods.

The welding works must be supervised. The type and scope of supervision must be agreed to by the parties. It is recommended to record the procedure data in welding protocols or on data carriers.

Within the scope of the quality assurance it is recommended to produce and test samples of joints before beginning and during the welding works.

Each welder has to be trained and must have a valid proof of qualification. The intended application range may be decisive for the kind of qualification. The welding certificate according to DVS 2212-1:2006 (D) in the groups I-4 or I-8 in conjunction with a complementary training certificate issued by an authorised training institute or by the particular machine manufacturer are valid as qualification proof.

1.3 Welding machines

Utilise proven welding techniques for the joining of components, only approved and maintained welding machines should be used. The application of non-approved welding techniques can result in a reduced joint quality in both strength and purity. In addition, welding parameters should have been recorded for every weld performed. A print-out label with significant welding information is required to identify and evaluate every weld. Welding machines and appliances must correspond to the guidelines of the DVS 2208-1:2007 (D).

When welding high purity thermoplastic piping systems, the following facts should be taken into consideration.

- Application of suitable and approved welding machines
- Application of trained and certified personnel
- Consideration of the prescribed welding guidelines (parameters)
- Performance of the welding process in the cleanroom area
- Complete control and documentation of the performed welding operations

The design of a system should consider installation conditions such as space and environment conditions. Based on the above criteria the choice of welding technique is crucial for a successful installation. The installation should be planned to fabricate assemblies and sub-assamblies to reduce the amount of welds conducted in restricted (confined) locations.

1.4 Preparations prior to the welding

The immediate welding area must be protected from unfavourable weather influences (e.g. moisture, wind, UV radiation, temperatures below +5 °C (+41 °F) or higher than +40 °C (+104 °F)). If it is ensured by suitable measures (e.g. pre-heating, tent, heating) that a component temperature sufficient for welding can be kept, as far as the welder is not hindered in his handling, work may be carried out at any outside temperature. If necessary, additional confirmation must be provided by carrying out sample welds under the mentioned conditions.

If the welding products are heated up non-uniformly due to the influence of sunshine, the temperatures should be equalised by covering the welding zone.

The pipe ends should be closed during the welding process.

The welding faces of the parts must be clean (free from dirt, oil, shavings or other residues) and in a straight cut planed surface condition before starting the welding process.

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

1.5 Weld evaluation

The control of the weld quality on-site should only be performed by certified personnel with proper knowledge of the welding technique. Different tests according to DVS guidelines may be performed:

- Visual test of the weld (DVS 2202-1:2006 (D))
- Tensile test for the determination of the short term welding factor (DVS 2203-1:2003 (D))
- Bending test for the determination of the bending angle (DVS 2203-5:1999 (D))
- Pressure test on the installed pipeline according to DVS 2210-1 supplement 2:2004 (D)

1.6 Installation of a high purity piping system

High purity components for DI systems should preferably be welded in a class ISO 7 environment or better. Prefabrications should be made in a cleanroom environment to minimise the amount of welds conducted in standard air conditions, to reduce potential contamination.

2 Infrared (IR) welding technology

according to DVS 2207-6:2003 (D)

This method is the next evolution of heating element butt fusion, where the components are not in contact with the heat source. The heating up of the pipe ends is performed by radiant heat. The advantage of the IR fusion (non-contact heating element butt welding) is a minimum bead size and the elimination of possible contamination from the heating element. The shape of the bead is also straighter, providing less area for bacterial growth. Compared to conventional heating element butt welding, the total welding times are reduced by up to 70 % with an increased welding factor and thus increased welding quality.

All welding parameters are recorded by the computer. All steps are controlled and sequential. Simplified handling together with a 100 % comprehensive welding system and complete traceability of the process are the unique and important features of the SP series. The joining pressure is electronically regulated according to the pre-programmed data. Any deviations will be immediately recorded and indicated on the touch screen/printout label.

2.1 Welding method

The welding faces of the parts are heated-up in a pressureless condition (no contact). After removing the heating element (changeover) the parts are joined together with a specific welding pressure and build-up time. During the cooling time the required pressure will be kept constant.

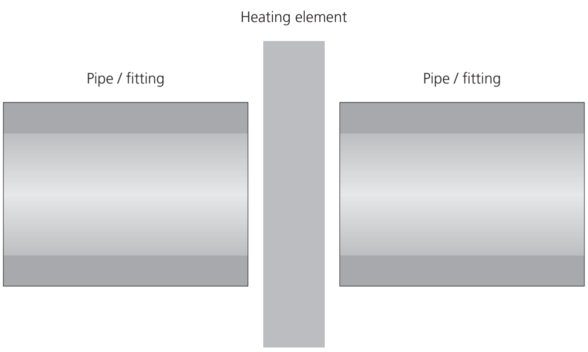


Figure F.1: Preparation of the welding.

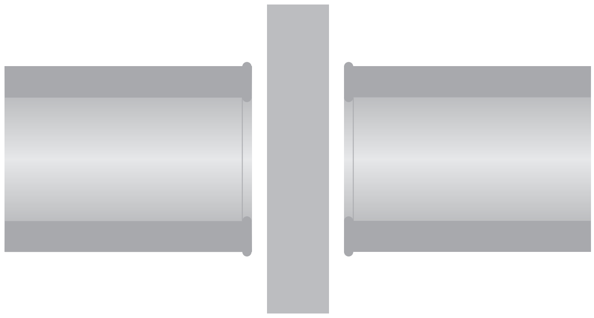


Figure F.2: Non-contact heating.

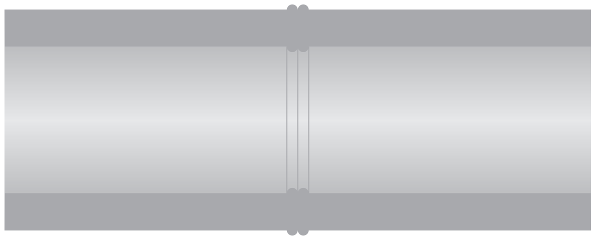


Figure F.3: Joining and cooling.

2.2 Preparations before welding

Ensure a sufficient power supply and place the welding machine in a dry and clean workshop (cleanroom) according to the manufacturer's recommendation.

The nominal wall thickness of the parts to be welded must correspond to the effective joining area and welding parameters.

If necessary, clean the heating element with clean lint-free paper before the start of each welding process. The non-stick coating of the heating element must be undamaged in the working area.

The heating element is heated-up to the set temperature automatically. When the desired temperature is reached, the countdown of the remaining time starts. The remaining time is used to get a uniform temperature distribution at the heating element.

The welding faces can be cleaned with cleaning agent, e.g. alcohol, prior to planing. After planing cleaning with a liquid is not permitted. Use special cleanroom paper or a soft brush to remove any shavings. It is also recommended to use a vacuum cleaner to clean the welding machine.

The misalignment of the welding faces to one another should not exceed the value of 0.1 × wall thickness.

Close any open ends of pipe and components with end caps or similar.

2.3 Recommended welding machines

AGRU SP series IR welding equipment operates fully automatically and can be used for different materials such as PVDF-UHP, PP-Pure, Polypure, ECTFE and optionally for PFA (PureBond®).

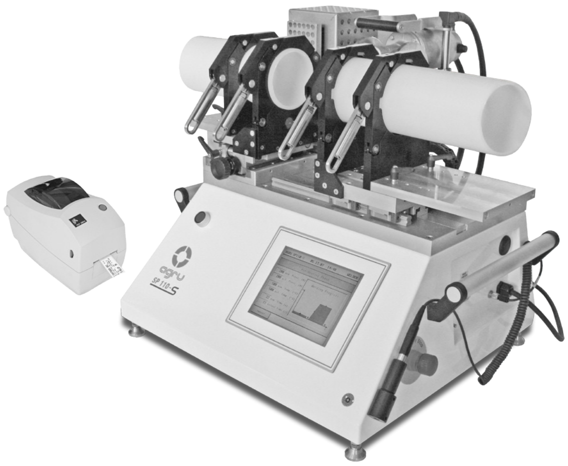


Figure F.4: IR welding machine SP 110-S.

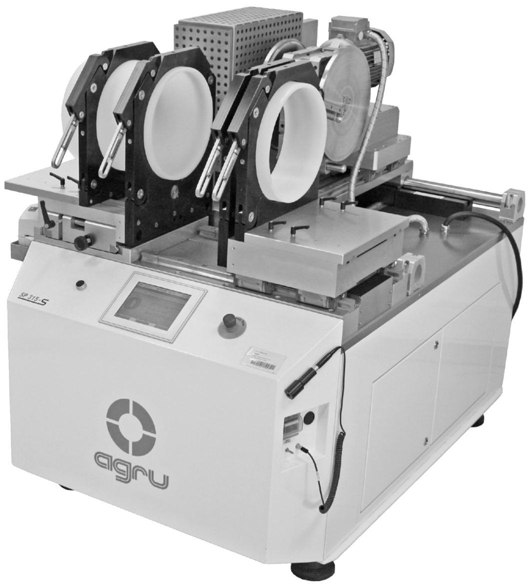


Figure F.5: IR welding machine SP 315-S.

2.4 Welding procedure SP series

2.4.1 Welding parameters

The welding parameters like pre-heating time, changeover time, joining pressure build-up time, joining and cooling time are preset and can not be altered by the operator. By setting the material, pressure range and size of the pipe the machine recognises automatically the welding parameter. For the values of the total welding times contact anwt@agru.at.

2.4.2 Heating time

With IR welding technology no alignment at the heating element is necessary because the welding parts are not in contact with the heating element.

The SP welding machine sets automatically all functions and parameters. When heating, the heat penetrates the parts to be welded (plasticising) and heats them up to the required welding temperature.

2.4.3 Changeover

After heating the heating element will be automatically withdrawn (changeover) without damaging and contamination of the welding area.

The changeover time is kept as short as possible.

2.4.4 Joining and cooling time

The faces to be welded come into contact at a speed of nearly zero. The required joining pressure will be rised linear to the required joining pressure automatically.

During cooling the joining pressure is maintained. Assembly or mechanical treatment is allowed after the entire cooling time.

After joining, a double bead surrounding the whole circumference must have been created. The bead development gives an orientation about the regularity of the welds among each other. Possible differences in the formation of the beads may be justified by different flow behaviour of the joined materials. K must be bigger than 0.

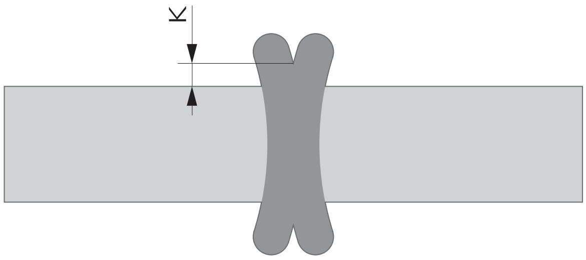


Figure F.6: Bead height K.

2.5 Process steps

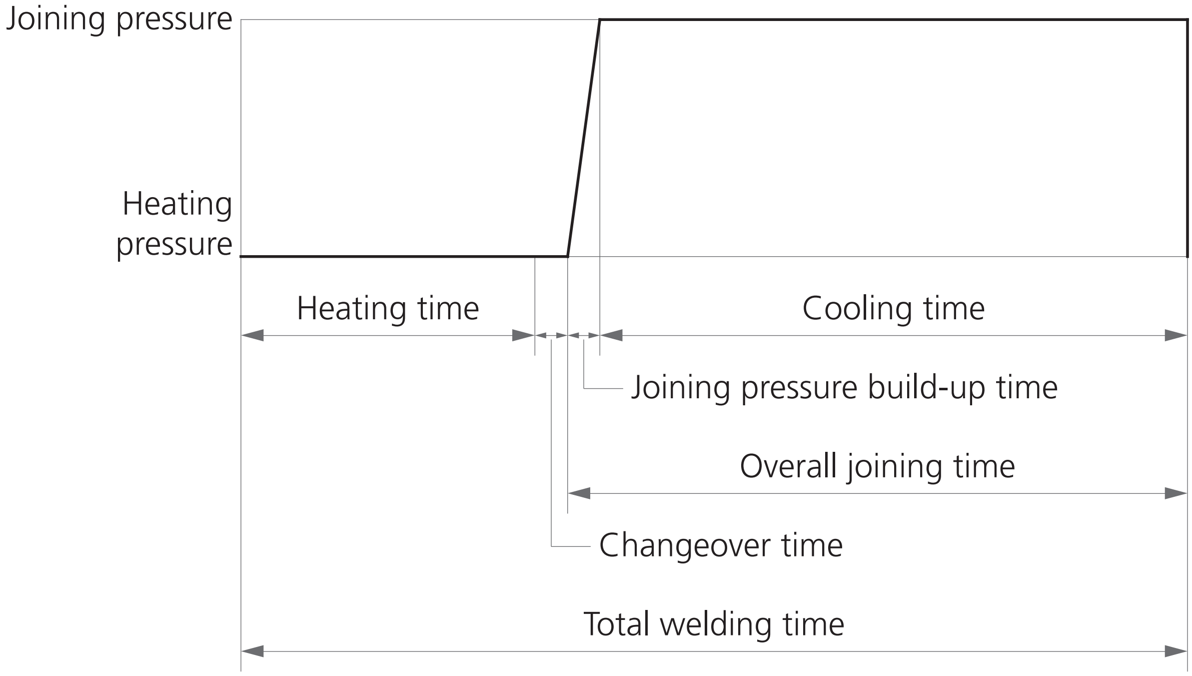


Figure F.7: Process steps of non-contact heating element butt welding (IR welding).

2.6 IR weld quality

Compared to conventional heating element butt welding, IR welding for PVDF-UHP, PP-Pure, Polypure and ECTFE is technologically the better welding method.

The IR welding bead is more than 50 % smaller, both outside and inside, than beads made by conventional contact butt welding methods. This results in significantly better hydraulic behaviour and of course improved cleanliness of the weld area. The risk of contamination is almost non-existent and consequently the IR welding technique using the AGRU SP series of welding machines, is ideal for applications in the semiconductor, food, life science and FPD industries.

2.7 Pressure test

Before the pressure testing, all joints must be completely cooled down (rule of thumb: 1 hour after the last welding). The pressure test has to be performed according to the relevant regulations (e.g. DVS 2210-1 supplement 2:2004 (D)). The piping system has to be protected from changes in the ambient temperature (UV radiation). Pressure test see Section 6.

3 Heating element butt welding

following to DVS 2207-11:2008 (D) and DVS 2207-15:2005 (D)

Heating element butt welding has been utilised for more than 30 years and has been proven to be a reliable and efficient joining method.

Butt welding is the parent of IR welding and still maintains its one advantage; it can be done in a variety of environments. Wind or a strong breeze can make IR welding troublesome and in these cases butt welding is preferred. If welds are to be made in an outside area, butt welding should be used. Field welds in place can also be accomplished with butt welding. A variety of different types of butt welding equipment is available. In general, butt welding is preferred for the welding of bigger sizes above OD 355 mm.

3.1 Welding method

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 (heating time) and joined under pressure after the heating element has been removed (joining). During cooling, the joining pressure has to be maintained.

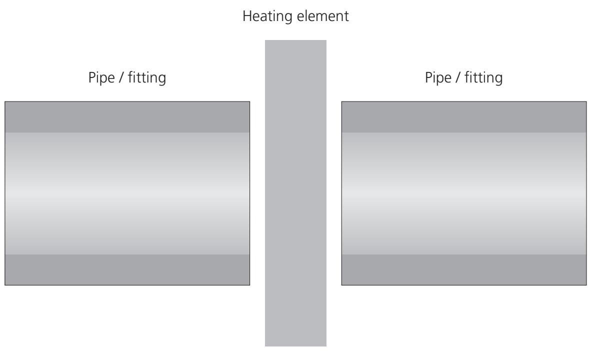


Figure F.8: Preparation of the welding.

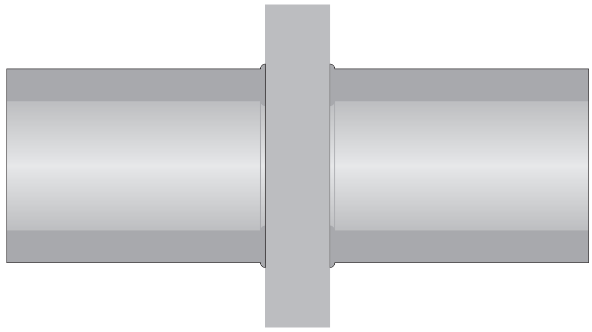


Figure F.9: Alignment and heating.

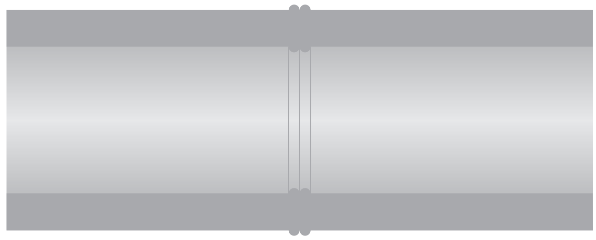


Figure F.10: Joining and cooling.

3.2 Preparations before welding

Check the required heating element temperature before each welding process. This can be done 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. To reach a thermal balance, the heating element has to maintain the required temperature for at least 10 minutes.

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

For the used machines, the particular joining pressure or joining force must be given. This can refer to information by the manufacturer, calculated or measured values. Additionally, any drag force, which is generated when the moveable clamp is pulled towards the fixed clamp, must be added to the specified joining force. This drag force is displayed on the indicator on the machine.

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

Before clamping the pipes and fittings in the welding machine they must be axially aligned. Ensure an easy longitudinal movement of the parts that will be welded by using e.g. adjustable dollies or swinging hangers.

Immediately before the welding process a clean, oil-free planing tool should be used to ensure parallel faces in the clamped position. Permissible gap width under alignment pressure see Table F.2.

Outside diameter		Gap width
[mm]	[inch]	[mm]
<355	<14″	0.5
400	16″	1.0

Table F.2: Permissible gap width.

Together with the control of the gap width, also the alignment should be checked. The misalignment of the joining areas to one another should not exceed the permissible dimension of 0.1 × wall thickness.

The machined welding faces should not be dirty or touched by hands otherwise a further planing process will be necessary. Shavings which have fallen into the pipe should be removed.

3.3 Specific alignment/joining pressure

In most cases the alignment/joining pressure p or the alignment/joining force F, which has to be adjusted, may be taken from the tables on the welding machines. For checking purposes or if the table with the pressure data is missing, the required alignment/joining pressure has to be calculated according to the following formula:

$$A_{pipe} = (OD \cdot s - s^2) \cdot \pi$$

Formula F.1: Pipe's annular surface.

$$F = p \cdot A_{pipe}$$

Formula F.2: Heating force.

A_{pipe} pipe's annular surface [mm²]
F alignment/joining force [N]
OD pipe outside diameter [mm]
p specific alignment/joining pressure [N/mm²] (see Table F.4)
s pipe wall thickness [mm]

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

3.4 Heating element temperatures

The heating element temperatures are listed in Table F.3. Generally the aim is to use higher temperatures for smaller wall thicknesses and the lower temperatures for larger wall thicknesses. Temperatures see Section 3.5.1.

3.5 Welding procedure

3.5.1 Welding parameters

Reference values for heating element butt welding of PVDF, PP and ECTFE pipes and fittings at outside temperatures of about 20 °C and low air speeds.

	Heating element temperature
PVDF	225 °C - 248 °C 437 °F - 478 °F
PP-Pure, Polypure	200 °C - 220 °C 392 °F - 428 °F
ECTFE	275 °C - 285 °C 527 °F - 545 °F

Table F.3: Heating element temperatures.

	Specific alignment/ joining pressure [N/mm²]
PVDF	0.10
PP-Pure, Polypure	0.10
ECTFE	0.08 - 0.09

Table F.4: Specific alignment/joining pressure.

Material	Wall thickness	Minimum alignment bead height	Heating time	Maximum changeover time	Joining pressure build-up time	Cooling time
	[mm]	[mm]	[sec]	[sec]	[sec]	[min]
PVDF		Alignment pressure p = 0.10 N/mm²	Heating pressure p = 0.01 N/mm²		Joining pressure 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
PP		Alignment pressure p = 0.10 N/mm²	Heating pressure p = 0.01 N/mm²		Joining pressure 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
ECTFE		Alignment pressure p = 0.085 N/mm²	Heating pressure p = 0.01 N/mm²		Joining pressure 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

Table F.5: Welding parameters.

3.5.2 Alignment (bead height)

The welding faces are pressed onto the heating element until the whole area is situated plane parallel on the heating element. This can be recognised by the formation of the beads. The alignment is finished when the bead height has reached the requested values around the whole circumference. The bead height indicates that the joining areas are completely located on the heating element. The alignment pressure is effective throughout the whole alignment operation. Pressures see Section 3.5.1.

3.5.3 Heating

During the heating process the welding faces must be in contact with the heating element at a low pressure. The pressure shall be close to zero (≤0.01 N/mm²). During the heating time the heat infiltrates the faces to be welded and heats them up to the required welding temperature.

3.5.4 Changeover

After the heating time the welding faces should be detached from the heating element. The heating element should be withdrawn (changeover) without damaging and soiling the welding faces. The welding faces must then be moved together quickly until they almost touch. The changeover time should be kept as short as possible, otherwise the plasticised surfaces would begin to cool which would have a negative effect on the weld quality.

3.5.5 Joining and cooling

The faces to be welded should come into contact at a speed of nearly zero. The required joining pressure should rise linear according to Table F.5.

During the cooling time the joining pressure must be maintained. A mechanical load on the joint is permissible at the earliest after the end of the cooling time. Assembly or mechanical treatment is allowed after the entire cooling time.

After joining, a double bead surrounding the entire circumference must have been created. The bead development gives an orientation about the regularity of the welds. Possible differences in the formation of the beads may be justified by different flow behaviour of the joined materials. K must be bigger than 0.

A welding protocol in accordance with the DVS 2207-1:2005 (D) should be filled in.

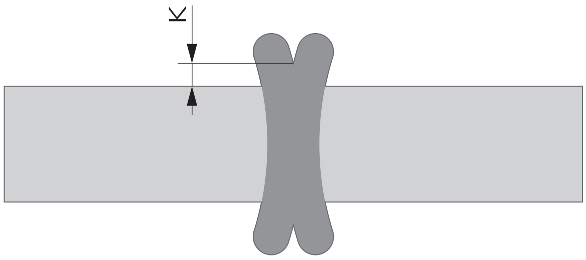


Figure F.11: Bead height K.

3.6 Process steps

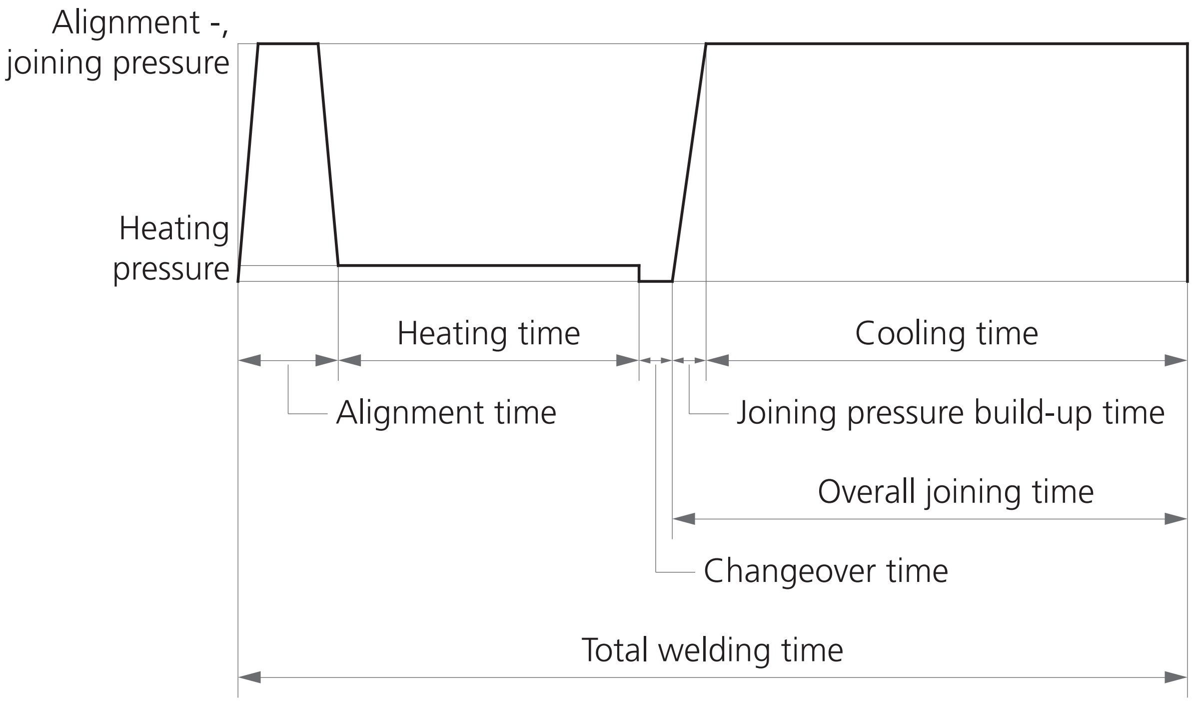


Figure F.12: Process steps of heating element butt welding.

3.7 Pressure test

Before pressure testing, all joints must be completely cooled down (rule of thumb: 1 hour after the last welding). The pressure test has to be performed according to the relevant standard (e.g. DVS 2210-1 supplement 2:2004 (D)). The piping system has to be protected from environment temperature changes during pressure testing. Pressure test see Section 6.

4 Beadless welding

Beadless welding should be used where system in-place drainage is required. Beadless welding may be used in the process stream or where CIP requirements are defined. The joints are free from internal beads and crevices. The primary method of beadless welding involves careful diffusion of heat through the external surfaces while maintaining internal support of material as it becomes molten. Once heated to desired temperature and duration, the molten material flows and readily joins as a single piece. An internal balloon is inserted in the weld area to prevent the formation on an internal bead.

The SP 110-B is designed for welding plastic piping systems in the following industries:

- Pharmaceutical industry
- Biotech industry
- Dialysis facilities
- Hospitals and laboratories
- Food and beverage industry
- Dairy industry
- Chemical industry
- Semiconductor industry

4.1 Welding method

During the fully automated welding process the temperature, pressure and time are accurately regulated and documented. All stored welding data can be used for the validation process.

The fully automated welding process consists of three phases:

- Pre-heating phase
- Welding phase
- Cooling phase

This beadless welding technology offers highest quality joints with excellent reproducibility.

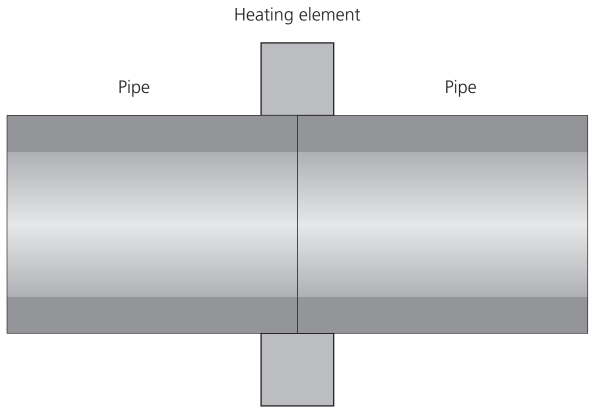


Figure F.13: Pre-heating phase.

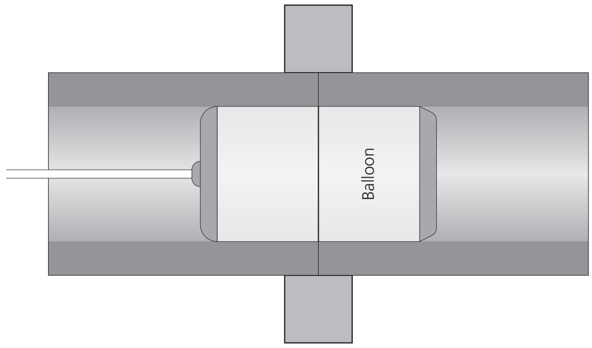


Figure F.14: Welding and cooling phase.

Figure F.15: Welded pipe.

4.2 Welding equipment

The AGRU SP 110-B beadless welding equipment offers the following features:

- Fully automated welding process
- Smooth inner bore and outer surface
- Smallest weld area required
- Fully drainable piping system
- Standard piping components can be welded
- Complete welding documentation for easy validation
- Suitable for PVDF-UHP, PP-Pure and Polypure

Figure F.16: SP 110-B beadless welding machine.

5 Detachable joints

5.1 Flange connections

If pipe joints are connected by means of flanges, the following guidelines have to be adhered to.

5.1.1 Aligning of parts

Firstly, the sealing faces have to be aligned plane parallel to each other and fit tightly to the sealing. Pulling the flanges together to compensate for a gap between them, must be avoided, due to the potential tensile stress which may be created.

5.1.2 Tightening of bolts

The length of the bolts has to be chosen in a way that the bolt thread ends with the bottom of the nut. Shims have to be placed at the bolt head and also at the nut. The connecting bolts have to be tightened using a torque wrench (torque values see www.agru.at).

5.1.3 General

It is recommend to brush over the thread, e. g. with molybdenum sulphide, so that the thread stays easy-running also at longer operation time.

For the selection of sealing material the chemical and thermal resistance has to be considered.

5.2 Unions

If pipe joints out of thermoplastics are connected by means of unions, the following regulations have to be adhered to:

For avoiding impermissible loads at the installation, unions with round sealing rings should be applied.

The union nut should be screwed manually or by means of a strap wrench. Common pipe wrenches should not be used!

Do not use unions in areas with bending stresses in the piping systems.

5.3 Thread connection

For the sealing of threaded connections we recommend only the use of PTFE (e.g. Teflon®) tapes. Hemp is not permissible.

5.4 Sanitary joint connection

Pipe joints out of thermoplastics can be connected by means of sanitary joint fittings. The measurement of the fittings are according to international standards (e.g. DIN 32676) and can be used to install sensors in a piping system.

5.5 Adhesive joints

PVDF, ECTFE and PP are not suitable for joining with any adhesives.

6 Pressure test

according to DVS 2210-1 supplement 2:2004 (D)

The internal pressure test is the conclusion to the pipe laying work and requires a ready-to-operate piping system or ready-to-operate sections for testing. The stresses resulting from the test pressure should constitute the experimental proof of the operational safety of the system. In this respect, emphasis should not be placed on the calculated operating overpressure but on the internal pressure capacity origination from the pipe wall thickness.

For high purity applications UPW or DI water should be used as test media. Pressure test with gases are not recommended.

6.1 Types of internal pressure tests

Types of internal pressure tests are:

- Preliminary test
- Main test
- Short-term test

The results of the test have to be recorded. Continuous pressure and temperature records have to be conducted.

6.1.1 Preliminary test

The preliminary test serves as preparation of the piping system for the actual test (main test). A stress strain equilibrium, generated by the internal pressure loads, arises during the preliminary test. This leads to a material dependent pressure drop that requires the repeated addition of water (repumping) in order to restore the test pressure as well as the frequent re-tightening of the flange screws.

6.1.2 Main test

The main test immediately follows the preliminary test. During the main test, a substantially lower pressure drop may be expected at an approximately lower constant pipe wall temperature.

In most cases, this makes it unnecessary to add any water to restore the test pressure. The inspections concentrate on the leak-tightness of the flange connections and on any conspicuous features in the piping system (e.g. major position changes).

6.1.3 Short-term test

The short-term test represents a special case since, according to general experience, no stress strain equilibrium can arise in the available time. In certain circumstances, imperfections at the joints may not be detected due to the short-term loads, which contradicts the point of the test. The short-term test should therefore only be used for pipe systems that do not have a hazard potential.

Subject and explanations		Preliminary test	Main test	Short-term test
Test pressure p_P (see Section 6.5.1)	Depending on the pipe wall temperature or the permissible testing pressure of the installed parts [3]	$\leq p_{P(zul)}$	$\leq 0.85 \cdot p_{P(zul)}$	$\leq 1.1 \cdot p_{P(zul)}$
Test duration (see Section 6.5.5)	Piping with or without branches and a total length of $L_{ges} \leq 100$ m [1]	≥3 h	≥3 h	≥1 h
	Piping with or without branches and a total length of 100 m < $L_{ges} \leq 500$ m	≥6 h	≥6 h	≥3 h
	Piping with or without branches and a total length of L_{ges} > 500 m	The piping system must be checked section by section. In this respect, it is necessary to comply with the test length of $L_{Prüf} \leq 500$ m [1]		
		≥6 h	≥6 h	≥3 h
Inspections during the test (see Section 6.5.4)	The inspection results, as well as the pressure and temperature changes during the test, must be documented in a test report.	≥3 inspections carried out over the test duration with restoration of the test pressure.	≥2 inspections carried out over the test duration without restoration of the test pressure.	≥1 inspection while keeping the test pressure constant.
Material specific pressure drop	Reference values, depending on the elastic modulus of the plastic concerned.	PP [2]	PP [2]	For short-term loads no values for the pressure drop are available.
		PVDF, ECTFE [2]	PVDF, ECTFE [2]	
Conclusion		Normal case (In relation to the specified duration of the preliminary and main tests).		Special case (consent of the customer or operator required).

Table F.6: Recommendations for carrying out the internal pressure test.

1) If L_{ges} exceeds the stipulated limiting length by no more than 10 %, the specified testing conditions may be retained. A limitation on the test length results from the necessity of being able to detect and evaluate reactions caused by changes in the test pressure and test temperature within the test duration. The longer the test length is, the more difficult it is to assign test pressure fluctuations. At test temperatures of 20 °C ±5 °C, test lengths >500 m may also generate usable results. The decision about this must be taken by the test supervisor responsible.
2) The DVS working group AG W 4.3a has decided to publish guide values for the pressure drop rates of the various thermoplastics on the basis of experimental tests. As soon as results are available, these will be published in the trade press.
3) Pipelines that contain components with a smaller operating pressure compared to the pipe, the maximum applicable test pressure has to be in accordance with the manufacturers recommendations.

6.2 Preparation of the internal pressure test

A prerequisite for the internal pressure test on plastic piping is the elimination of any bubbles (residual air volume) in the system before the preliminary test. To accomplish this venting points, which must be open during the rinsing or filling of the line, must be provided. If possible at all high points of the pipe system. The rinsing speed should be at least 1.0 m/s.

6.2.1 Filling of the line

The piping system is filled from the lowest point. The filling must be made at a rate that the air emerging at the high points has time to escape. Reference values for the filling rates are given in Table F.7.

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

Table F.7: Reference values for the filling of the pipeline.

If a piping system has several low points it may be necessary, in certain circumstances, to fill it section by section from each individual low point.

Between filling and testing the piping system, enough time must be left for the air to escape the system via venting points (reference value: ≥6 h - 12 h) depending on the pipe's nominal diameter.

In case of diameters larger than DN 150, which do not have any definite high points and are laid with only a slight inclination, it may be necessary to use a pig to eliminate any bubbles remaining inside the pipe.

6.2.2 Application of the test pressure

When applying the test pressure up to its maximum value, it must be ensured that the chosen pressure rise rate does not cause any surges in the piping system that is to be tested. Guide values for this are given in Figure F.17.

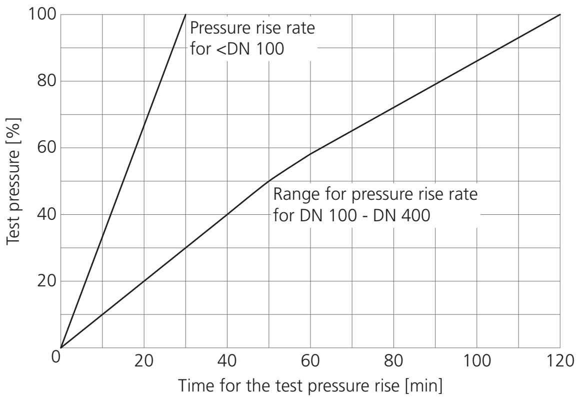


Figure F.17: Time for the test pressure rise.[4)]

6.3 Facilities for and remakrs about the execution of the internal pressure test

It is advisable to use motor-driven pumps for carrying out the internal pressure test. The use of small manually-actuated pumps (e .g. piston pump) must be restricted to short pipe sections with nominal diameters up to DN 50.

The standard equipment for pressure testing comprises the following components:

- Centrifugal or piston pump
- Receiver vessel
- Non-return valve
- Water meter (if necessary, also a measuring vessel)
- Pressure gauge (displaying and recording)
- Temperature gauge (displaying or recording)

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4) Guide value for the pressure rise rate for piping ≥DN 500:

$$\Delta p_P = \frac{500}{DN}$$

DN nominal diameter [mm]
Δp_P test pressure rise rate [bar/10 min]

- Shut-off and venting valves
- Venting possibility for the testing facility

6.3.1 Measuring and display devices

6.3.1.1 Internal pressure measurement

The internal pressure is measured at the absolute low point of the line. The device displaying the internal pressure (manometer) must have a reading accuracy of 0.1 bar over the range of the test pressure as well as a pressure display. It is also necessary to have a recording pressure gauge of accuracy class 0.6 (DIN 16070). The internal overpressure must be recorded continuously throughout the test duration.

6.3.1.2 Temperature measurement

In order to be able to evaluate the influences of temperature during the test, it is advised to measure the ambient temperature and the water temperature in the pipe system at the same time. It is recommended to use devices that record the temperature.

On exposed pipe sections that are subject to direct sunlight during the test, it is necessary to either check the pipe surface temperature T_{Ra} or to protect the pipe section from uncontrolled heating. The results must be noted in the test report.

6.3.1.3 Measurement of the quantity of supplied water

Particularly in case of pipings that cannot be inspected visually, it is mandatory to measure the quantity of the supplied water for increasing or restoring the test pressure. If the quantity of the supplied water drops continuously during a 6-hour test with only a slight change in the ambient temperature (±5 °C), the pipe system may be assumed to be leak-tight. It is sufficient to install a calibrated water meter (impeller wheel or ring piston meter) as the measuring facility with which the smallest unit can be read off in litres. If measuring vessels are used, a scale division of ≤0.1 litre should be chosen. The permissible error limit when reading off the quantity of supplied water is 5 %.

6.3.1.4 Measurement of the quantity of discharged water

Since the test pressure must be reduced at the beginning of the main test, it is recommended to measure and log the quantity of discharged water as well as the reduction in the internal pressure Δp_p. This should be carried out using the same criteria as for measuring the quantity of supplied water.

6.3.2 Testing and measured results

6.3.2.1 Checking of the pressure drop rates

During the preliminary and main tests, the pressure drop rates specified in Table F.6 must not be exceeded. The pressure drop rates established on the basis of the recorded data must be transferred to the test record sheet. The pressure drop rate may be calculated from the maximum value, over a test duration of two hours. In this way, the higher pressure drop rate at the start is compensated for.

If there is a specific pressure drop that is considerably above the values specified in Table F.6, the tested piping system must be subject to a detailed inspection - in particular the joints and especially the flanged joints. If necessary, the bolts of the flanged joints must be re-torqued due to the strain processes from the internal pressure loads. It is recommended to use a torque-controlled tool (see DVS 2210-1 supplement 3:2006 (D)).

Furthermore, it must be established whether the ambient temperature has an influence on the increase in the pressure drop rate. If there are no indications of any external influences and the pressure drop does not diminish, the test must be terminated and repeated.

6.3.2.2 Reduction in the test pressure

If the pressure drop corresponds to the guide values specified in Table F.6 and the test pressure is reduced within ≤2 min at the end of the preliminary test by draining water, it is necessary to observe the subsequent change in internal pressure. The main test can be continued if the internal pressure stabilises or increases slightly within 30 min.

6.3.3 Repetition of the preliminary test

If there is no cease in the pressure drop after reducing the test pressure at the end of the preliminary test and if the pressure drop cannot be linked to any external temperature influences, a leak may be assumed. In this case, the test must be halted, the piping inspected and the internal pressure subsequently increased to the initial value of the preliminary test, while simultaneously measuring the supplied water quantity.

After a minimum of 1 h, the reduction in the test pressure must be repeated while measuring the discharged water quantity. If there is once again no stabilisation of the test pressure, the pressure on the pipe section tested must be relieved ($p_P = 0$) and the entire preliminary test must be repeated.

6.3.4 Repetition of the main test

If the internal pressure during the main test drops more than the pressure drop rates specify in Table F.6, a leak may be assumed. If the cause of the increased pressure drop is found and rectified during the inspection of the piping without the test pressure falling below 80 % of its initial value, the main test can be continued. In all other cases, the main test must be terminated and repeated. If there is a time span of >4 h between the termination and the repetition of the main test, the preliminary test must also be repeated.

6.4 Test report and test supervision

The internal pressure test procedure and other test procedures, as well as their results must be logged. All data relevant for the evaluation of the test must be specified on the record sheet, according to the example in the DVS 2210-1 supplement 2:2004 (D) appendix.

The execution of the test should be overseen by a supervisory person or a construction supervisory agency.

In particular, knowledge and experience relating to the handling of piping made of plastics are a prerequisite for stipulating the test pressures as well as for recording and documenting the test results.

6.5 Test pressure, test temperature and test duration

6.5.1 Establishing the test pressure

The permissible test pressure $p_{P\,(zul)}$ is calculated according to the following equation:

$$p_{P\,(zul)} = \frac{s}{OD} \cdot \frac{20 \cdot \sigma_{v\,(T,\,t)}}{S_P \cdot A_G}$$

Formula F.3: Permissible test pressure.

A_G processing specific or geometrical reduction factor [1][5)]($A_G \geq 1.0$)
OD pipe outside diameter [mm]
s pipe wall thickness [mm]
$\sigma_{v\,(T,\,t)}$ creep strength for pipe wall temperature T_R and t = 100 h [N/mm²] (according to DVS 2205-1, supplements 1:2011 (D) to 25:2007 (D))
S_P minimum safety margin for the creep strength [1] (see Table F.8)
$p_{P\,(zul)}$ permissible test pressure [bar]

	PP-Pure & Polypure	PVDF
S_P	1.40	1.40

Table F.8: Minimum safety margin.

The user is free to stipulate a greater safety margin than specified in Table F.8.

5) Further remarks: Processing specific and geometrical reduction factors are, for example welded joints with a long-term welding factor $f_s \leq 0.5$ or unreinforced nozzle cutouts in the piping. Information about this can be taken from the documents of the fitting manufacturers. If necessary, reduction factors must be established using common strength calculations.

The permissible test pressure $p_{P\,(zul)}$ depending on the pipe wall temperature can be taken directly from Figure F.18 and Figure F.19.

When working at test pressures that are lower than the test pressure established according to Formula F.3, $p_P = 1.3 \times p_B$ (operating overpressure) may be assumed as the minimum value.

6.5.2 Test pressure diagrams

Figure F.18 and Figure F.19 are intended to illustrate the temperature dependent test pressures for thermoplastic piping. Moreover, they serve to make it easier for the construction site personnel to determine the test pressure.

The test pressure curves were compiled for one group of plastics taking into account the lowest strength parameter in each case and the minimum value of $p_{P\,(zul)}$ calculated according to Formula F.3.

No processing specific or geometrical reduction factors have been used in these curves.

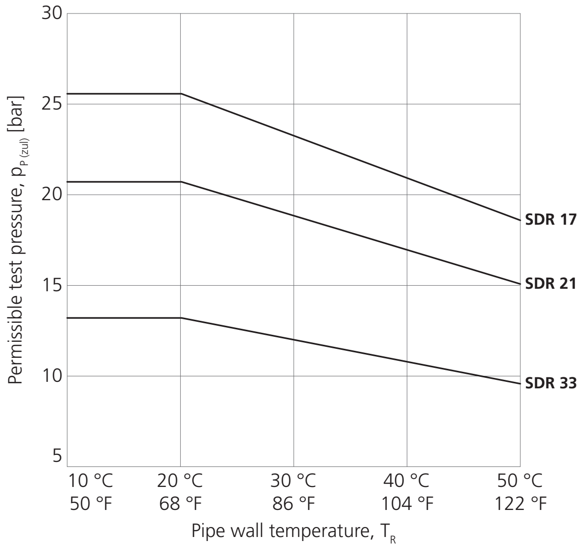

Figure F.18: Test pressure curves for piping made of PVDF.

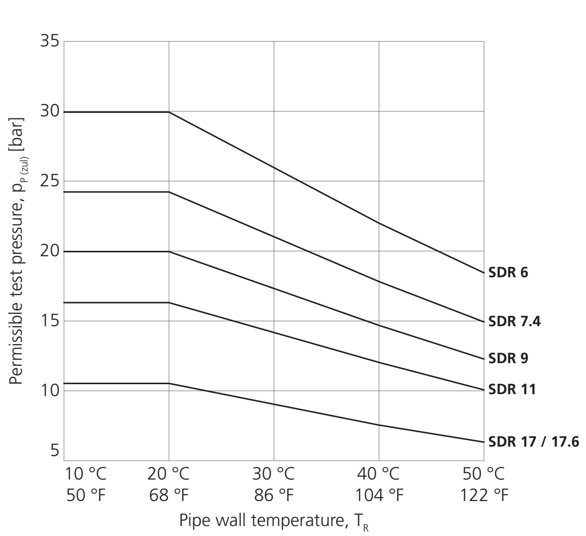

Figure F.19: Test pressure curves for piping made of PP-Pure and Polypure (PP-R).

6.5.3 Remarks about the pipe wall temperature (testing temperature)

If it is assumed that the pipe wall temperature (testing temperature) will change during the internal pressure test, the test pressure must relate to the maximum temperature to be expected.

If a temperature, that leads to a higher pipe wall temperature T_R than assumed, is measured on the pipe surface when taking control measurements during the test, the test pressure must immediately after the measurement be reduced to the value in Figure F.18 / Figure F.19 or calculated value corresponding to that temperature.

In a simplified form, the pipe wall temperature may be assumed to be the arithmetic mean between T_i and T_{Ra}.

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

Formula F.4: Mean pipe wall temperature.

T_i temperature of the testing medium inside the pipe [°C]
T_R mean pipe wall temperature [°C]
T_{Ra} temperature at the pipe surface [°C]

Attention must be paid not only to the influence of the temperature on the test pressure of the plastic piping but also, particularly in the case of the contraction procedure, to ensuring a pipe wall temperature which is as constant as possible.

In the case of plastic piping to be tested outdoors, it is a problem to keep the pipe wall temperature constant and this may restrict the use of the test procedure concerned. In order to ensure the meaningfulness of the test, it is imperative to record the temperatures as listed in the example of the test record sheet according to the example in the DVS 2210-1 supplement 2:2004 (D) appendix.

If it is anticipated that the mean pipe wall temperature of a pipe section will be higher than the temperature resulting from Formula F.4 because of direct sunlight, the test pressure must be lowered correspondingly.

The measurement and recording of the temperature inside the pipe (temperature of the testing medium) requires the positioning of a measuring nozzle at the least favourable position in the pipe system. If it is ensured, by taking suitable measures, that the pipe wall temperature does not rise above a predetermined maximum value, it is not necessary to measure the temperature of the testing medium. In the case of piping made of plastics with a low notched impact strength (e.g PP-H), an internal pressure test is not advised for pipe wall temperatures <10 °C.

6.5.4 Remarks about automatically operating testing facilities

If automatically operating facilities are used for internal pressure tests, the visual inspections during the test may be reduced to two operations in total. The inspections must be carried out 1 h after the test pressure has been reached as well as at the end of the main test. The prerequisites for reducing the inspections are that the test pressure and temperatures (T_i , T_{Ra} and $T_{ambient}$) are recorded continuously and that the water inflow is automatically stopped in the event of a leak.

6.5.5 Remarks about the test duration

The test duration specified in Table F.6 relates to a test without interruptions. If leaks or any other incidents require an interruption of the test or the temporary lowering of the test pressure, the corresponding interruption times are not included in the overall test duration.

If an internal pressure test has already been carried out on the piping that had subsequently been modified, which necessitates another test, this can be performed using the same conditions as the first test.

The prerequisite for internal pressure tests that are conducted over extended times or are repeated is that the entire test duration does not exceed 100 h, on which Formula F.3 is based.

Particular attention must be paid to the fact that the loading time of t = 100 h assumed for calculations, i.e. the maximum test duration, relates to a permissible test pressure at a defined pipe wall temperature. If the correlation between the test pressure and the test temperature changes, this may lead to the shortening of the maximum test duration to <100 h. In general, it is necessary to avoid any extension to the test duration specified in Table F.6.

In order to prevent any damage to the piping during the test, all operations and their associated times must be recorded continuously and subjected to an accompanying loading analysis.

G Product information

1 Ball valves

Figure G.1: Ball valves in PVDF-UHP and PP-Pure.

1.1 Features

- Radial installation or removal
- Ball double-sided blocked
- Recommended flow direction on the body
- Full sectional area of flow (nominal bore)
- Floating ball
- Safety handle system

1.2 Component parts

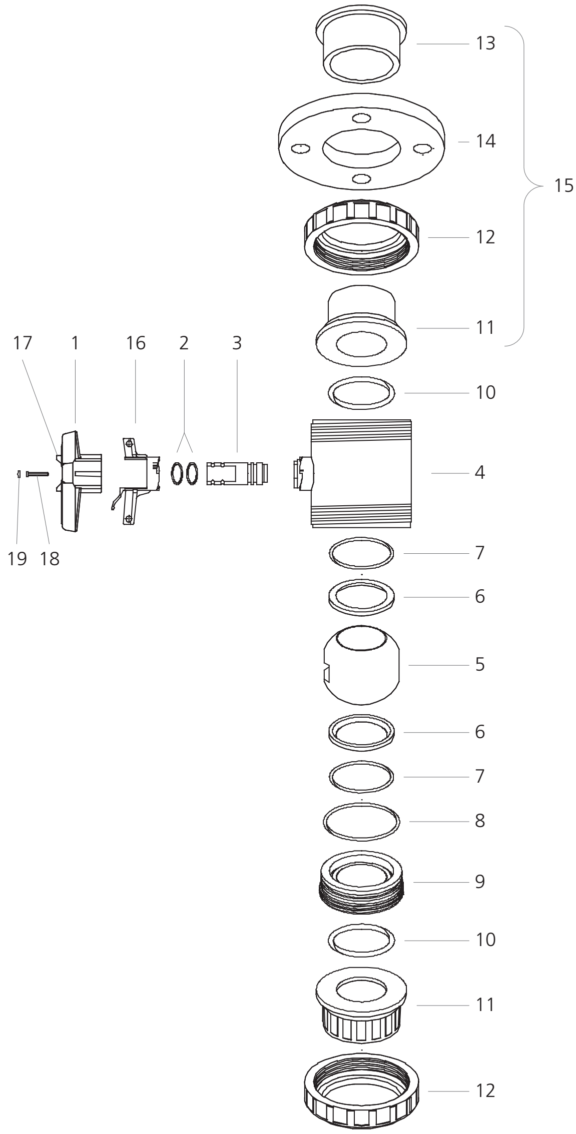

Figure G.2: Exploded assembly drawing.

1. Handle	12. Union
2. O-ring	13. Flange adapter / stub flange
3. Shaft	14. Flange
4. Body	15. Connection set
5. Ball	16. Spring loaded locking insert
6. Ball seating joints	17. Key for opening thrust collar
7. O-ring	18. Screw
8. O-ring	19. Cover
9. Thrust collar	
10. O-ring	
11. End connection	

1.3 Technical data

- **Dimensions:**
  OD 20 mm, OD ½" (DN 15) to
  OD 90 mm, OD 3" (DN 80)
- **Body materials:**
  PVDF-UHP
  PP-Pure
- **Sealing material:**
  FPM (Viton®)
- **Ball seating joints:**
  PTFE (Teflon®)
- **End connections:**
  Union with fusion spigots
  Flange connections in DIN (ANSI and JIS on request)
- **Operating pressure/temperature for water:**
  PVDF at 20 °C (68 °F)

OD 20 mm - OD 75 mm:	MOP 16 bar
OD ½" - OD 2½":	MOP 232 psi
OD 90 mm:	MOP 10 bar
OD 3":	MOP 145 psi

PP-Pure at 20 °C (68 °F)

OD 20 mm - OD 75 mm:	MOP 10 bar
OD ½" - OD 2½":	MOP 145 psi
OD 90 mm:	MOP 6 bar
OD 3":	MOP 87 psi

For other temperatures see Figure G.5 and Figure G.6

1.4 Flow characteristic

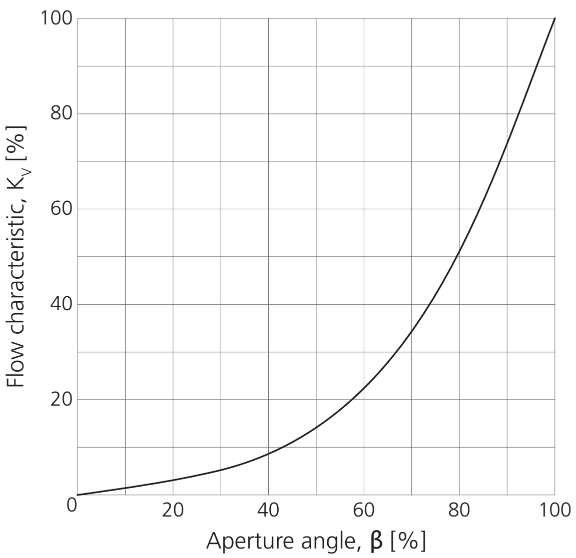

Figure G.3: Flow characteristic.

1.5 Flow rate - pressure loss - diagram

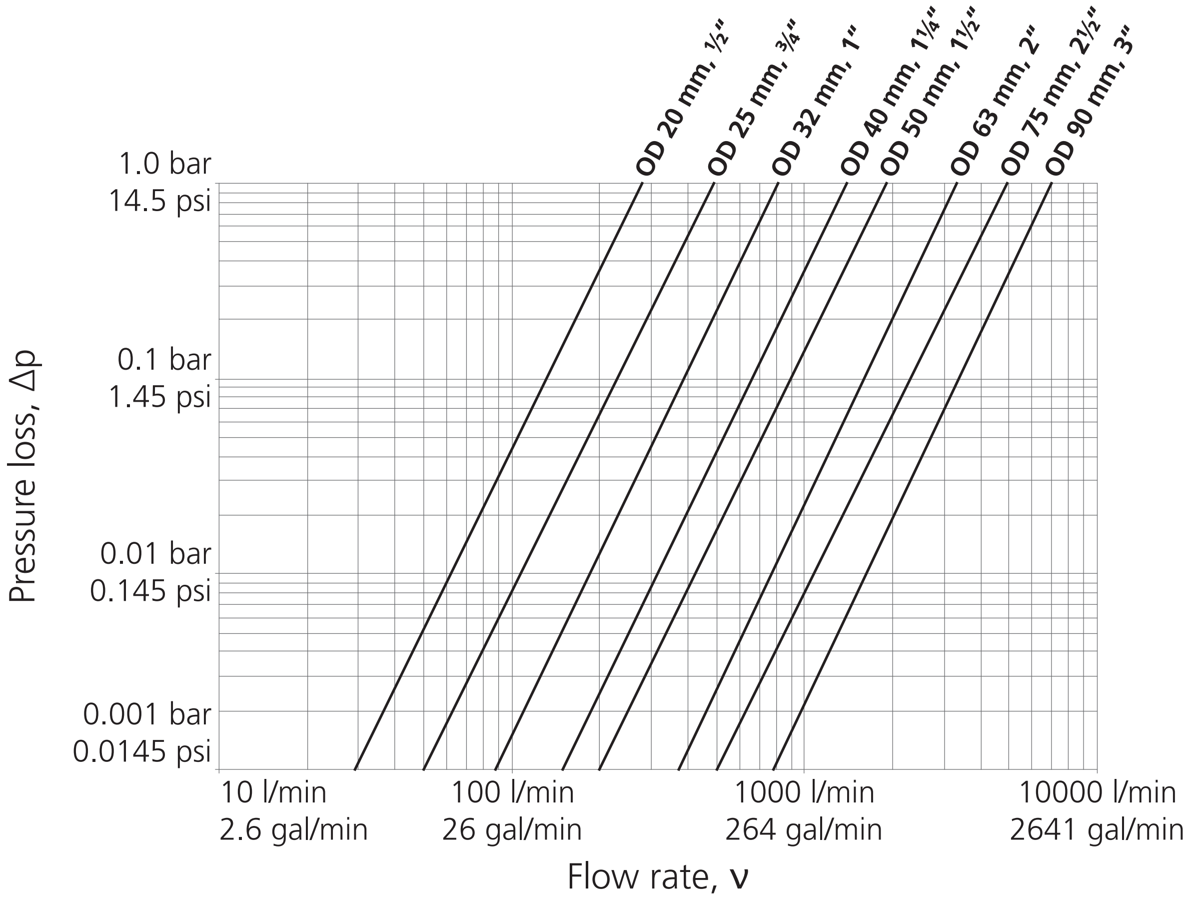

Figure G.4: Flow rate - pressure loss - diagram for the medium water at +20 °C (68 °F).

1.6 Pressure - temperature - diagram

1.6.1 PVDF-UHP

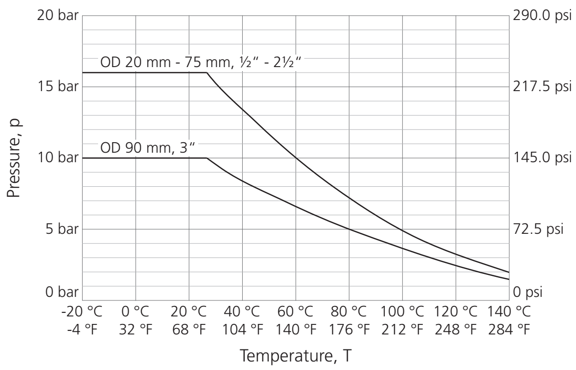

Figure G.5: Pressure - temperature - diagram of PVDF-UHP valid for water and a service life of 25 years.

1.6.2 PP-Pure

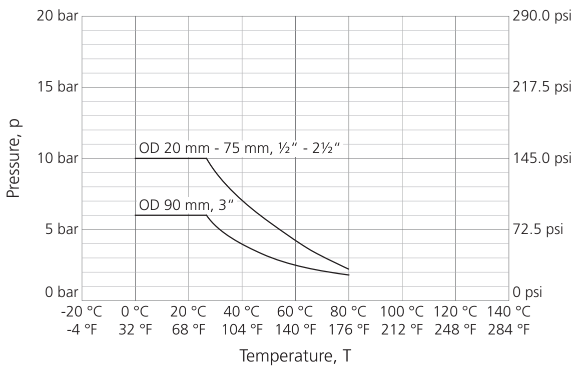

Figure G.6: Pressure - temperature - diagram of PP-Pure valid for water and a service life of 25 years.

2 Sampling valve

Figure G.7: Sampling valve in PVDF-UHP.

2.1 Features

- Lock and metering ring
- Extensive range of accessories
- Additional safety ring
- Without lock and metering ring full sectional area of flow possible
- Two thread standards are available
  - BSP
  - NPT
- Valve is designed to be used together with the PVDF-UHP instrumentation fitting

2.2 Component parts

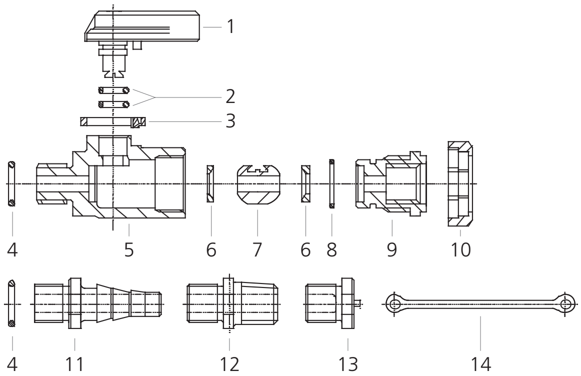

Figure G.8: Exploded assembly drawing.

1. Handle	8. O-ring
2. O-ring	9. Thrust collar
3. Lock and meter ring	10. Circlip
4. O-ring	11. Hose adaptor
5. Body	12. Thread adaptor
6. Ball seating joints	13. End plug
7. Ball	14. Clip tie

2.3 Technical data

- **Dimension:**
  OD 10 mm, OD ¼“ (DN 6)
- **Body material:**
  PVDF-UHP
- **Sealing material:**
  FPM (Viton®)
- **Ball seating joint:**
  PTFE (Teflon®)
- **End connections:**
  Thread connection with hose adaptor
  Thread adaptor (BSP-NPT)
  End plug
- **Operating pressure/temperature for water:**
  10 bar (145 psi) at 20 °C (68 °F)
  For other temperatures see Figure G.10

2.4 Flow characteristic

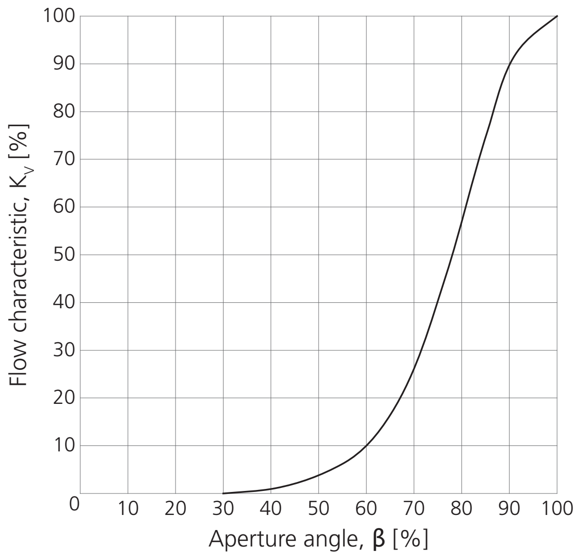

Figure G.9: Flow characteristic.

2.5 Pressure - temperature - diagram

2.5.1 PVDF-UHP

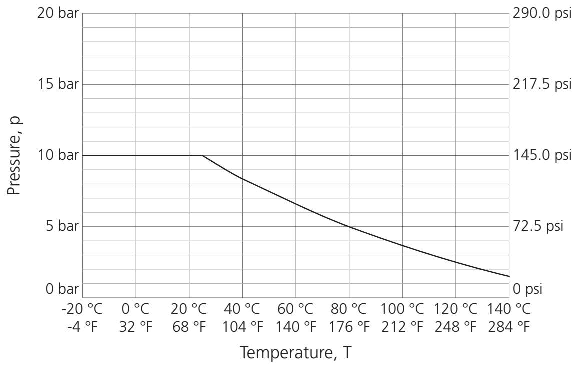

Figure G.10: Pressure - temperature - diagram of PVDF-UHP valid for water and a service life of 25 years.

3 Diaphragm valves, manual

Figure G.11: Manually operated diaphragm valves.

3.1 Features

- Corrosion resistant, only valve body and diaphragm in contact with the media
- Suitable for chemical aggressive media
- Excellent flow characteristics
- Radial installation or removal with union and flange connections
- Easy replacement of the diaphragm
- Safety handle system and positioning indicator

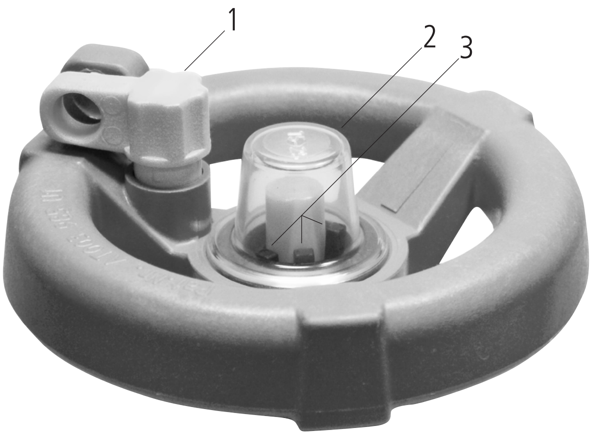

Figure G.12: Hand wheel diaphragm valve.

1. Locking device	3. Opening position indicator of the diaphragm (75 %, 50 %, 25 %)
2. Sight glass	

3.2 Component parts

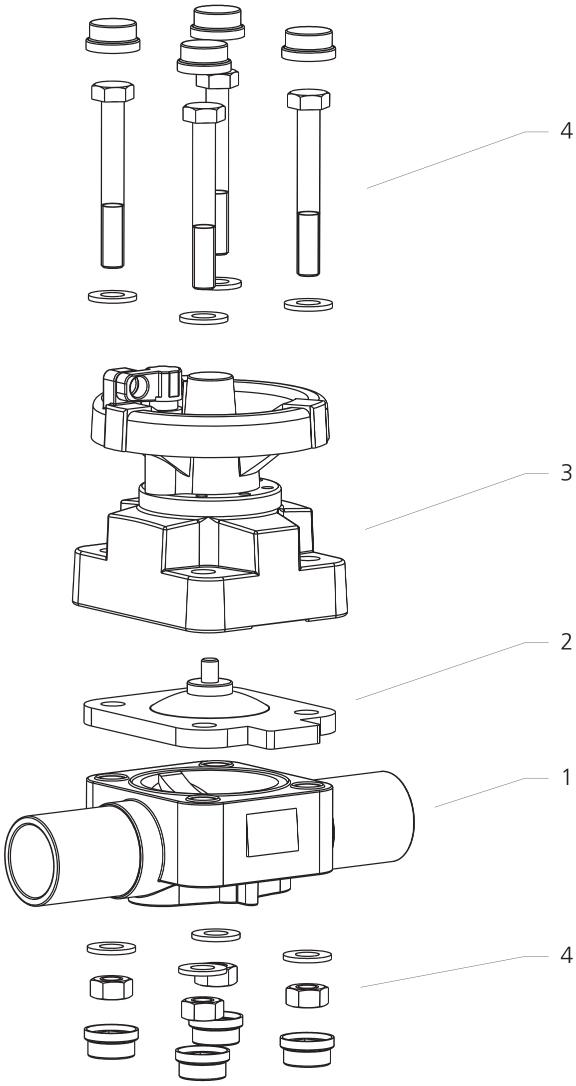

Figure G.13: Exploded assembly drawing.

1. Valve body	4. Screw set with cover
2. Diaphragm	
3. Manual actuator	

3.3 Technical data

- **Dimensions:**
  OD 20 mm, OD ½" (DN 15) to
  OD 140 mm, OD 5" (DN 125)
- **Body materials:**
  PVDF-UHP
  PP-Pure
  Polypure
  ECTFE
- **Diaphragm materials:**
  EPDM
  PTFE with EPDM backing diaphragm
- **End connections:**
  Fusion spigots
  Unions with fusion spigots
  Flange connections in DIN, ANSI and JIS
- **Operating pressure/temperature for water:**
  10 bar (145 psi) at 20 °C (68 °F)
  For other temperatures see Figure G.16 and Figure G.17

3.4 Flow characteristic

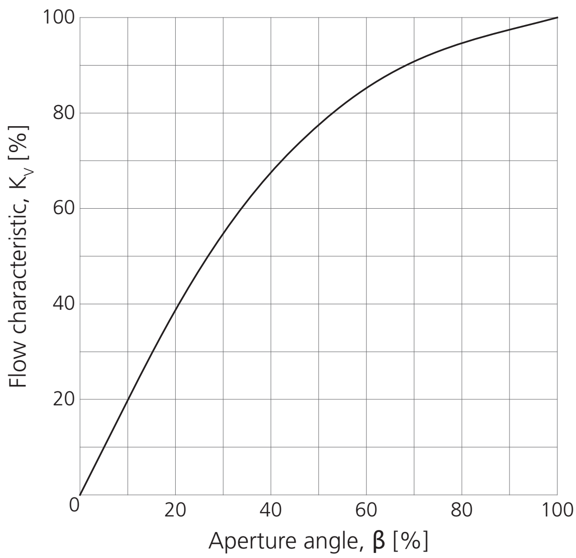

Figure G.14: Flow characteristic.

3.5 Flow rate - pressure loss - diagram

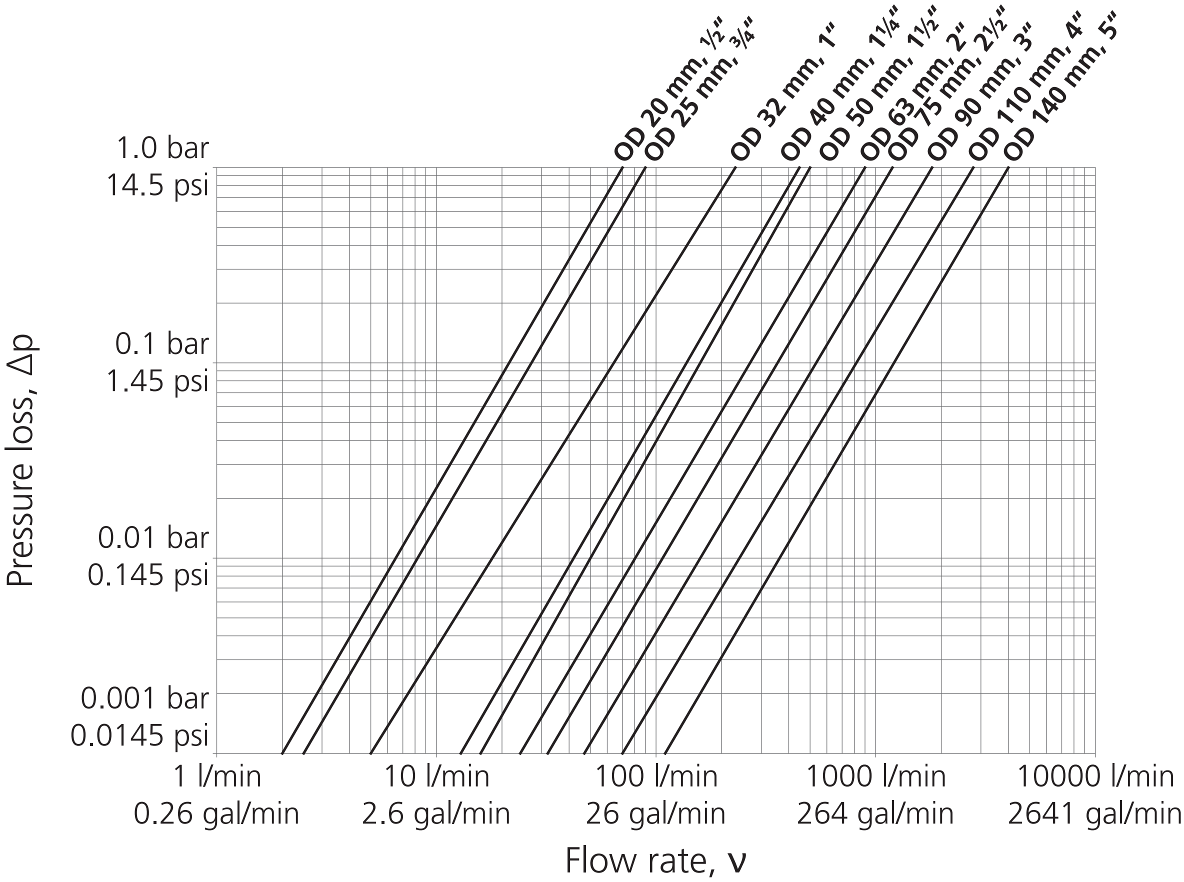

Figure G.15: Flow rate - pressure loss - diagram for the medium water at +20 °C (68 °F).

3.6 Flow rate at different opening positions

OD		Opening positions							
		25 %		50 %		75 %		100 %	
		Flow characteristic		Flow characteristic		Flow characteristic		Flow characteristic	
		K_v	C_v	K_v	C_v	K_v	C_v	K_v	C_v
[mm]	[in]	[l/min]	[US gal/min]	[l/min]	[US gal/min]	[l/min]	[US gal/min]	[l/min]	[US gal/min]
20	½"	36	9.51	57	15.06	68	17.97	72	19.02
25	¾"	47	12.42	74	19.55	88	23.25	93	24.57
32	1"	110	29.06	176	46.50	210	55.48	221	58.39
40	1 ¼"	225	59.45	358	94.58	428	113.08	450	118.89
50	1 ½"	250	66.05	400	105.68	475	125.50	500	132.10
63	2"	438	115.72	695	183.62	831	219.55	875	231.18
75	2 ½"	543	143.46	935	247.03	1085	286.66	1205	318.36
90	3"	744	196.56	1056	279.00	1224	323.38	1360	359.31
110	4"	1685	445.18	2800	739.76	3335	881.11	3750	990.75
140	5"	1790	472.92	2985	788.64	3540	935.27	3980	1051.52

Table G.1: Flow rate at different opening positions.

3.7 Pressure - temperature - diagram

3.7.1 PVDF-UHP

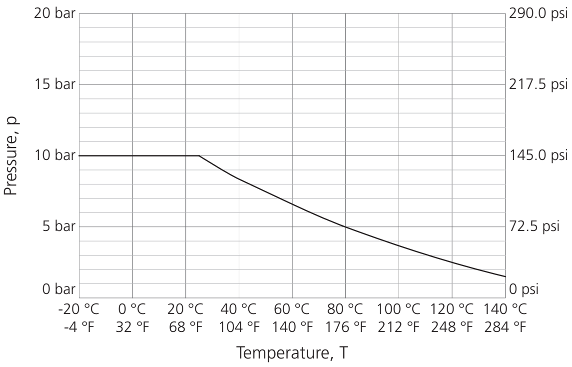

Figure G.16: Pressure - temperature - diagram of PVDF-UHP valid for water and a service life of 25 years.

3.7.2 PP-Pure & Polypure

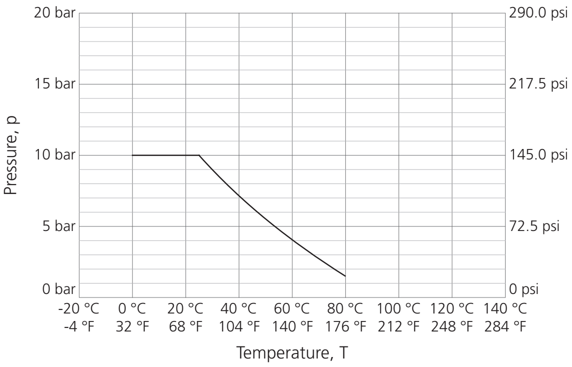

Figure G.17: Pressure - temperature - diagram of PP-Pure and Polypure valid for water and a service life of 25 years.

3.8 Operating torque

3.8.1 EPDM diaphragm

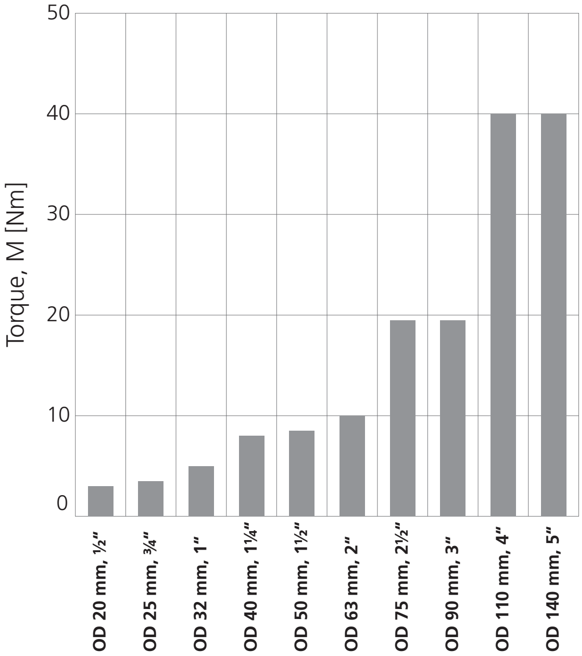

Figure G.18: Required torque of the hand wheel to close the EPDM diaphragm valve.

3.8.2 EPDM/PTFE diaphragm

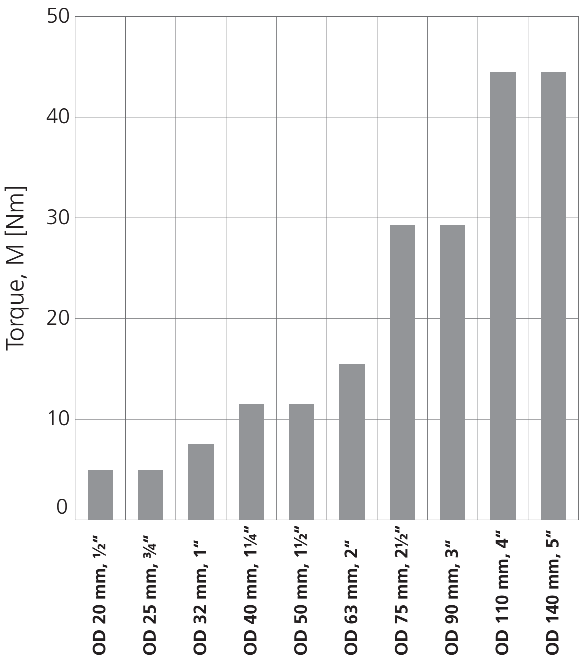

Figure G.19: Required torque of the hand wheel to close the EPDM/PTFE diaphragm valve.

4 Diaphragm valves, pneumatic

Figure G.20: Pneumatically operated diaphragm valve in PVDF.

4.1 Features

- Fast opening and closing of the valve
- Positioning indicator
- Suitable for chemical aggressive media
- Easy replacement of the diaphragm
- Control air connection made of stainless steel

4.2 Component parts

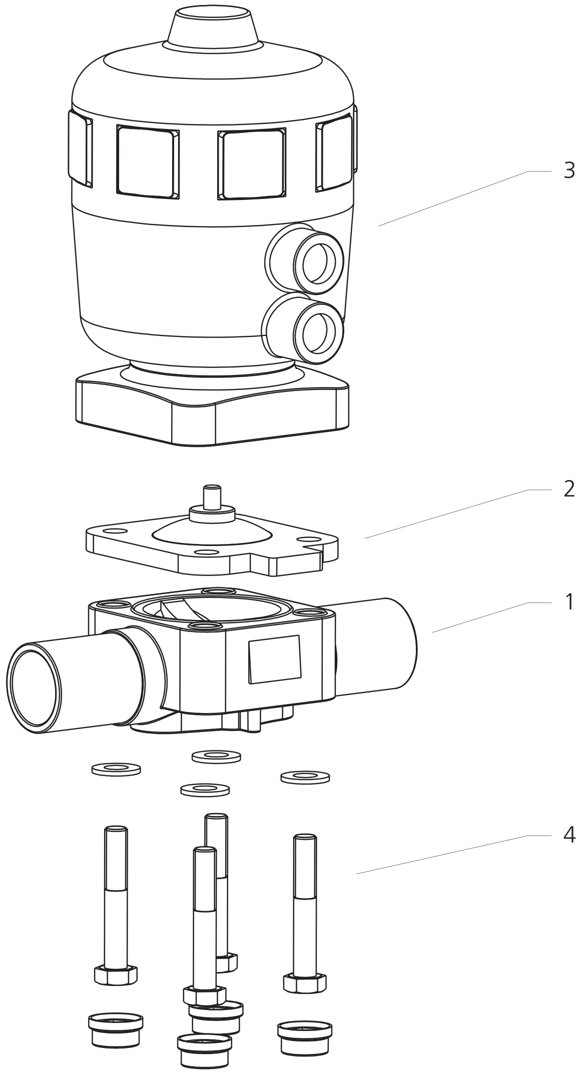

Figure G.21: Exploded assembly drawing.

1. Valve body	4. Screw set with cover
2. Diaphragm	
3. Pneumatic actuator	

4.3 Technical data

- **Dimensions:**
  OD 20 mm, OD ½" (DN 15) to
  OD 63 mm, OD 2" (DN 50)
- **Body materials:**
  PVDF-UHP
  PP-Pure (on request)
  Polypure (on request)
  ECTFE
- **Diaphragm materials:**
  EPDM
  PTFE with EPDM backing diaphragm

- **End connections:**
  Fusion spigots
  Union with fusion spigots
  Flange connection in DIN, ANSI and JIS
- **Operating pressure/temperature for water:**
  10 bar (145 psi) at 20 °C (68 °F)
  For other temperatures see Figure G.24 and Figure G.25
- **Control function:**
  NC (A): Fail safe closed
  NO (B): Fail safe open
  DA (I): Double acting
- **Control fluid:**
  Neutral gases and air
- **Ambient temperature for actuator body material:**
  PA, glass fibre reinforced
  -10 °C (+14 °F) to
  +60 °C (+140 °F)

4.4 Flow characteristic

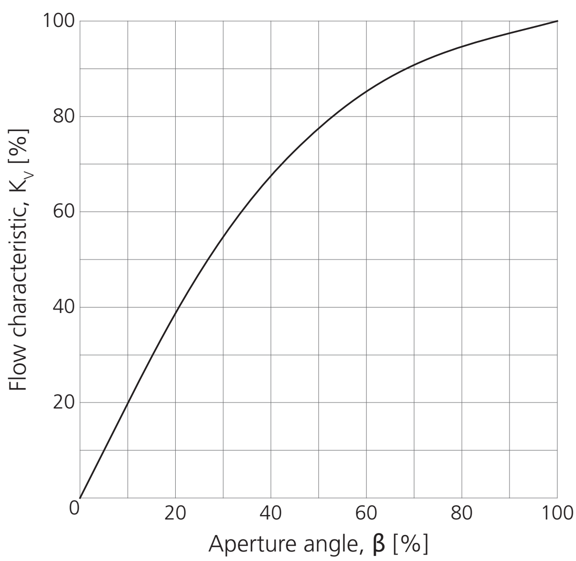

Figure G.22: Flow characteristic.

4.5 Flow rate - pressure loss - diagram

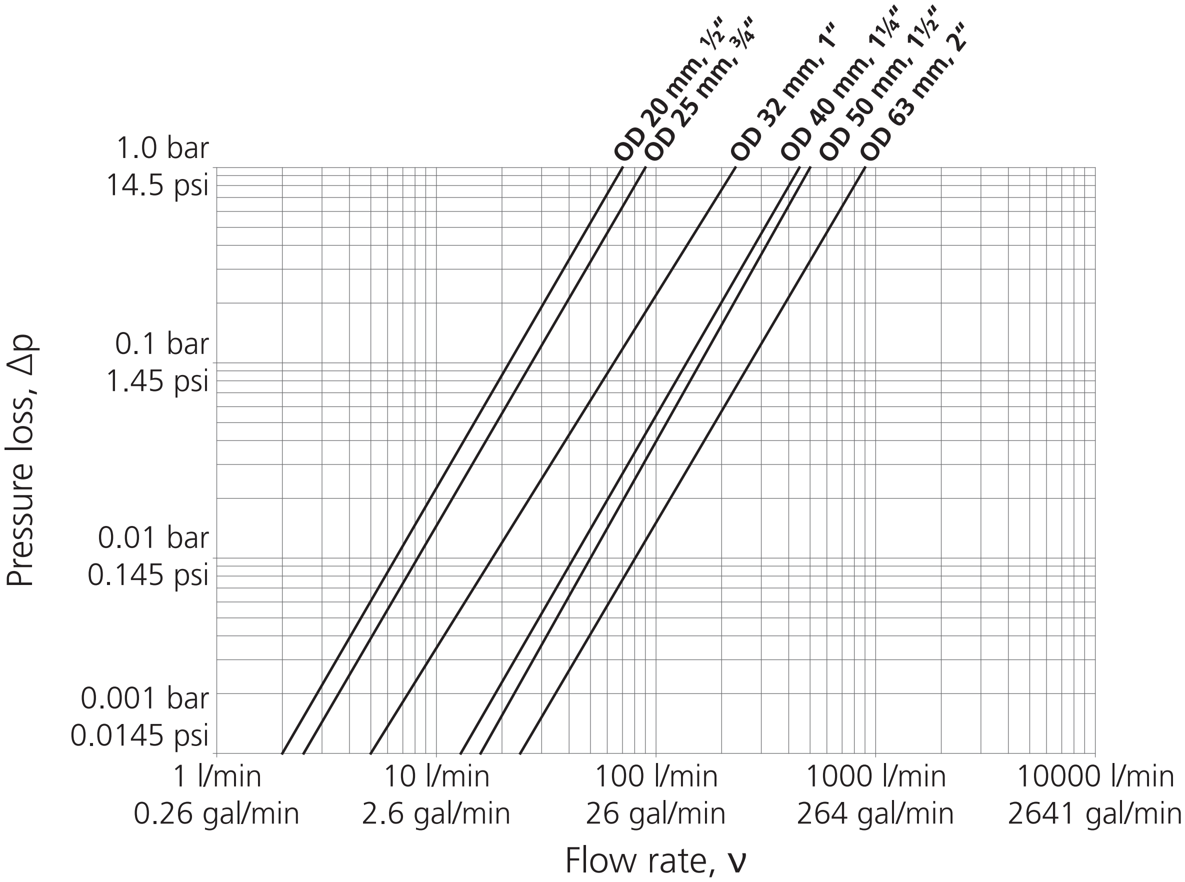

Figure G.23: Flow rate - pressure loss - diagram for the medium water at +20 °C (68 °F).

4.6 Pressure - temperature - diagram

4.6.1 PVDF-UHP

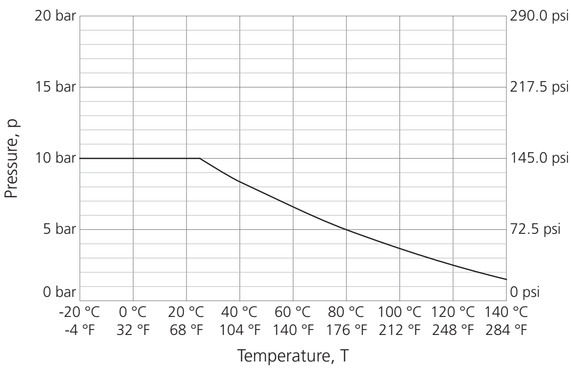

Figure G.24: Pressure - temperature - diagram of PVDF valid for water and a service life of 25 years.

4.6.2 PP-Pure and Polypure

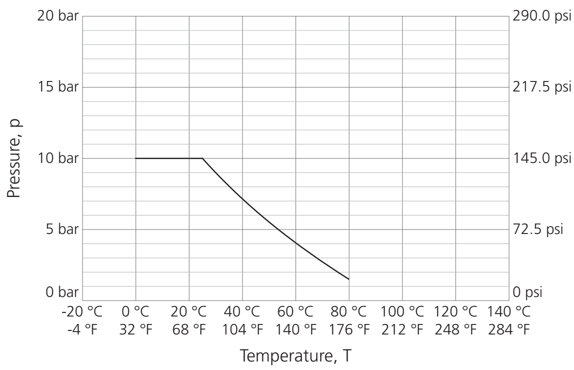

Figure G.25: Pressure - temperature - diagram of PP-Pure and Polypure valid for water and a service life of 25 years.

4.7 Control pressure for actuators

OD		Permissible control pressure for pneumatic actuators			
		Mimimum		Maximum	
[mm]	[in]	[bar]	[psi]	[bar]	[psi]
20	½"	2	29	10	145
25	¾"	2	29	10	145
32	1"	2	29	10	145
40	1¼"	2	29	7	101.5
50	1½"	2	29	7	101.5
63	2"	2	29	7	101.5

Table G.2: Permissible control pressure.

4.7.1 NC (fail safe closed)

OD		Minimum control pressure at a minimum/maximum operating pressure			
		Minimum operating pressure		Maximum operating pressure	
[mm]	[in]	[bar]	[psi]	[bar]	[psi]
20	½"	5	72.5	4	58
25	¾"	5	72.5	4	58
32	1"	5.5	79.7	4.5	65.2
40	1¼"	5.5	79.7	4	58
50	1½"	5.5	79.7	4	58
63	2"	5.5	79.7	3	43.5

Table G.3: Minimum control pressure for opening NC diaphragm valves.

4.7.2 NO (fail safe open)

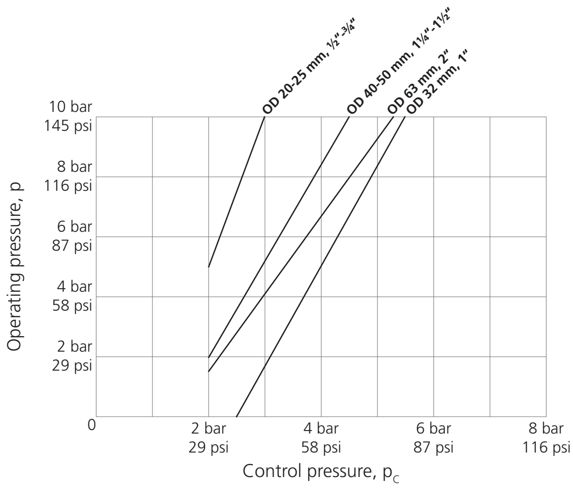

Figure G.26: NO control pressure for EPDM diaphragms.

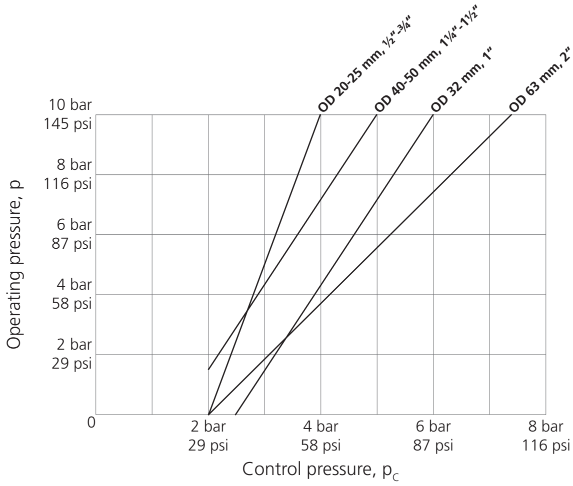

Figure G.27: NO control pressure for EPDM/PTFE diaphragms.

4.7.3 DA (double acting)

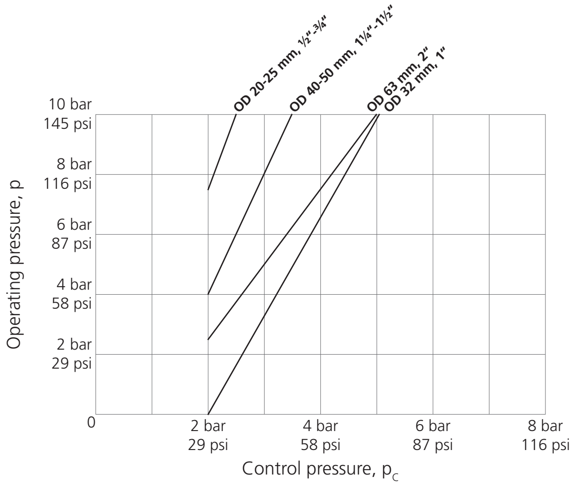

Figure G.28: DA control pressure for EPDM diaphragms.

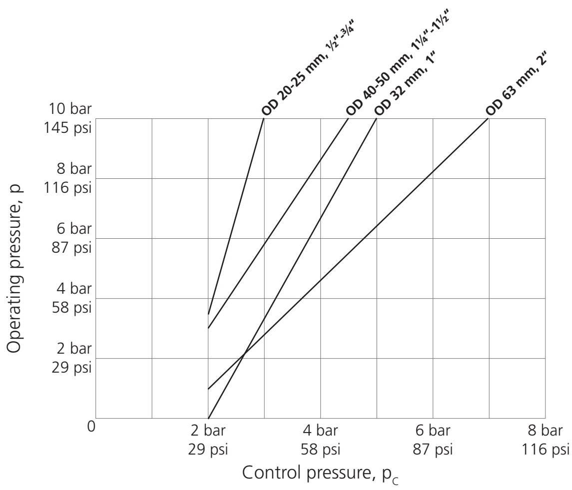

Figure G.29: DA control pressure for EPDM/PTFE diaphragms.

5 T-diaphragm valves, manual

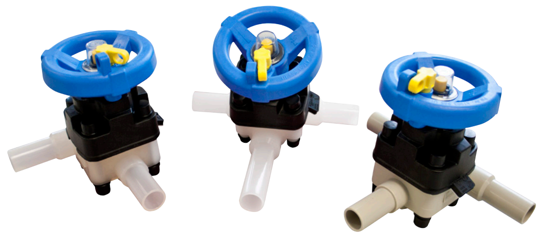

Figure G.30: T-diaphragm valve.

5.1 Features

- Zero dead leg valve
- Safety handle system and positioning indicator
- Corrosion resistant
- Suitable for chemical aggressive media
- Easy replacement of the diaphragm

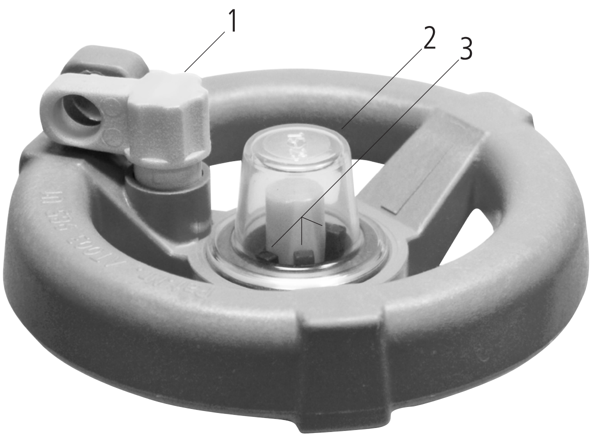

Figure G.31: Hand wheel diaphragm valve.

1. Locking device	3. Opening position indicator of the diaphragm (75 %, 50 %, 25 %)
2. Sight glass	

5.2 Component parts

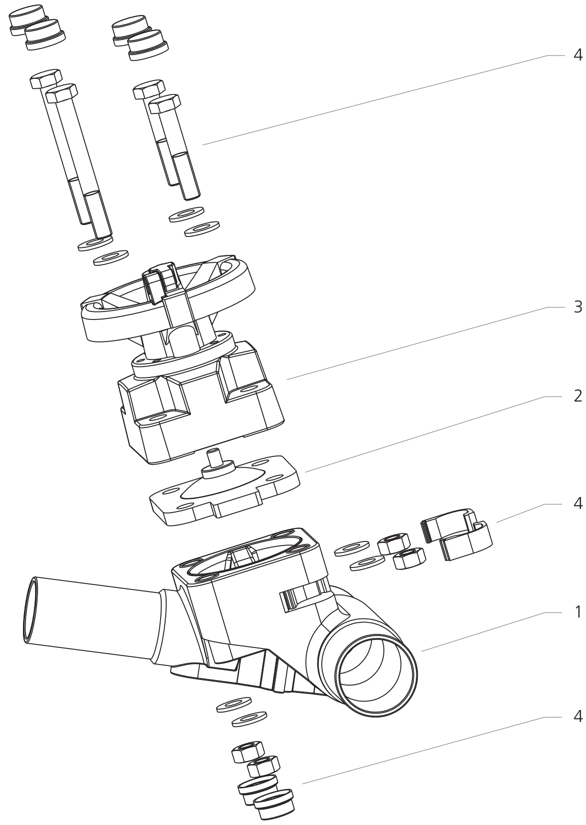

Figure G.32: Exploded assembly drawing using the example of PVDF-UHP.

1. Valve body	4. Screw set with cover
2. Diaphragm	
3. Hand wheel actuator	

5.3 Technical data

- **Dimensions:**
  OD 20/20 mm, OD ½"/½" (DN 15/15) to
  OD 110/63 mm, OD 4"/2" (DN 100/50)
- **Body materials:**
  PVDF-UHP
  PP-Pure
  Polypure
- **Diaphragm materials:**
  EPDM
  PTFE with EPDM backing diaphragm
- **End connections:**
  Fusion spigots

- **Operating pressure/temperature for water:**
  10 bar (145 psi) at 20 °C (68 °F)
  For other temperatures see Figure G.33 and Figure G.34

5.4 Pressure - temperature - diagram

5.4.1 PVDF-UHP

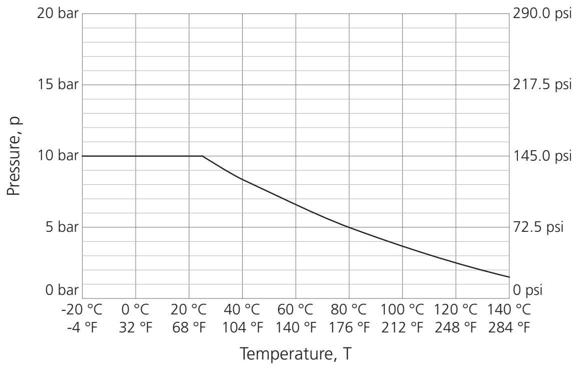

Figure G.33: Pressure - temperature - diagram of PVDF valid for water and a service life of 25 years.

5.4.2 PP-Pure and Polypure

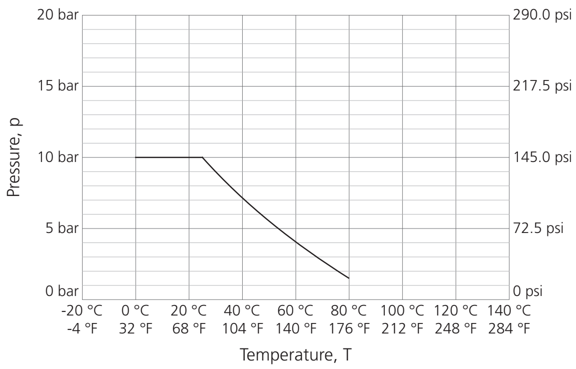

Figure G.34: Pressure - temperature - diagram of PP-Pure and Polypure valid for water and a service life of 25 years.

5.5 Flow rates of PVDF T-diaphragm valves

OD		Flow characteristic	
		K_v	C_v
[mm]	[in]	[l/min]	[US gal/min]
20/20	½"/½"	n.a.	n.a.
25/20	¾"/½"	58	15.32
25/25	¾"/¾"	58	15.32
32/20	1"/½"	184	48.61
32/25	1"/¾"	188	49.67
32/32	1"/1"	195	51.52
40/20	1¼"/½"	199	52.58
40/25	1¼"/¾"	205	54.16
40/32	1¼"/1"	210	55.48
40/40	1¼"/1¼"	n.a.	n.a.
50/20	1½"/½"	216	57.07
50/25	1½"/¾"	220	58.12
50/32	1½"/1"	228	60.24
50/50	1½"/1½"	n.a.	n.a.
63/20	2"/½"	227	59.97
63/25	2"/¾"	233	61.56
63/32	2"/1"	240	63.41
63/40	2"/1¼"	435	114.93
63/50	2"/1½"	503	132.89
63/63	2"/2"	574	151.65
75/25	2½"/¾"	243	64.20
75/32	2½"/1"	250	66.05
75/40	2½"/1¼"	447	118.10
75/50	2½"/1½"	520	137.38
75/63	2½"/2"	582	153.76
90/20	3"/½"	n.a.	n.a.
90/25	3"/¾"	249	65.79
90/32	3"/1"	258	68.16
90/40	3"/1¼"	460	121.53
90/50	3"/1½"	532	140.55
90/63	3"/2"	601	158.78
110/20	4"/¾"	n.a.	n.a.
110/25	4"/¾"	256	67.64
110/32	4"/1"	265	70.01
110/40	4"/1¼"	n.a.	n.a.
110/50	4"/1½"	548	144.78
110/63	4"/2"	623	164.60

Table G.4: Flow rates of PVDF T-diaphragm valves at 100 % opening position.

6 T-diaphragm valves, pneumatic

Figure G.35: Pneumatically operated T-diaphragm valve.

6.1 Features

- Fast opening and closing of the valve
- Zero dead leg valve
- Corrosion resistant
- Suitable for chemically aggressive media
- Positioning indicator
- Control air connection made of stainless steel

6.2 Component parts

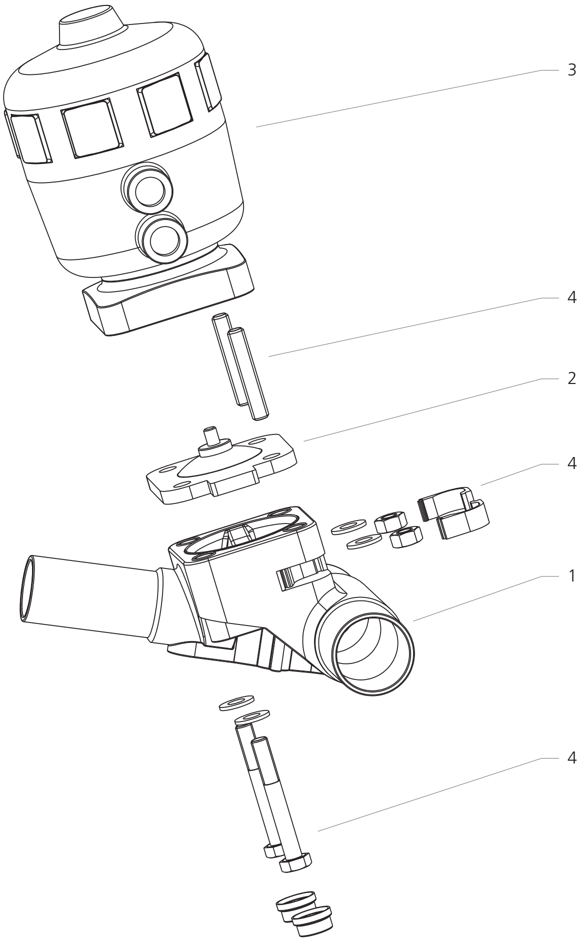

Figure G.36: Exploded assembly drawing using the example of PVDF-UHP.

1. Valve body	4. Screw set with cover
2. Diaphragm	
3. Pneumatic actuator	

6.3 Technical data

- **Dimensions:**
  OD 20/20 mm, OD ½"/½" (DN 15/15) to
  OD 110/63 mm, OD 4"/2" (DN 100/50)
- **Body materials:**
  PVDF-UHP
  PP-Pure (on request)
  Polypure (on request)
- **Diaphragm materials:**
  EPDM
  PTFE with EPDM backing diaphragm
- **End connections:**
  Fusion spigots

- **Operating pressure/temperature for water:**
  10 bar (145 psi) at 20 °C (68 °F)
  For other temperatures see Figure G.37 and Figure G.38
- **Control function:**
  NC (A): Fail safe closed
  NO (B): Fail safe open
  DA (I): Double acting
- **Control fluid:**
  Neutral gases and air
- **Ambient temperature for actuator body material:**
  PA, glass fibre reinforced
  -10 °C (+14 °F) to
  +60 °C (140 °F)

6.4 Pressure - temperature - diagram

6.4.1 PVDF-UHP

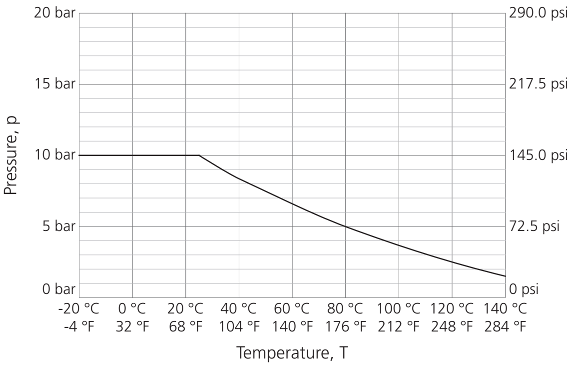

Figure G.37: Pressure - temperature - diagram of PVDF valid for water and a service life of 25 years.

6.4.2 PP-Pure and Polypure

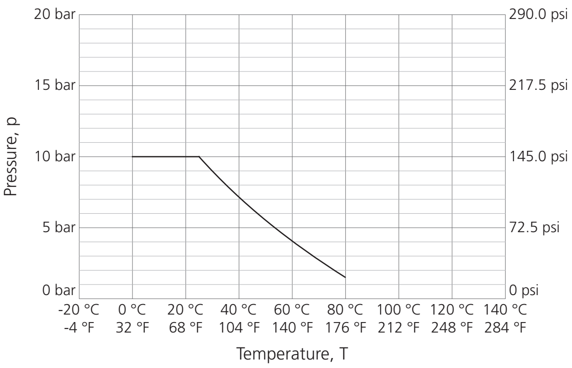

Figure G.38: Pressure - temperature - diagram of PP-Pure and Polypure valid for water and a service life of 25 years.

6.5 Flow rates of PVDF T-diaphragm valves

OD		Flow characteristic	
		K_v	C_v
[mm]	[in]	[l/min]	[US gal/min]
20/20	½"/½"	n.a.	n.a.
25/20	¾"/½"	58	15.32
25/25	¾"/¾"	58	15.32
32/20	1"/½"	184	48.61
32/25	1"/¾"	188	49.67
32/32	1"/1"	195	51.52
40/20	1¼"/½"	199	52.58
40/25	1¼"/¾"	205	54.16
40/32	1¼"/1"	210	55.48
40/40	1¼"/1¼"	n.a.	n.a.
50/20	1½"/½"	216	57.07
50/25	1½"/¾"	220	58.12
50/32	1½"/1"	228	60.24
50/50	1½"/1½"	n.a.	n.a.
63/20	2"/½"	227	59.97
63/25	2"/¾"	233	61.56
63/32	2"/1"	240	63.41
63/40	2"/1¼"	435	114.93
63/50	2"/1½"	503	132.89
63/63	2"/2"	574	151.65
75/25	2½"/¾"	243	64.20
75/32	2½"/1"	250	66.05
75/40	2½"/1¼"	447	118.10
75/50	2½"/1½"	520	137.38
75/63	2½"/2"	582	153.76
90/20	3"/½"	n.a.	n.a.
90/25	3"/¾"	249	65.79
90/32	3"/1"	258	68.16
90/40	3"/1¼"	460	121.53
90/50	3"/1½"	532	140.55
90/63	3"/2"	601	158.78
110/20	4"/¾"	n.a.	n.a.
110/25	4"/¾"	256	67.64
110/32	4"/1"	265	70.01
110/40	4"/1¼"	n.a.	n.a.
110/50	4"/1½"	548	144.78
110/63	4"/2"	623	164.60

Table G.5: Flow rates of PVDF T-diaphragm valves at 100 % opening position.

6.6 Control pressure for actuators

OD		Permissible control pressure for pneumatic actuators			
		Mimimum		Maximum	
[mm]	[in]	[bar]	[psi]	[bar]	[psi]
20	½"	2	29	10	145
25	¾"	2	29	10	145
32	1"	2	29	10	145
40	1¼"	2	29	7	101.5
50	1½"	2	29	7	101.5
63	2"	2	29	7	101.5

Table G.6: Permissible control pressure.

6.6.1 NC (fail safe closed)

OD		Minimum control pressure at a minimum/maximum operating pressure			
		Minimum operating pressure		Maximum operating pressure	
[mm]	[in]	[bar]	[psi]	[bar]	[psi]
20	½"	5	72.5	4	58
25	¾"	5	72.5	4	58
32	1"	5.5	79.7	4.5	65.2
40	1¼"	5.5	79.7	4	58
50	1½"	5.5	79.7	4	58
63	2"	5.5	79.7	3	43.5

Table G.7: Minimum control pressure for opening NC diaphragm valves.

6.6.2 NO (fail safe open)

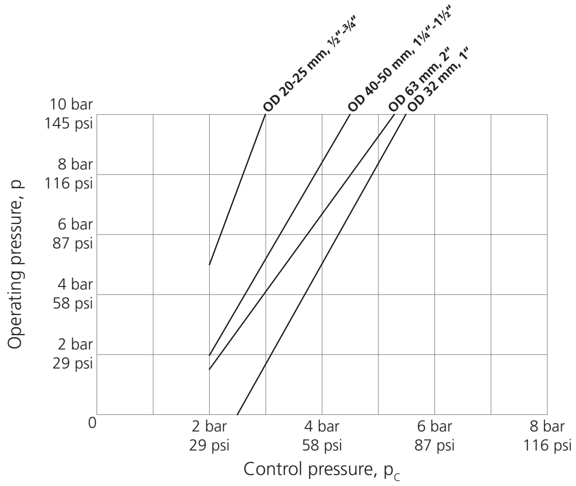

Figure G.39: NO control pressure for EPDM diaphragms.

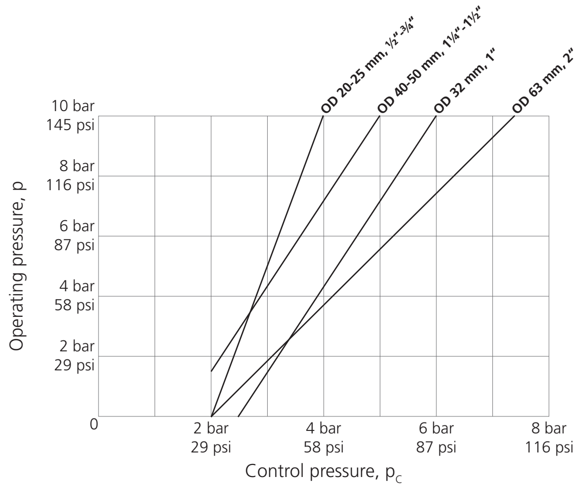

Figure G.40: NO control pressure for EPDM/PTFE diaphragms.

6.6.3 DA (double acting)

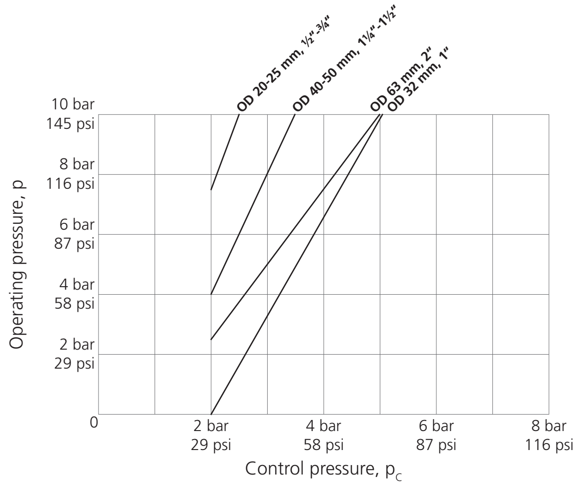

Figure G.41: DA control pressure for EPDM diaphragms.

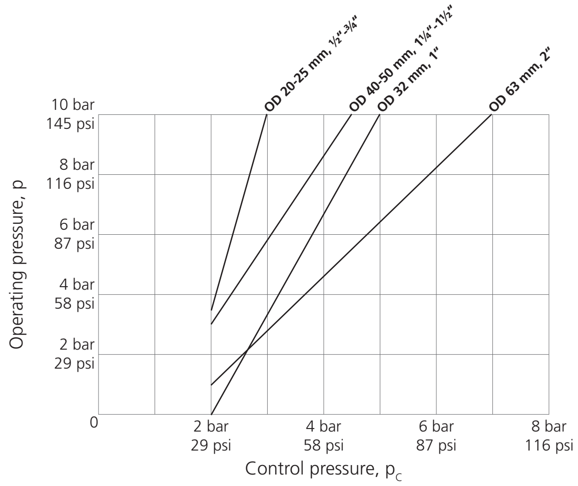

Figure G.42: DA control pressure for EPDM/PTFE diaphragms.

7 Pneumatic actuator accessories

7.1 Electrical position indicator

Figure G.43: Electrical position indicator.

7.1.1 Features

- Simple installation, convertible or retrofittable
- Self-adjusting trip cam for „closed" position
- LEDs provide the local operational status and position indication
- Compact IP65 enclosure
- Mechanical or inductive limit switches

7.1.2 Technical data

- **Material body:**
  Polyamide
- **Material cover:**
  Polycarbonate
- **Electrical connection:**
  PG11 union / cable screwing M16 × 1.5
- **Ambient temperature:**
  -20 °C (-4 °F) to +60 °C (+140 °F)
- **Protection class:**
  IP65
- **LED display:**
  green = valve open
  red = valve closed
  orange = supply voltage
- **Mechanical limit switch**
  - 2 mechanical limit switches (open and closed)
  - Power supply:
    12 V - 48 V (AC/DC)
    110 V - 250 V (AC/DC)
- **Inductive limit switch**
  with 3-wire technology
  - 2 inductive limit switches (open and closed)
  - Output version:
    PNP (normally open contact)
  - Power supply:
    10 V - 30 V (DC)

7.2 External magnetic-inductive position indicator

Figure G.44: External magnetic-inductive position indicator.

7.2.1 Features

The magnetic-inductive sensor reacts to the approach of the magnetic piston in the pneumatic actuator. Thus, the piston position can be visually and electrically displayed with an LED. In addition it permits the use of a stroke limiter.

7.2.2 Technical data

- **2 external inductive limit switches**
  (open and closed)
- **Material body:**
  PBTP (glass fibre reinforced)
- **Ambient temperature for the position indicator:**
  -20 °C (-4 °F) to +70 °C (158 °F)
- **Protection class:**
  IP67
- **Output version:**
  PNP (normally open contact)
- **Operating voltage:**
  10 - 30 V (DC)

7.3 Min./max. stroke limitation

Figure G.45: Min./max. stroke limitation.

7.3.1 Features

- Min./max. flow setting
- Integrated, clear visual position indication
- Upper and lower stop adjustable with standard screw driver
- To be used as manual override
- Can be combined with external magnetic-inductive position indication

7.4 Max. stroke limitation

Figure G.46: Max. stroke limitation.

7.4.1 Features

- Max. flow setting
- Without visual position indication
- Easy adjustment with Allen key
- Can be combined with external magnetic-inductive position indication

8 Check valves with spring

Figure G.47: Check valve with spring.

8.1 Features

- Radial installation or removal
- Flow direction is shown on the valve body
- The cone design provides an excellent flow rate
- Maintenance free operation over a long working period

8.2 Component parts

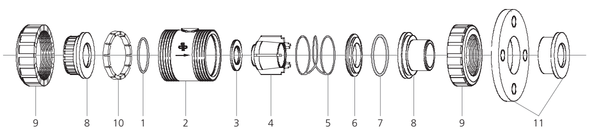

Figure G.48: Exploded assembly drawing.

1.	O-ring	7.	O-ring
2.	Body	8.	End connection
3.	Flat gasket	9.	Union
4.	Cone	10.	Retaining ring
5.	Spring	11.	Flange connection
6.	Thrust collar		

8.3 Technical data

- **Dimensions:**
  OD 20 mm, OD ½" (DN 15) to
  OD 90 mm, OD 3" (DN 80)
- **Body materials:**
  PVDF-UHP
  PP-Pure
- **Sealing materials:**
  FPM (Viton®)
- **Spring material:**
  PTFE (Teflon®) coated spring (WST 1.4401)
- **End connections:**
  Flange connections DIN, ANSI and JIS
  Union with fusion spigots
- **Operating pressure/temperature for water:**
  PVDF at 20 °C (68 °F)

OD 20 mm - OD 75 mm:	MOP 16 bar
OD ½" - OD 2½":	MOP 232 psi
OD 90 mm:	MOP 10 bar
OD 3":	MOP 145 psi

  PP-Pure at 20 °C (68 °F)

OD 20 mm - OD 75 mm:	MOP 10 bar
OD ½" - OD 2½":	MOP 145 psi
OD 90 mm:	MOP 6 bar
OD 3":	MOP 87 psi

  For other temperatures see Figure G.50 and Figure G.51
- **Opening pressure:**
  0.06 bar (0.87 psi)

8.4 Flow rate - pressure loss - diagram

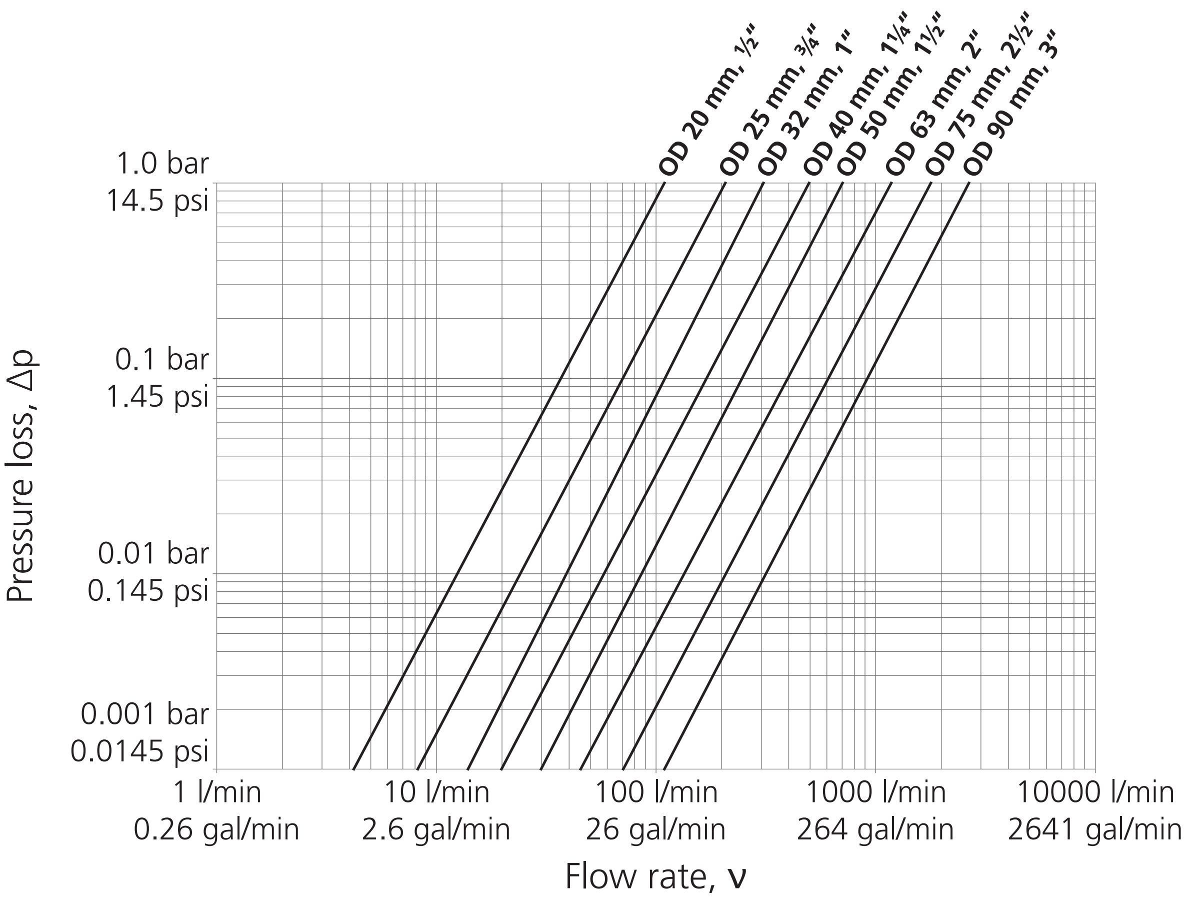

Figure G.49: Flow rate - pressure loss - diagram for the medium water at +20 °C (68 °F).

8.5 Pressure - temperature - diagram

8.5.1 PVDF-UHP

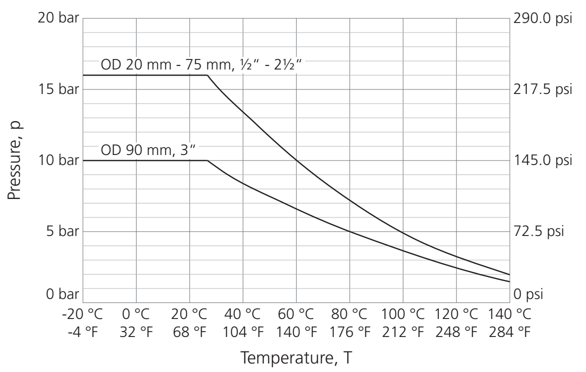

Figure G.50: Pressure - temperature - diagram of PVDF-UHP valid for water and a service life of 25 years.

8.5.2 PP-Pure

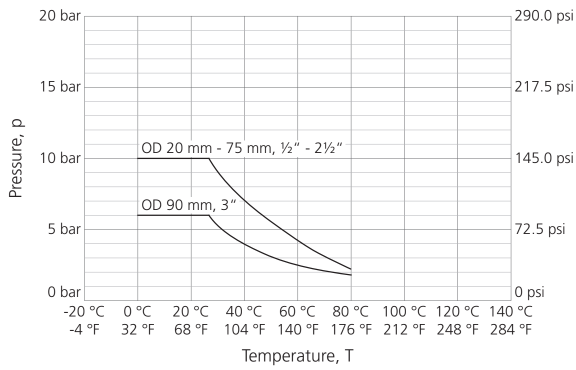

Figure G.51: Pressure - temperature - diagram of PP-Pure valid for water and a service life of 25 years.

9 Swing type check valves S4

Figure G.52: Swing type check valve S4 with spring.

9.1 Features

- Support ring screw for assembling
- Maintenance free operation
- Low pressure drop
- Short installation length

9.2 Component parts

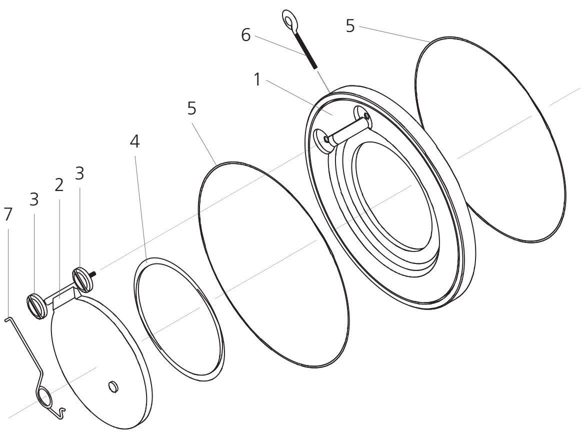

Figure G.53: Exploded assembly drawing.

1. Body	5. O-Ring
2. Disc	6. Ring screw
3. Screw	7. Spring
4. O-Ring	

9.3 Technical data

- **Dimensions:**
  OD 40 mm, OD 1¼" (DN 32) to
  OD 280 mm, OD 11" (DN 250)
- **Body materials:**
  PVDF-UHP
  PP-Pure
- **Sealing materials:**
  FPM (Viton®)
- **Spring material:**
  V4A (HASTELLOY® on request)
- **End connections:**
  Flange connections DIN
- **Operating pressure/temperature for water:**
  PVDF at 20 °C (68 °F)
  OD 40 mm - OD 280 mm: MOP 8 bar
  OD 1¼" - OD 11": MOP 116 psi
  PP-Pure at 20 °C (68 °F)
  OD 40 mm - OD 280 mm: MOP 6 bar
  OD 1¼" - OD 11": MOP 87 psi
  For other temperatures see Figure G.55 and Figure G.56
- **Opening pressure:**
  about 20 mbar (0.29 psi)

9.4 Flow rate - pressure loss - diagram

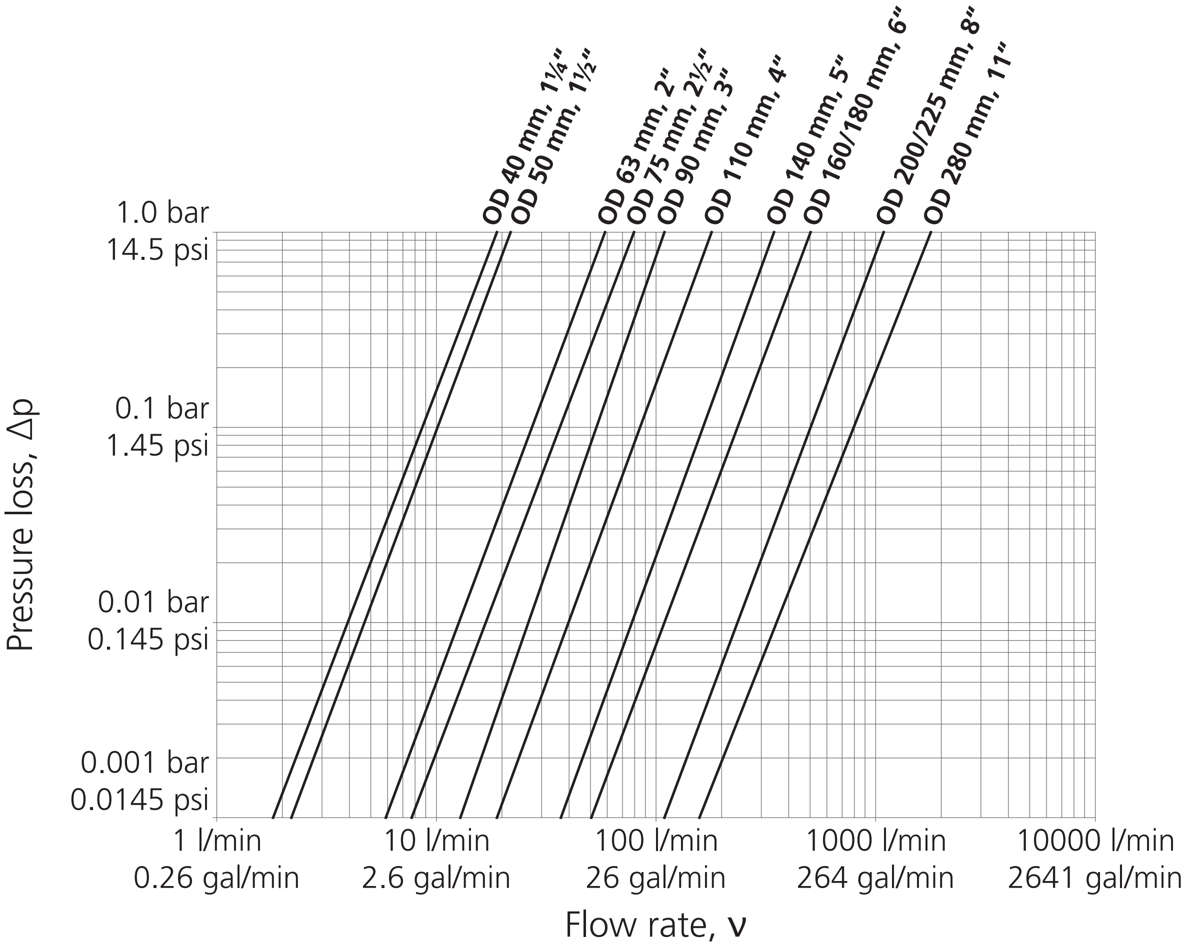

Figure G.54: Flow rate - pressure - diagram for the medium water at +20 °C (68 °F).

9.5 Pressure - temperature - diagram

9.5.1 PVDF-UHP

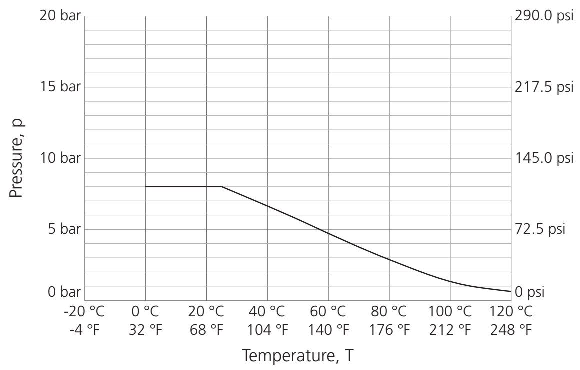

Figure G.55: Pressure - temperature - diagram of PVDF valid for water and a service life of 25 years.

9.5.2 PP-Pure

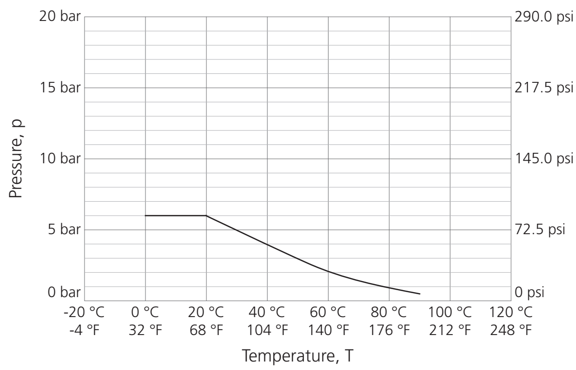

Figure G.56: Pressure - temperature - diagram of PP-Pure valid for water and a service life of 25 years.

9.6 Installation instructions

A back pressure of 0.3 bar (4.35 psi) is necessary to maintain pressure tightness of the valve. For installation on pumps (pressure part) please note the following:

- No direct installation on pump flanges or bends
- Before and after the check valve, a straight length of pipe, at least 5 times the DN of the pipe is required

Caution:
We recommend the use of an additional installation adaptor to ensure that the valve can open fully without interference from the wall of the pipe.

10 Swing type check valves K4

Figure G.57: Swing type check valve K4.

10.1 Features

- No metal parts in contact with the medium
- Excellent flow rates
- Disc opening up to 85°
- Easy and quick installation by means of integrated sizing hole template
- Optional spring forces for an operating pressure up to 3 bar (43.5 psi), 7 bar (101.5 psi) or 10 bar (145 psi)
- No special fitting on the opening gate neccessary
- Valve position indicator

10.2 Component parts

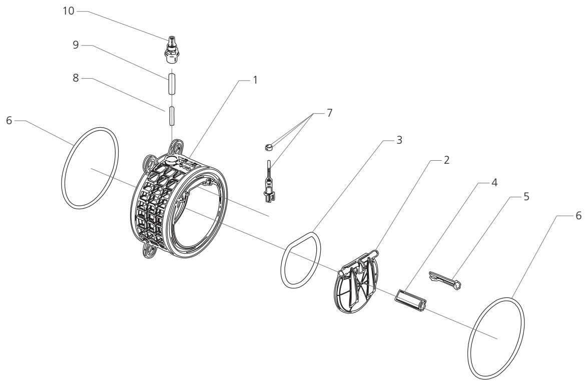

Figure G.58: Exploded assembly drawing.

1. Body	6. O-ring
2. Disc	7. Plug with o-ring
3. O-ring disc	8. Spring PN3
4. Fixing bolg left	9. Spring PN7
5. Fixing bolg right	10. Cap transparent

10.3 Technical data

- **Dimensions:**
  OD 75 mm, OD 2½" (DN 65) to
  OD 280 mm, OD 11" (DN 250)
- **Body materials:**
  PVDF-UHP
  PP-Pure
- **Sealing materials:**
  FPM (Viton®)
- **End connections:**
  Flange connections DIN, ANSI and JIS
- **Operating pressure/temperature for water:**
  PVDF at 20 °C (68 °F)
  OD 75 mm - OD 280 mm: MOP 10 bar
  OD 2½" - OD 11": MOP 145 psi
  PP-Pure at 20 °C (68 °F)
  OD 75 mm - OD 280 mm: MOP 6 bar
  OD 2½" - OD 11": MOP 87 psi
  For other temperatures see Figure G.60 and Figure G.61

10.4 Flow rate - pressure loss - diagram

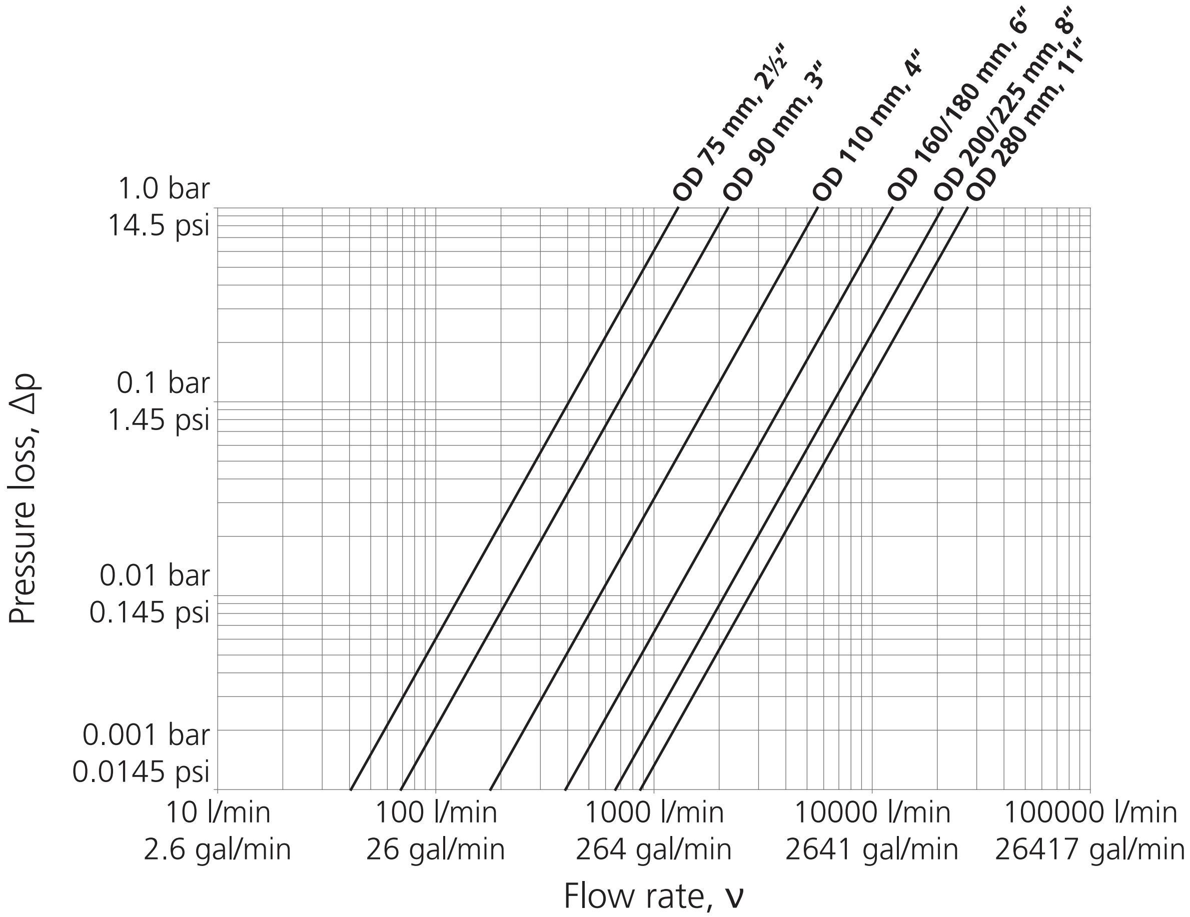

Figure G.59: Flow rate - pressure - diagram for the medium water at +20 °C (68 °F).

10.5 Pressure - temperature - diagram

10.5.1 PVDF-UHP

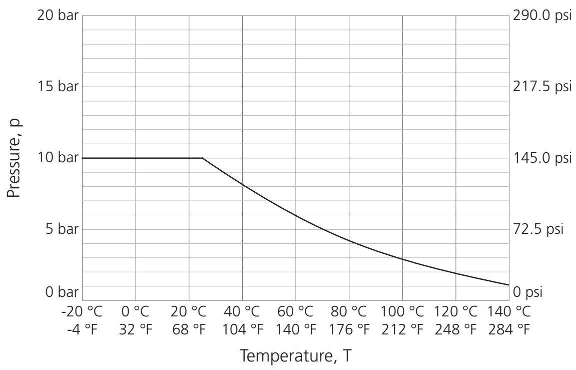

Figure G.60: Pressure - temperature - diagram of PVDF valid for water and a service life of 25 years.

10.5.2 PP-Pure

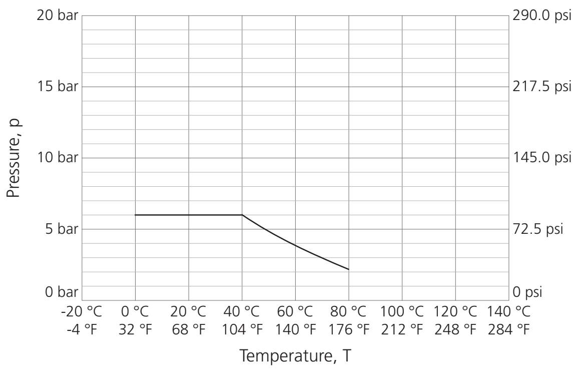

Figure G.61: Pressure - temperature - diagram of PP-Pure valid for water and a service life of 25 years.

11 Pressure reducing valves V82

Figure G.62: Pressure reducing valve V82.

11.1 Features

Pressure reducing valves reduce the system pressure to a defined value. Utilising the differential pressure, the pressure reducing valve sets itself to the set operating pressure. There is no direct relation between the output pressure (operating pressure) and inlet pressure.

- All parts in contact with the medium are made of highly resistant plastics
- The pressure gauge is isolated from the process fluid
- Good application characteristics due to the optimisation of piston, spring and control surface
- Require very little maintenance and may be installed in any position
- Valve adjustment possible under operating pressure
- Flow direction is shown on the valve body

11.2 Technical data

- **Dimensions:**
  OD 20 mm, OD ½" (DN 15) to
  OD 75 mm, OD 2½" (DN 65)
- **Body materials:**
  PVDF-UHP
  PP-Pure
- **Sealing materials:**
  PTFE/EPDM
- **End connections:**
  Fusion spigots
- **Type V82 with diaphragm protected pressure gauge for the reading of output pressure**
- **Operating temperature:**
  PVDF:
  -20 °C (-4 °F) up to +100 °C (+212 °F)
  PP-Pure:
  -10 °C (+14 °F) up to +80 °C (+176 °F)
  Depending on the process media
- **Adjustment range:**
  0.5 bar (7.25 psi) up to 9 bar (130.5 psi)
- **Operating pressure/temperature for water and a service life of 10 years:**
  OD 20 mm (OD ½") - OD 63 mm (OD 2"):
  max. 10 bar (145 psi) at 20 °C (68 °F)
  OD 75 mm (OD 2½"): max. 6 bar (87 psi) at 20 °C (68 °F)

11.3 Component parts

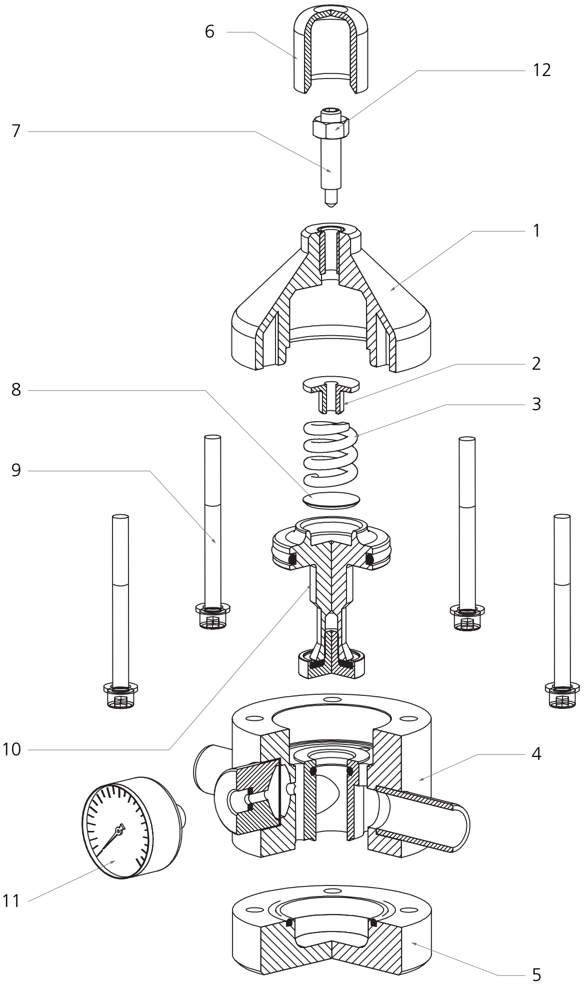

Figure G.63: Exploded assembly drawing.

1.	Valve upper body	8.	Spring support plate
2.	Spring plate	9.	Cheese-head screw with hexagon socket
3.	Compression spring	10.	Piston, complete
4.	Valve body	11.	Pressure gauge
5.	Valve lower body	12.	Lock nut
6.	Cap		
7.	Adjustment screw, complete		

11.4 Setting the operating pressure

- Unscrew the cap (6) from the upper body (1)
- Loosen the lock nut (12)
- Turn the adjustment screw (7) with a screwdriver / hexagon socket spanner as follows:
  - Clockwise = increases the output pressure
  - Anti-clockwise = reduces the output pressure
- Tighten the lock nut (12)

11.5 Characteristic diagram

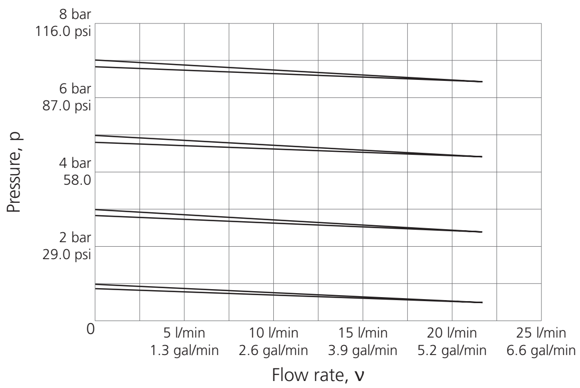

Figure G.64: Characteristic diagram for DN 15 (OD 20 mm, OD ½").

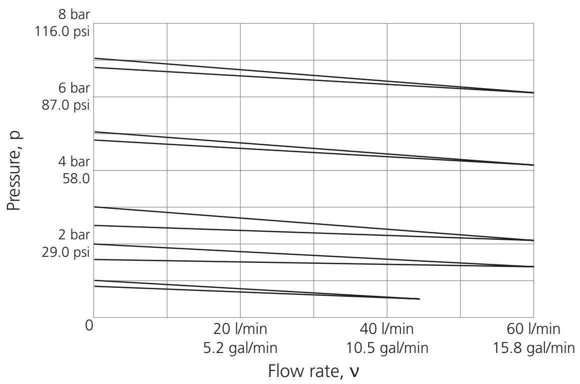

Figure G.65: Characteristic diagram for DN 20 (OD 25 mm, OD ¾") and DN 25 (OD 32 mm, OD 1").

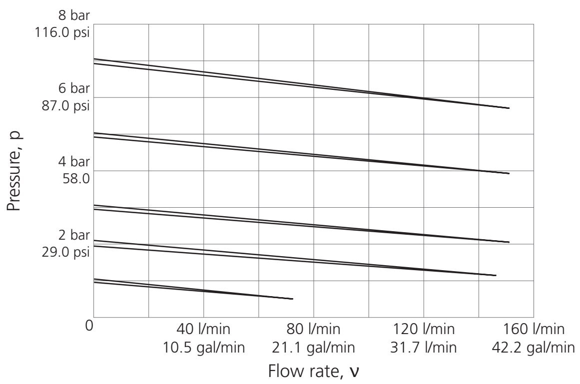

Figure G.66: Characteristic diagram for DN 32 (OD 40 mm, OD 1¼") and DN 40 (OD 50 mm, OD 1½").

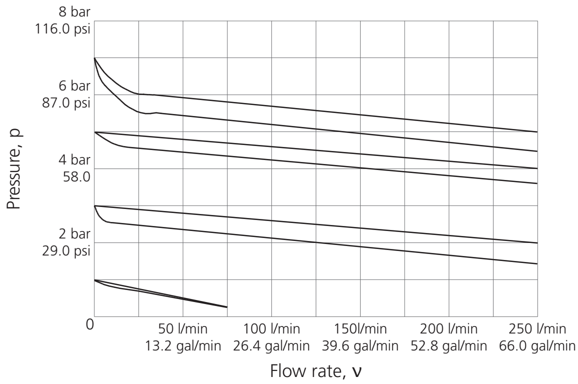

Figure G.67: Characteristic diagram for DN 50 (OD 63 mm, OD 2").

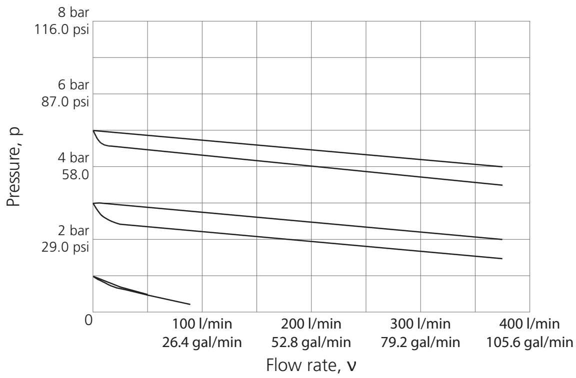

Figure G.68: Characteristic diagram for DN 65 (OD 75 mm, OD 2½").

12 Pressure reducing valves V782

Figure G.69: Pressure reducing valve V782.

12.1 Features

Pressure reducing valves reduce the system pressure to a defined value. Utilising the differential pressure, the pressure reducing valve sets itself to the set operating pressure. There is no direct relation between the output pressure (operating pressure) and inlet pressure.

- All parts in contact with the medium are made of highly resistant plastics
- The control diaphragm separates the actuating drive from the flow section
- The shape of the housing enables excellent flow rates
- Control deviations are kept low by the large control surface and the spiral springs
- Require very little maintenance and may be installed in any position
- Valve adjustment possible under operating pressure
- Flow direction is shown on the valve body

12.2 Technical data

- **Dimensions:**
  OD 20 mm, OD ½" (DN 15) to
  OD 50 mm, OD 1½" (DN 40)
- **Body materials:**
  PVDF-UHP
  PP-Pure
- **Sealing materials:**
  PTFE/EPDM
- **End connections:**
  Fusion spigots
- **Type V782 without pressure gauge**
- **Hysteresis:**
  max. ~0.4 bar (5.8 psi)
- **Pressure difference between input and output:**
  min. 1 bar (14.5 psi)
- **Operating temperature:**
  PVDF:
  -20 °C (-4 °F) up to +100 °C (+212 °F)
  PP-Pure:
  -10 °C (+14 °F) up to +80 °C (+176 °F)
  Depending on the material and process media
- **Adjustment range:**
  0.5 bar (7.25 psi) up to 9 bar (130.5 psi)
- **Operating pressure/temperature for water and a service life of 10 years:**
  OD 20 mm (OD ½") - OD 50 mm (OD 1½"):
  max. 10 bar (145 psi) at 20 °C (68 °F)

12.3 Component parts

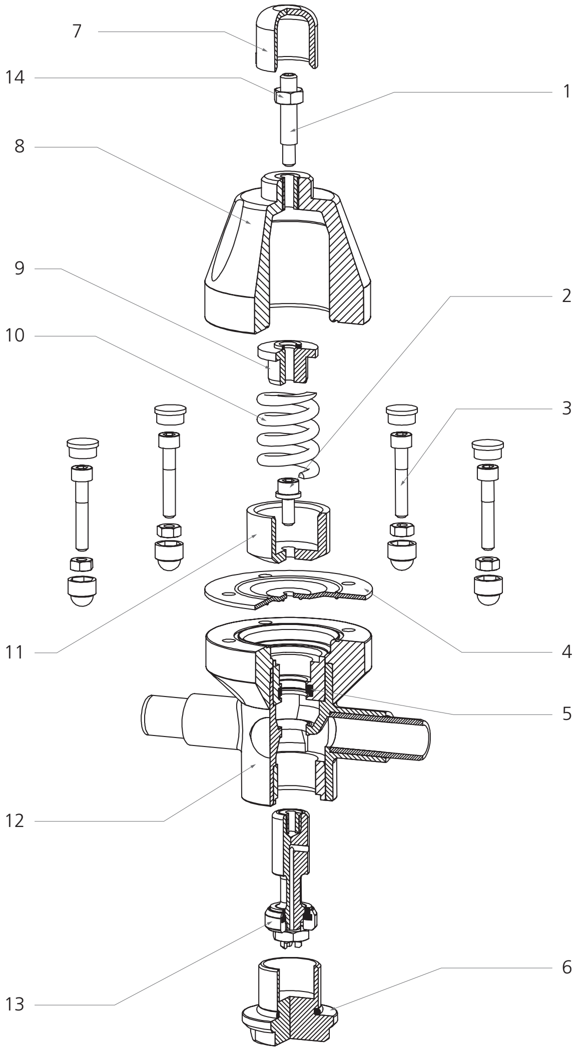

Figure G.70: Exploded assembly drawing.

1.	Adjustment screw, complete	7.	Cap
2.	Hexagon socket screw	8.	Valve upper body
3.	Hexagon socket screw with nut and cap	9.	Spring plate
4.	Diaphragm	10.	Compression spring
5.	Lip ring	11.	Pressure plate
6.	Plug with O-ring	12.	Valve lower body
		13.	Piston, complete
		14.	Lock nut

12.4 Setting the operating pressure

- Unscrew the cap (7) from the upper body (8)
- Loosen the lock nut (14)
- Turn the adjustment screw (1) with a screwdriver / hexagon socket spanner as follows:
  - Clockwise = increases the output pressure
  - Anti-clockwise = reduces the output pressure
- Tighten the lock nut (14)

12.5 Characteristic diagram

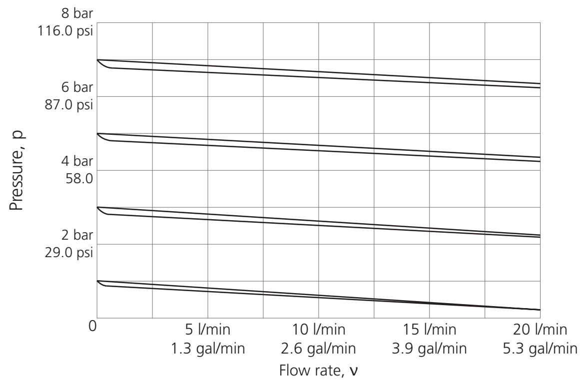

Figure G.71: Characteristic diagram for DN 15 (OD 20 mm, OD ½").

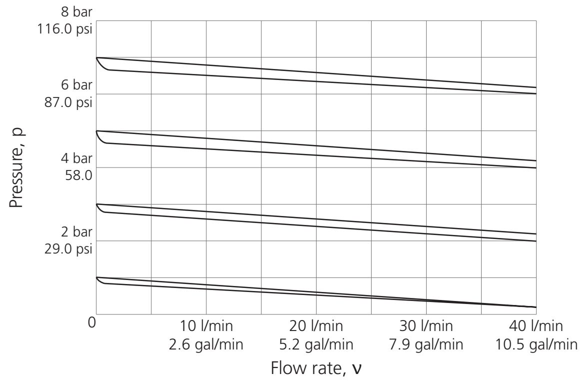

Figure G.72: Characteristic diagram for DN 20 (OD 25 mm, OD ¾").

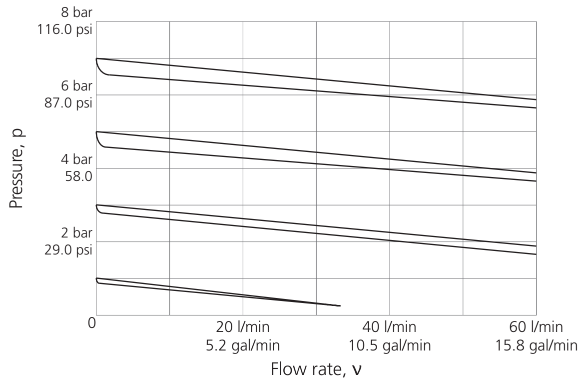

Figure G.73: Characteristic diagram for DN 25 (OD 32 mm, OD 1").

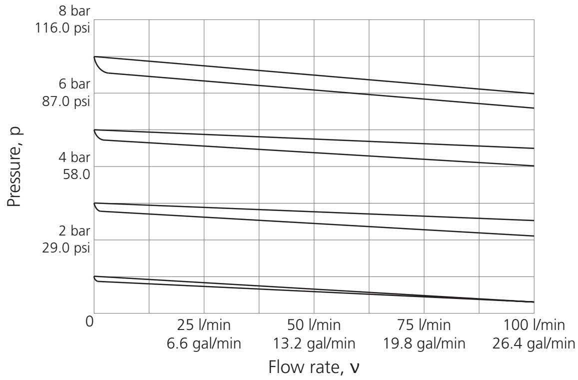

Figure G.74: Characteristic diagram for DN 32 (OD 40 mm, OD 1¼").

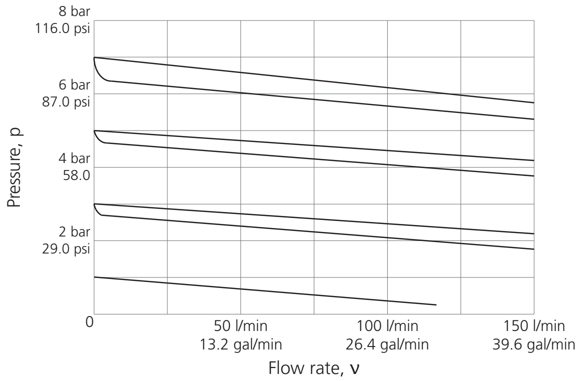

Figure G.75: Characteristic diagram for DN 40 (OD 50 mm, OD 1½").

13 Pressure retaining valves V186

Figure G.76: Pressure retaining valve V186.

13.1 Features

Pressure retaining valves are used where a constant back pressure is required for operating process systems. When installed as a bypass, it can also be used as a relief valve for reducing pressure peaks. The pressure retaining valve has an almost zero-static lower body that makes it particularly suitable for the use in high-purity water applications. The variety of available materials covers a wide rage of applications.

- Good control characteristic
- Generates system dependent working pressure upstream of the valve
- Compact design, only valve body and diaphragm are wetted by process media
- Can be installed in any position
- Valve adjustment possible under operating pressure

13.2 Component parts

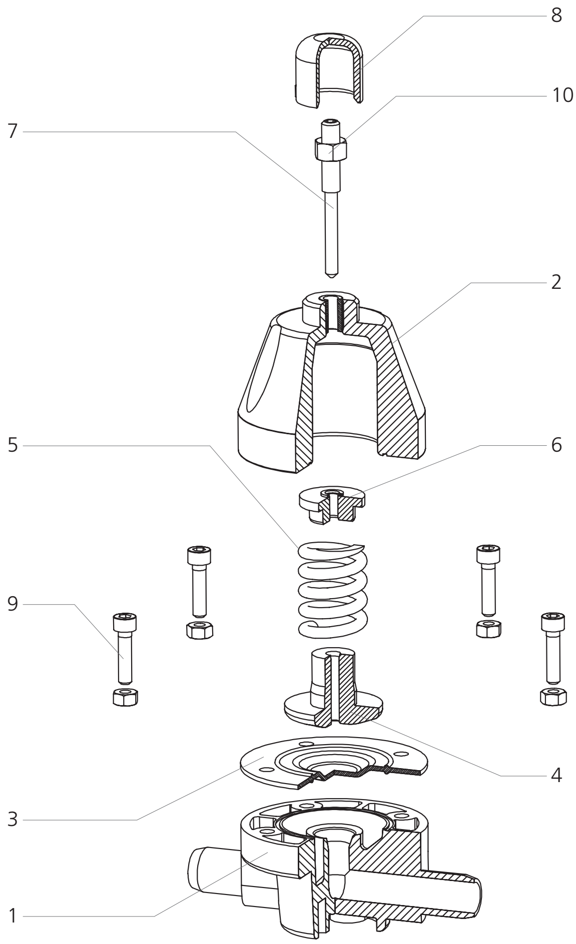

Figure G.77: Exploded assembly drawing.

1.	Valve lower body	7.	Adjustment screw with nut
2.	Valve upper body	8.	Cap
3.	Diaphragm	9.	Hexagon socket screw with nut
4.	Compressor	10.	Lock nut
5.	Compression spring		
6.	Spring plate		

13.3 Technical data

- **Dimensions:**
  OD 20 mm, OD ½" (DN 15) to
  OD 63 mm, OD 2" (DN 50)
- **Body materials:**
  PVDF-UHP
  PP-Pure
- **Sealing materials:**
  PTFE/EPDM
- **End connections:**
  Fusion spigots

- **Operating temperature:**
  PVDF:
  -20 °C (-4 °F) up to +100 °C (+212 °F)
  PP-Pure:
  -10 °C (+14 °F) up to +80 °C (+176 °F)
  Depending on the process media
- **Adjustment range:**
  0.5 bar (7.25 psi) up to 9 bar (130.5 psi)
- **Operating pressure/temperature for water and a service life of 10 years:**
  OD 20 mm (OD ½“) - OD 63 mm (OD 2“):
  max. 10 bar (145 psi) at 20 °C (68 °F)

13.4 Adjusting the operating pressure

- Unscrew the cap (8) and loosen the lock nut (10)
  - Increasing the operating pressure:
    Turn the adjustment screw (7) clockwise.
  - Reducing the operating pressure:
    Turn the adjustment screw (7) anti-clockwise
- Secure the set pressure with the lock nut (10)

13.5 Characteristic diagram

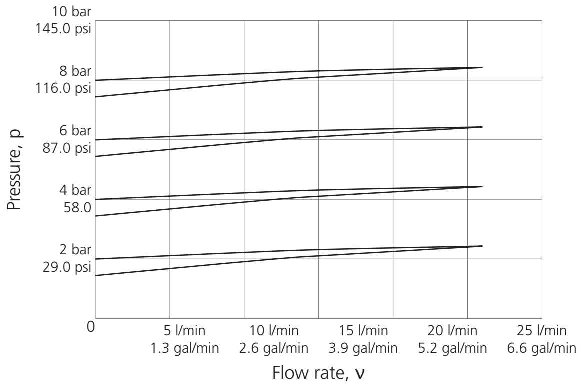

Figure G.78: Characteristic diagram for DN 15 (OD 20 mm, OD ½“).

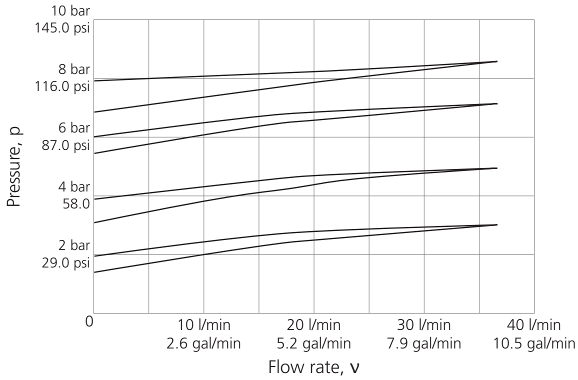

Figure G.79: Characteristic diagram for DN 20 (OD 25 mm, OD ¾“).

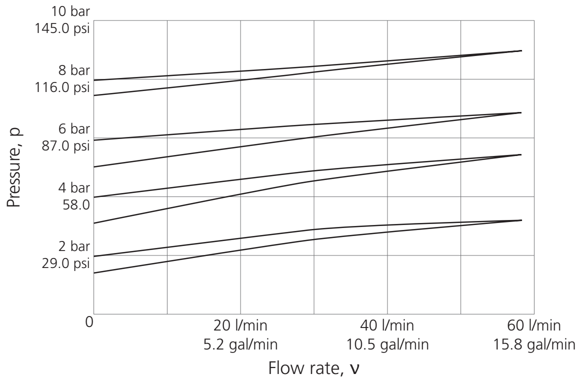

Figure G.80: Characteristic diagram for DN 25 (OD 32 mm, OD 1“).

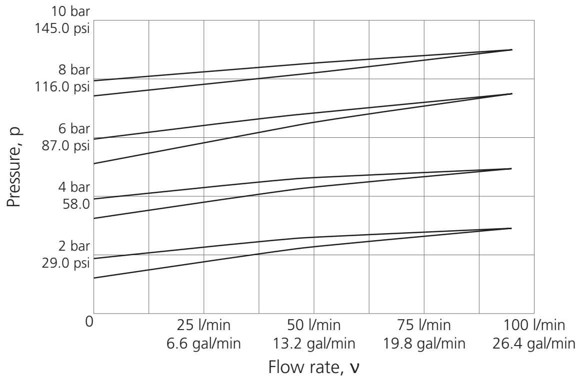

Figure G.81: Characteristic diagram for DN 32 (OD 40 mm, OD 1¼“).

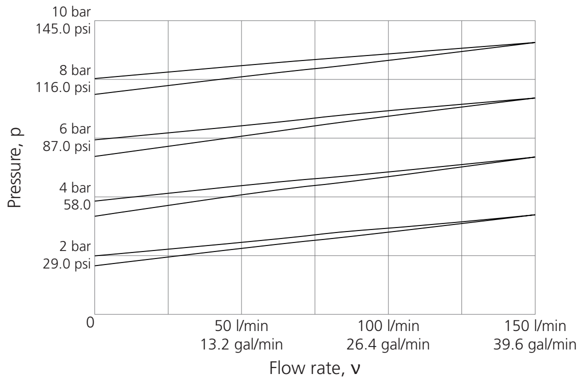

Figure G.82: Characteristic diagram for DN 40 (OD 50 mm, OD 1½").

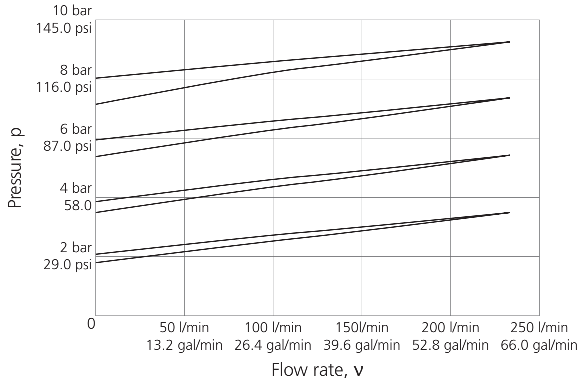

Figure G.83: Characteristic diagram for DN 50 (OD 63 mm, OD 2").

14 Pressure relief valves V185

Figure G.84: Pressure relief valve V185.

14.1 Features

The pressure relief valve V185 protects systems and pipelines against overpressure and pressure peaks. The third pipe spigot integrated in the valve body allows an installation in the main line.

- Good control characteristic
- Compact design, only valve body and diaphragm are in contact with the process media
- Can be installed in any position

14.2 Component parts

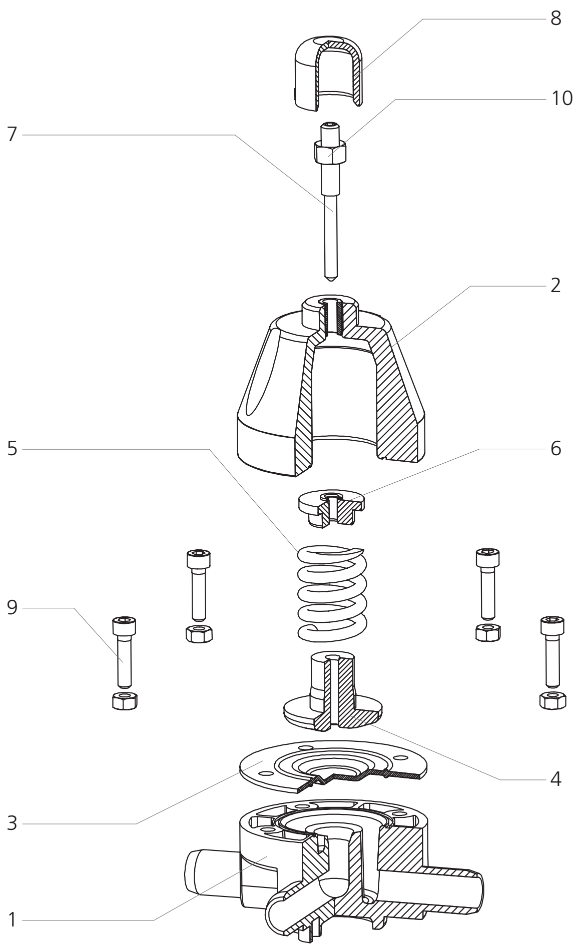

Figure G.85: Exploded assembly drawing.

1. Valve lower body	7. Adjustment screw with nut
2. Valve upper body	8. Cap
3. Diaphragm	9. Hexagon socket screw with nut
4. Compressor	10. Lock nut
5. Compression spring	
6. Spring plate	

14.3 Technical data

- **Dimensions:**
  OD 20 mm, OD ½" (DN 15) to
  OD 63 mm, OD 2" (DN 50)
- **Body materials:**
  PVDF-UHP
  PP-Pure
- **Sealing materials:**
  PTFE/EPDM
- **End connections:**
  Fusion spigots

- **Operating temperature:**
  PVDF:
  -20 °C (-4 °F) up to +100 °C (+212 °F)
  PP-Pure:
  -10 °C (+14 °F) up to +80 °C (+176 °F)
  Depending on the process media
- **Adjustment range:**
  0.5 bar (7.25 psi) up to 9 bar (130.5 psi)
- **Operating pressure/temperature for water and a service life of 10 years:**
  OD 20 mm (OD ½") - OD 63 mm (OD 2"):
  max. 10 bar (145 psi) at 20 °C (68 °F)

14.4 Adjusting the operating pressure

- Unscrew the cap (8) und loosen the lock nut (10)
- Increase the operating pressure: Turn the adjustment screw (7) clockwise
- Reducing the operating pressure: Turn the adjustment screw (7) anti-clockwise
- Secure the set pressure with the lock nut (10)

14.5 Characteristic diagram

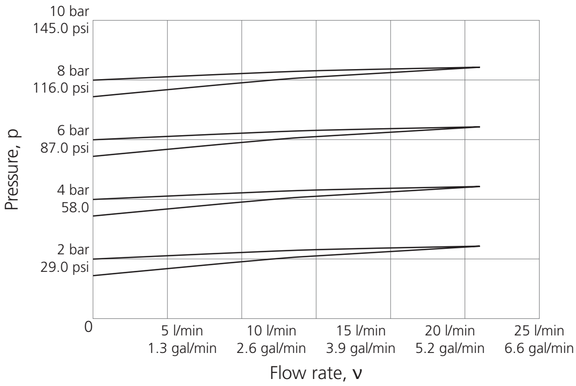

Figure G.86: Characteristic diagram for DN 15 (OD 20 mm, OD ½").

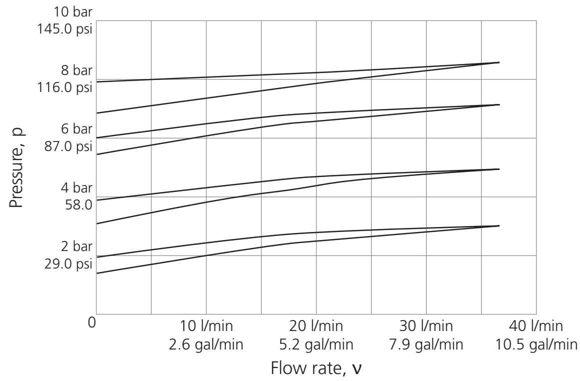

Figure G.87: Characteristic diagram for DN 20 (OD 25 mm, OD ¾").

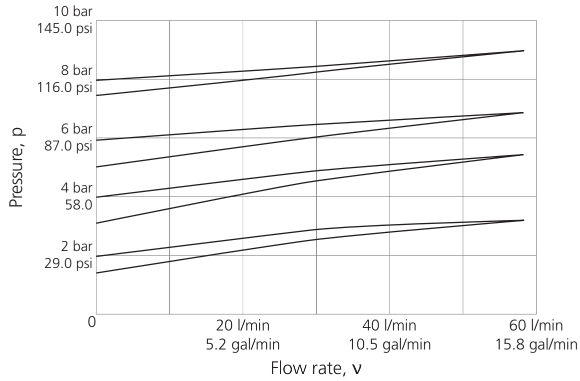

Figure G.88: Characteristic diagram for DN 25 (OD 32 mm, OD 1").

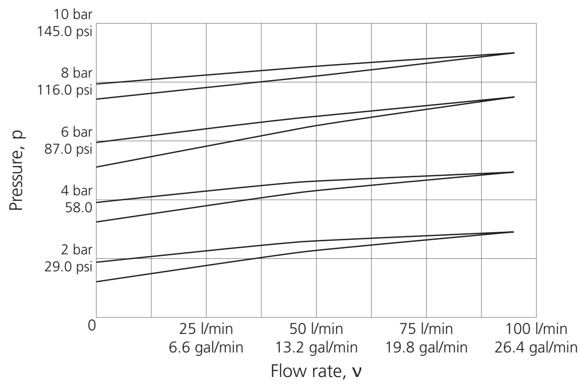

Figure G.89: Characteristic diagram for DN 32 (OD 40 mm, OD 1¼").

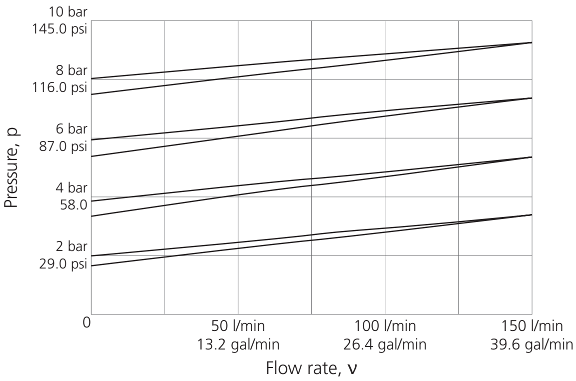

Figure G.90: Characteristic diagram for DN 40 (OD 50 mm, OD 1½").

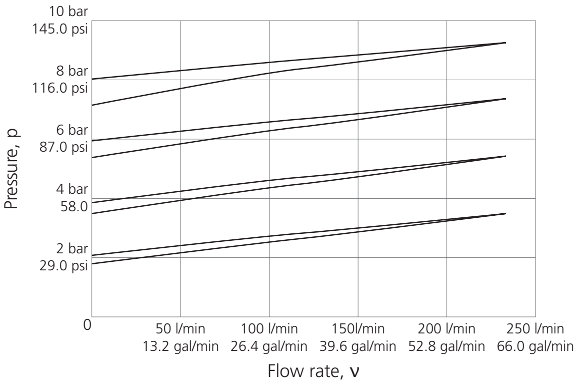

Figure G.91: Characteristic diagram for DN 50 (OD 63 mm, OD 2").

15 Gauge guards Z700

Figure G.92: Gauge guard Z700.

15.1 Features

The diaphragm-protected pressure gauge is used to measure the pressure of neutral and aggressive media. The pressure gauge is separated from the medium by a PTFE-coated diaphragm. The pressure is transmitted via a buffer fluid. The large diaphragm surface and the low compressibility of the buffer fluid allows for a more accurate display.

- All parts that come into contact with the medium are made of highly resistant plastics
- The pressure gauge is maintenance-free and can be installed in any position
- The large PTFE coated diaphragm area provides high accuracy

15.2 Component parts

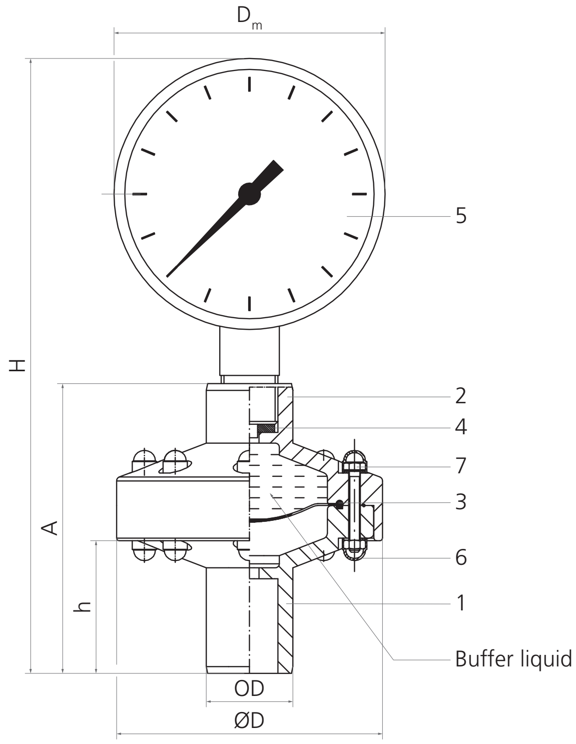

Figure G.93: Sectional drawing.

1.	Welding spigot	5.	Pressure gauge
2.	Upper body	6.	Hexagonal cap
3.	Diaphragm	7.	Hexagon screw complete with washer and nut
4.	Pressure gauge seal		

15.3 Technical data

- **Dimensions:**
  OD 25 mm, OD ¾" (DN 20) and
  OD 32 mm, OD 1" (DN 25)
- **Body materials:**
  PVDF-UHP
  PP-Pure
- **Sealing materials:**
  PTFE/EPDM
- **Connection:**
  Fusion spigot
- **Pressure gauge connections:**
  OD 25 mm = R ¼"
  OD 32 mm = R ½"

- **Operating temperature:**
  PVDF:
  -20 °C (-4 °F) up to +100 °C (+212 °F)
  PP-Pure:
  -10 °C (+14 °F) up to +80 °C (+176 °F)
  Depending on the material and process media
- **Accuracy:**
  Standard Class 2.5
- **Operating pressure/temperature for water and a service life of 10 years:**
  max. 10 bar (145 psi) at 20 °C (68 °F)
- **Display range:**
  0 bar (0 psi) to 10 bar (145 psi)

16 Flow meters M123 & M23

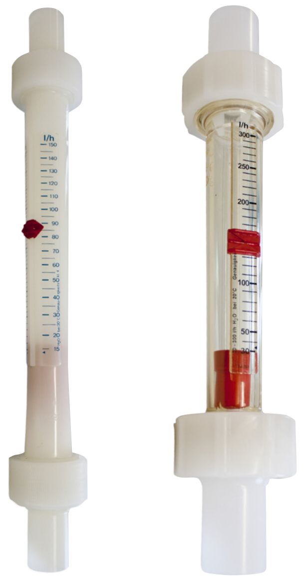

Figure G.94: Flow meter.

16.1 Features

The flow meter M23 & M123 operates on the float principle and is used for flow rate measurements in pipelines. The medium flows through the vertically installed flow meter from bottom to top. This raises the float and shows the current flow rate on the scale on the measuring device.

The flow meters are supplied with a water scale and two setpoint indicators.

- Measuring tube
  - M123: translucent (PVDF or PSU)
  - M23: transparant (PVDF)
- Fracture proof and corrosion resistant
- Radial installation or removal
- PVDF float

16.2 Component parts

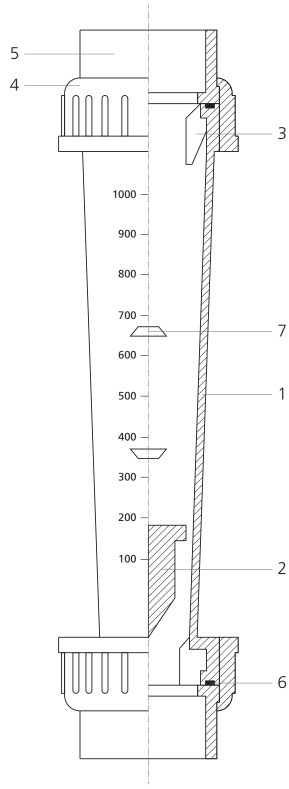

Figure G.95: Sectional drawing.

1. Measuring tube	5. Union end
2. Suspended float	6. O-ring
3. Insert top	7. Setpoint indicator
4. Union nut	

16.3 Technical data

- **Dimensions:**
  Flow meter M123:
  OD 20 mm, OD ½" (DN 15) to
  OD 32 mm, OD 1" (DN 25)
  Flow meter M23:
  OD 32 mm, OD 1" (DN 25) to
  OD 75 mm, OD 2½" (DN 65)
- **Tube materials:**
  PVDF
  PSU
- **Material of end connection:**
  PVDF-UHP
  PP-Pure
- **Float material:**
  PVDF
- **Sealing material:**
  FPM

- **End connection:**
  Fusion spigots
- **Measuring accuracy:**
  Accuracy class 4 as defined by VDE/DIN 3513 page 2
- **Operating temperature:**
  PVDF:
  0 °C (+32 °F) up to +100 °C (+212 °F)
  PP-Pure:
  0 °C (+32 °F) up to +80 °C (+176 °F)
  Depending on the process media
- **Operating pressure/temperature for water and a service life of 10 years:**
  max. 10 bar (145 psi) at 20 °C (68 °F)

16.4 Pressure losses

16.4.1 M123

OD	Measuring range		M123	
	[l/h]	[gal/h]	[mbar]	[psi]
20 mm (½")	8 - 80	2.1 - 21	4.38	0.06
	15 - 150	3.9 - 39	4.38	0.06
	20 - 200	5.2 - 52	4.38	0.06
OD 32 mm (¾")	15 - 150	3.9 - 39	8.12	0.12
	30 - 300	7.9 - 79	8.12	0.12
	50 - 500	13.2 - 132	8.12	0.12
	100 - 1000	26.4 - 264	8.12	0.12

Figure G.96: Pressure losses of the flow meter M123.

16.4.2 M23

OD	Measuring range		M23	
	[l/h]	[gal/h]	[mbar]	[psi]
32 mm (¾")	15 - 150	3.9 - 39	18.17	0.26
	50 - 500	13.2 - 132	18.17	0.26
	100 - 1000	26.4 - 264	18.17	0.26
50 mm (1½")	200 - 2000	52.8 - 528	24.67	0.357
	300 - 3000	79.2 - 792	24.67	0.357
63 mm (2")	600 - 6000	158 - 1585	24.99	0.362
	1200 - 12000	317 - 3170	24.67	0.357
75 mm (2½")	2000 - 20000	528 - 5283	24.99	0.362
	3000 - 30000	792 - 7925	24.67	0.357

Figure G.97: Pressure losses of the flow meter M23.

17 Flow meters M335

Figure G.98: Flow meter M335.

17.1 Features

The flow meter M335 operates on the float principle and is used for flow rate measurements in pipelines. The medium flows trough the vertically installed flow meter from bottom to top. This raises the float and shows the current flow rate on the scale on the measuring device.

The flow meters are supplied with a water scale and a percentage scale, and two setpoint indicators.

- Transparent (PSU) metering tube
- Fracture proof and corrosion resistant
- Radial installation or removal
- PVDF float
- From DN 50 (150 - 1500 l/h) with guide bar for stabilisation of float within volume flow

17.2 Component parts

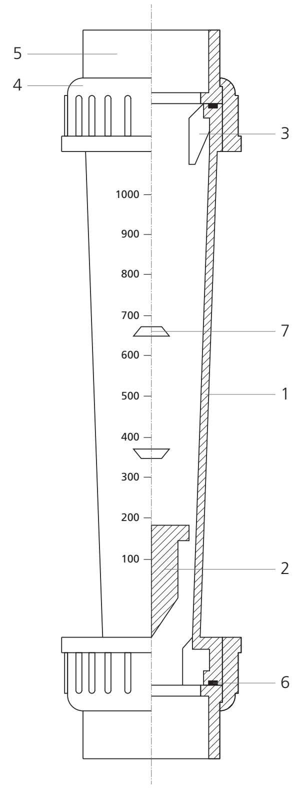

Figure G.99: Sectional drawing.

1.	Measuring tube	5.	Union end
2.	Suspended float	6.	O-ring
3.	Insert top	7.	Setpoint indicator
4.	Union nut		

17.3 Technical data

- **Dimensions:**
  OD 32 mm, OD 1" (DN 25) to
  OD 75 mm, OD 2½" (DN 65)
- **Tube material:**
  PSU
- **Material of end connection:**
  PVDF-UHP
  PP-Pure
- **Float material:**
  PVDF
- **Sealing material:**
  FPM
- **End connection:**
  Fusion spigots

- **Measuring accuracy:**
  Accuracy class 4 as diefined by
  VDE/DIN 3513 page 2
- **Operating temperature:**
  PVDF:
  0 °C (+32 °F) up to +100 °C (+212 °F)
  PP-Pure:
  0 °C (+32 °F) up to +80 °C (+176 °F)
  Depending on the process media
- **Operating pressure/temperature for water and a service life of 10 years:**
  max. 10 bar (145 psi) at 20 °C (68 °F)

17.4 Pressure losses M335

OD	Measuring range		M335	
	[l/h]	[gal/h]	[mbar]	[psi]
32 mm (1")	50 - 500	13.2 - 132	22.84	0.33
	100 - 1000	26.4 - 264	22.84	0.33
40 mm (1¼")	150 - 1500	39.6 - 396	22.84	0.33
	250 - 2500	66.0 - 660	22.84	0.33
50 mm (1½")	200 - 2000	52.8 - 528	24.99	0.36
	300 - 3000	79.2 - 792	24.99	0.36
	600 - 6000	158 - 1585	24.99	0.36
63 mm (2")	600 - 6000	158 - 1585	24.99	0.36
	1000 - 10000	264 - 2641	24.99	0.36
	1500 - 15000	396 - 3962	28.23	0.41
75 mm (2½")	2000 - 20000	528 - 5283	45.67	0.66
	3000 - 30000	792 - 7925	45.67	0.66
	8000 - 60000	2113 - 15850	47.24	0.685

Figure G.100: Pressure losses of the flow meter M335.

H Chemical resistance

1 General chemical properties of PVDF-UHP

PVDF-UHP is resistant to a wide range of chemicals.

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

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

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

- Amine, basic media with a index of pH >12
- Compounds, which can produce free radicals under certain circumstances
- Smoking sulfuric acid
- High polar solvents (acetone, ethyl acetate, dimethyl-formamide, dimethylsulphoxide, ...); here PVDF-UHP 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-UHP is situated in a milieu with a pH >12 or in the presence of free radicals (for example elemental chlorine) and it is exposed to a mechanical use in the same time.

The following essential parameters should be considered for every single case:

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

2 General chemical properties of PP-Pure and Polypure

In comparison to metals, where an attack of chemicals leads to an irreversible chemical change of the material, it's mostly physical processes which reduce the plastics' utility value. That physical changes are e.g. swelling and solution processes where the composition of the plastics can be changed in a way that affects the mechanical properties. Reducion factors have to be taken into account when designing facilities and parts of those in such cases.

PP-Pure and Polypure are resistant to diluted solutions of salts, acids and alkalis if these are not strong oxidising agents. Good resistance to many solvents such as alcohols, esters and ketones is also given.

At the contact with solvents like aliphatic and aromatic compounds and chlorinated hydroxycarbon you experience a strong swelling, especially at raised temperatures. A destruction commences only rarely.

The resistance can be strongly reduced by stress cracking corrosion due to ampholytiocs (chromic acid, concentrated sulphuric acid).

3 General chemical properties of ECTFE

ECTFE shows a remarkable hardiness and excellent chemical resistance to most organic and inorganic chemicals (pH 0 to 14, max. 140 °C) as well as solvents (max. 120 °C). This is valid for:

- Sulphuric acid H_2SO_4 (98 %)
- Hydrochloric acid HCl (37 %)
- Hydrofluoric acid HF (90 %)
- Sodium hydroxide NaOH (50 %)
- Hydrogen peroxide H_2O_2 (60 %)
- Nitric acid HNO_3 (65 %)
- Solvents
- Chlorine and chlorine compounds

For more information on chemical resistance refer to the chemical resistance table on www.agru.at or contact anwt@agru.at.

I Standards and approvals

1 Approvals

AGRU products are tested according to the company's QC guidelines on a regular basis. Furthermore, independent accredited test institutes perform scrutiny and supervision of our products.

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.

Following institutes are commissioned for the production:

- TÜV-Süd (Germany)
- MPA, Darmstadt (Germany)
- Hessel Ingenieurtechnik GmbH, Aachen (Germany)
- SKZ, Würzburg (Germany)
- TGM, Vienna (Austria)
- OFI, Vienna (Austria)
- FM - Factory Mutual (USA)

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

1.1 DIBt

- Z-40.23.202
  Pipes of Polyvinylidenefluoride (PVDF)
- Z-40.23-201
  Fittings of Polyvinylidenefluoride (PVDF)
- Z-40.23-233
  Pipes of Polypropylene (PP-H / PP-R)
- Z-40.23-234
  Fittings of Polypropylene (PP-R)

1.2 ÖNORM

- ON 87272 (ÖNORM B 5174 approved)
  PP-R pipes for the conveyance of liquid or gaseous medium.

1.3 TÜV

TÜV certified according to AD2000-leaflet HP120 R

- PP, PVDF - Diaphragm valve
- PP, PVDF - T-diaphragm valve
- PP-H, PP-R - Pipes and fittings
- PVDF - Pipes and fittings

1.4 CE

- CE0036
  - Pressure equipment directive 97/23/EC
  - Valves and fittings of Polypropylene and Polyvinylidenefluoride (PVDF)

1.5 FM specification test report

Specification tested examination of AGRU PVDF sheets, pipes and fittings for use as clean room materials in accordance with FM approvals test standard 4910.

1.6 Material approvals polyvinylidene fluoride (PVDF)

(provided by the resin manufacturer)

1.6.1 Food product contact, physiological harmlessness, toxicology

1.6.1.1 EU

The fluorinated monomers used in PVDF-UHP polymers meet the requirements of the Commission Regulation No 10/2011 and is intended to come into contact with foodstuff.

1.6.1.2 France

Attestation de conformité sanitaire (pour la résine Solef 1010): Conformément à l'arrêté du 29 mai 1997 modifié et aux circulaires du Ministère de la Santé DGS/VS4 n° 99/217 du 12 avril 1999 et DGS/VS4 n° 2000/232 du 27 avril 2000

1.6.1.3 Germany

Solef PVDF 1008 and 1010 resins have been tested and comply with:

- the KTW recommendations of the German Federal Health Office at temperature up to 80 °C (176 °F); the plastic materials are tested in respect of its influence on the appearance quality of the water, the release of its constituents into the water and its disinfectants demand

- DVGW W270; the plastic materials are tested for the microbial resistance

1.6.1.4 United Kingdom

Thames Water Services: approval for use of pipes in SOLEF PVDF 1010 to transport hot and cold water for domestic consumption (report No. 2141C of 27 July 1988)

Solef® 1008 and 1010 grades that have met the requirements of the Water Regulations Advisory Scheme (WRAS) Tests of Effects on Water Quality – BS 6920, Hot and Cold Water Use and are suitable for use in contact with potable water

1.6.1.5 USA

PVDF-UHP polymers are certified to the NSF Standard 51 at the maximum temperature of 126 °C (259 °F). The PVDF-UHP material is certified for all food types (dry solids, aqueous, acidic, dairy products, oil and alcoholic beverages).

PVDF-UHP polymers are certified to meet the NSF Standard 61 at 85 °C (185 °F).

1.6.2 Fire behaviour, heat resistance

Underwriters Laboratories Inc.: UL 94 V-O approval for various SOLEF grades

Factory Mutual (FM) Class File 4910: Clean room materials flammability testing of SOLEF 1010/0001 PVDF of 29 August 2000

1.6.3 Medical applications

1.6.3.1 USP classification

Solef PVDF 1008 has been tested according to USP chapter 88 „Biological reactivity test, in vivo" and has demonstrated its compliance with the requirements of USP plastic class VI.

1.6.3.2 FDA confirmation

Solef® homopolymers comply with the specifications of the United States Food and Drug Administration (FDA) 21CFR 177.2510

1.7 Material approvals polypropylene (PP-R)

(provided by the resin manufacturer)

1.7.1 Statement of compliance to food contact regulations

1.7.1.1 Austria

Kunststoffverordnung Nr. 476/2003 und Änderungen 242/2005, 452/2006, 325/2007 und 140/2009

1.7.1.2 Belgium

Koninklijk Besluit - Arrêté Royal van/du 03.07.2005 and subsequent amendmends incl. Koninklijk Besluit - Arrêté Royal van/du 08.03.2009 (M.B. 23.03.2009)

1.7.1.3 Czech Republic, the

Vyhlaska Ministerstva zdravotnictvi c. 38/2001 Sb, c. 186/2003 Sb, c. 207/2006 Sb, c. 551/2006 Sb, c. 271/2008, c.386/2008 Sb, c. 127/2009 Sb

1.7.1.4 Denmark

Fødevaredirektoratets Bekendtgørelse nr.167 (03.03.2009)

1.7.1.5 EU

Regulation (EC) No 1935/2004 - so far applicable for raw materials

Commission Directive 2002/72/EC amended by 2004/1/EC, 2004/19/EC, 2005/79/EC, 2007/19/EC and 2008/39/EC

Regulation (EC) 1895/2005 - BADGE, NOGE and BFDGE are not used for the production of this grade

1.7.1.6 Finland

KTM Asetukset 953/2002, 141/2005, 181/2005, 762/2006, 1065/2007 ja 107/2009

1.7.1.7 France

Repression des Fraudes (2002), No. 1227 et Arrêté du 2 janvier 2003, Arrêté du 29 mars 2005, Arrêté du 9 aout 2005, Arrêté du 19 octobre 2006, Arrêté du 25 avril 2008 et Arrêté du 19 novembre 2008

1.7.1.8 Germany

Bedarfgegenständeverordnung vom 23.12.1997 und Änderungen vom 21. Dezember 2000, 7. April 2003, 13. Juli 2005, 30. November 2006, 20. Dezember 2006 und 30. April 2008 sowie BfR-Empfehlungen A VII Polypropylen, Stand 01.06.2007

1.7.1.9 Great Britain

England: Statutory Instrument 2009 No. 205; Northern-Ireland: Statutory Rule 2009 No. 56; Scotland: Statutory Instrument 2009 No. 30; Wales: Statutory Instrument 2009 No.481 and BPF-BIBRA (1995), Polymer Specification 5, Polypropylene

1.7.1.10 Italy

Decreto Ministeriale n.220, 26.04.1993 and subsequent amendmends (last update: D.M. n.215, 10.12.2008) and D.M. n.34, 21.03.1973

1.7.1.11 Netherlands, the

Verpakkingen- en Gebruiksartikelenbesluit, 1979 (Warenwet), Deel A, Hoofdstuk 1, Kunststoffen, as amendmended (last update from 26.11.2008)

1.7.1.12 Norway

Sosial- og helsedepartementets forskrift 1993-12-21-1381

1.7.1.13 Portugal

Decreto-Lei n° 29/2009 de 02.02.2009

1.7.1.14 Spain

Real Decreto 866/2008 y R.D. 103/2009 y ANAIP (1982), Anexo 1, Anexo 4

1.7.1.15 Sweden

Statens Livsmedelsverks kungörelse LIVSFS 2003:2 och ändr. LIVSFS 2004:31, 2005:14, 2005:28, 2006:6, 2006:20, 2008:7, 2009:2

1.7.1.16 Switzerland

Verordnung der EDI über Bedarfsgegenstände 23.11.2005; Stand 01.01.2009, 3. Abschnitt Bedarfsgegenstände aus Kunststoff

1.7.2 Migration limits

Monomers and additives used for the manufacturing of this grade are not regulated with specific migration limits.

Substances authorised as food additives are not present in the end product in such quantities that migration to foodstuffs could exceed the limits set in the relevant food legislation.

In accordance with Article 2 of Directive 2002/72/EC (as amended), the overall migration shall not exceed 60 mg/kg or 10 mg/dm² respectively from plastic materials and articles. Compliance with these requirements shall be measured from the finished food contact articles by using real food or appropriate food simulants at the time/temperature conditions as applicable acccording to the rules as specified in Directives 82/711/EC (as amended) and 85/572/EC.

1.7.3 Medical applications

1.7.3.1 USP classification

PP-Pure and Polypure resins have been tested according to USP chapter 88 „Biological reactivity test, in vivo" and have demonstrated their compliance with the requirements of USP plastic class VI.

1.7.3.2 FDA confirmation

FDA, CFR, Title 21 (2009), 177.1520 (a)(3)(i)(c)(1), (b) and (c)3.1a Olefin polymers

According to FDA this product can be used in contact with all food types as described in table 1 of CFR 21 §176.170(c), under conditions of use B through H as described in Table 2 of CFR 21§176.170(c).

1.8 Material approvals ethylene chlorotrifluoroethylene (ECTFE)

(provided by the resin manufacturer)

1.8.1 Food product contact, physiological harmlessness, toxicology

1.8.1.1 EU

The fluorinated monomers used in the Halar copolymers meet the requirements of the Commission Regulation No 10/2011 and is intended to come into contact with foodstuff.

1.8.1.2 USA

ECTFE polymers are certified to meet NSF Standard 61 at 85 °C (185 °F)

1.8.2 Medical applications

1.8.2.1 USP classification

ECTFE has been tested according to USP chapter 88 “Biological reactivity tests, in vivo” and has demonstrated its compliance with the requirements of USP plastic class VI.

2 Standards

AGRU PURAD high purity pipes, fittings and semi-finished products are manufactured out of special grade moulding materials and produced according to relevant international standards.

Hereafter a summary of the most important standards for PP-Pure, Polypure, ECTFE and PVDF-UHP are given.

2.1 ÖNORM Österreichisches Normeninstitut

- ÖNORM B 5174 Pipes of Polypropylene - Dimensions, requirements, tests, marking of conformity

2.2 DIN Deutsches Institut für Normung

- DIN 1910, Part 3
  Welding, welding of plastics, processes
- DIN 8077
  Polypropylene (PP) pipes - PP-H, PP-B, PP-R, PP-RCT - Dimensions
- DIN 8078
  Polypropylene (PP) pipes - PP-H, PP-B, PP-R, PP-RCT - General quality requirements and testing
- DIN 16774, Part 1
  Plastic moulding materials; polypropylene and propylene copolymer thermoplastics; classification and designation
- DIN 16928
  Pipes of thermoplastic materials - pipe joints, elements for pipes, laying of pipes - General directions

2.3 CEN Comité Européen de Normalisation

- EN 1046
  Plastic piping and ducting systems - systems outside building structures for the conveyance of water or sewage - practices for installation above and below ground
- EN 10204
  Metallic products - Types of inspection documents

2.4 ISO International Organization for Standardization

- ISO 3
  Preferred numbers
  Series of preferred numbers
- ISO/DIS 161 Part 1
  Thermoplastic pipes for the conveyance of fluids - Nominal outside diameters and nominal pressures
  Part 1: Metric series
- ISO 472
  Plastics vocabulary

- ISO 1873
  Plastics - Polypropylene and propylene-copolymer thermoplastics - Designation
- ISO/DIS 3213
  Polypropylene (PP) pipes - Effect of time and temperature on expected strength
- ISO 3609
  Polypropylene (PP) pipes - Tolerances on outside diameters and wall thickness
- ISO 4065
  Thermoplastic pipes - Universal wall thickness table
- EN ISO 9001
  Quality management systems - Requirements
- EN ISO 9080
  Plastic piping and ducting systems - Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation
- ISO 10931
  Plastics piping systems for industrial applications polyvinylidene fluoride (PVDF) Specifications for components and the system
- ISO 11922 Part 1
  Thermoplastics pipes for the conveyance of fluids - Dimensions and tolerances
  Part 1: Metric series
- ISO 12162
  Thermoplastics materials for pipes and fittings for pressure applications - Classification and designation - Overall service (design) coefficient
- ISO 15494
  Plastics piping systems for industrial applications - polybutene (PB), polyethylene (PE) and polypropylene (PP) - Specifications for components and the system - Metric series

2.5 DVS Deutscher Verband für Schweißen und verwandte Verfahren

- DVS 2207, Part 6
  Welding of thermoplastics - non contact heated tool welding (IR) of pipes, pipeline, components and sheets
- DVS 2207, Part 11
  Welding of thermoplastics - heated tool welding of pipes, pipeline, components and sheets out of PP
- DVS 2207, Part 15
  Welding of thermoplastics - heated tool welding of pipes, pipeline, components and sheets out of PVDF
- DVS 2208, Part 1
  Welding of thermoplastics - machines and devices for the heated tool welding of pipes, pipeline, components and sheets
- DVS 2210, Part 1
  Industrial pipelines made of thermoplastics planning and execution, above-ground pipe systems

2.6 ASTM American Society for Testing and Materials

- ASTM D 2122
  Determining dimensions of thermoplastic pipe and fitting
- ASTM D 2749
  Dimensions of plastic pipe
- ASTM D 3222
  Standard specification for PVDF moulding and extrusion materials
- ASTM D 4101
  Standard specification for PP

J Table of abbreviations

1 Table of abbreviations

2D	Two-dimensional
3D	Three-dimensional
AC	Alternating current
AMC	Airborne Molecular Contamination
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BGA	Federal Ministry of Health (Germany)
BSP	British Standard Pipe
CAD	Computer-aided design
CE	European Conformity
CEN	European Committee for Standardisation
CIP	Cleaning in Place
CMP	Chemical Mechanical Polishing/ Planarization
DA	Double action
DC	Direct current
DI	Deionised water
DIBt	German Institute for Civil Engineering
DIN	German Institute for Standardisation
DN	Diameter Nominal
DRAM	Dynamic Random Access Memory
DVD	Digital Versatile Disc
DVS	German Welding Society
DXF	Drawing Interchange Format
e.g.	exempli gratia
ECTFE	Ethylene chlorotrifluoroethylene
EEC	European Economic Community Directive
EN	European Committee for Standardisation
EPDM	Ethylene propylene diene monomer
ePTFE	Expanded polytetrafluoroethylene
FAQ	Frequently asked questions
FDA	Food and Drug Administration
FM	Factory Mutual
FPD	Flat panel display
FPM	Fluorinated propylene monomer
h	Hour(s)
H_2O_2	Hydrogen peroxide
H_2SO_4	Sulphuric acid
HCl	Hydrogen chloride
HDPE	High density polyethylene
HF	Hydrogen fluoride
HNO_3	Nitric acid
hPW	Highly purified water
IP	Ingress Protection Rating
IPA	Isopropyl alcohol
IR	Infrared
ISO	International Organization for Standardisation
JIS	Japanese Industrial Standards
KTW	German quality standard for rubber and plastic components in contact with drinking water
LCD	Liquid crystal display
LED	Light-emitting diode
LOI	Limiting Oxygen Index
M16	Metric screw threads; major thread diameter: 16 mm
MEMS	Microelectromechanical systems
MFR	Melt Flow Rate

min	Minute(s)
MOP	Maximum operating pressure
n.a.	not available
NaOH	Sodium hydroxide
NC	Normally closed
NO	Normally open
NPT	National pipe thread
NSF	National Sanitation Foundation
OD	Outside diameter
OLED	Organic light-emitting diode
ÖNORM	Austrian Standards Institute
PA	Polyamide
PBTP	Polybutylene terephthalate
PCB	Printed circuit board
PDP	Plasma display panel
PE	Polyethylene
PFA	Perfluoroalkoxy
PG	German standard for screw threads (Panzergewinde)
pH	potentia hydrogenii
PNP	Transistor type (positive - negative - positive [charged regions])
PP	Polypropylene
PP-H	Polypropylene homopolymer
PP-R	Polypropylene random copolymer
PSU	Polysulphone
PTFE	Polytetrafluoroethylene
PV	Photovoltaics
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride
PW	Purified water
R	Radius
SEMATECH	Semiconductor Manufacturing Technology
SEMI	Semiconductor Equipment and Materials International
SI	International System of Units
SP	AGRU’s welding machine series
STEP	Standard for the exchange of product model data
TABER	Abrasion test
TFT	Thin-film transistor
TOC	Total organic carbon
TÜV	Technical Inspection Association (Germany)
UHP	Ultra High Purity
UL	Underwriters Laboratories Inc.
UPW	Ultrapure Water
USP	United States Pharmacopeia
UV	Ultraviolet (light)
VDE	Association for Electrical, Electronic and Information Technologies
Vent	Ventilation
WFI	Water for Injection