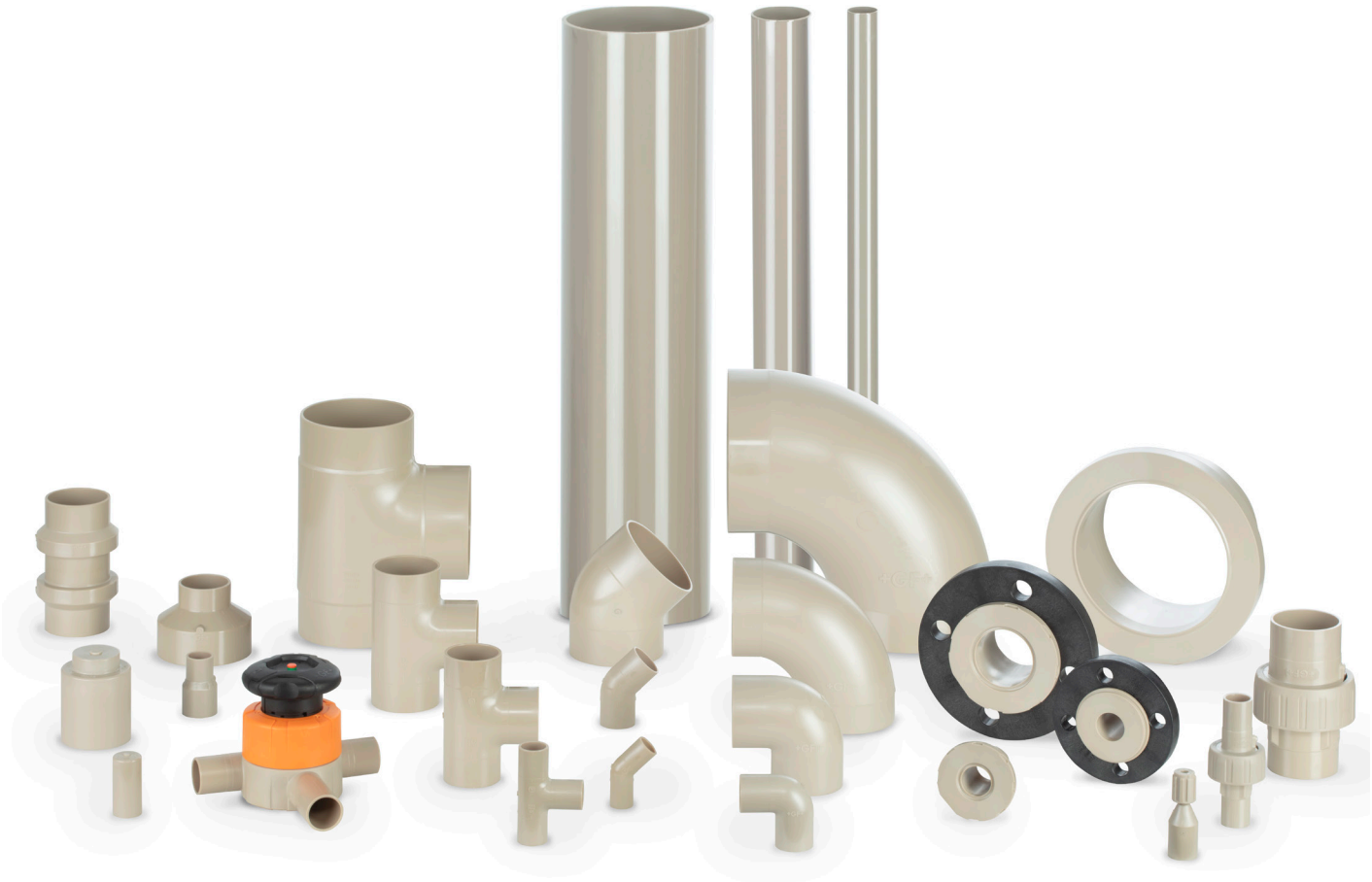


PEEK – SYGEF Ultra
Planning Fundamentals

Plan, Build, Operate

Materials and Piping Systems

PEEK

Content

2147863
Planning Fundamentals PEEK (09/2026)

CH-8201 Schaffhausen/Switzerland

PEEK - Polyetheretherketone

1.1 Reference values

Property	Value[1]	Units	Test standard
Density	1.30	g/cm³	EN ISO 1183-1
Yield stress[2]	≥ 94	N/mm²	EN ISO 527-1
Tensile modulus[2]	≥ 3'700	N/mm²	EN ISO 527-1
Charpy notched impact strength[2]	≥ 8	kJ/m²	EN ISO 179-1/1eA
Heat distortion temperature HDT A 1.80 MPa	≥ 157 ≥ 315	°C °F	EN ISO 75
Melting point	≥ 340 ≥ 644	°C °F	ASTM D3418
Thermal conductivity[2]	0.19	Btu-in./h-ft2-°F	ASTM E1530
Water absorption[2] / 24 h	≤ 0.1	%	ASTM D570
Color	Natural		
Limiting oxygen index (LOI)	≥ 36.8	%	ASTM D2863

[1] Typical characteristics measured at the material should not be used for calculations.
[2] At 23 °C (73.4 °F)

General

Polyetheretherketone (PEEK) is a high-performance semi-crystalline thermoplastic belonging to the polyaryletherketone (PAEK) family. Its molecular structure results in an exceptional combination of mechanical strength, low creep, thermal stability and excellent hydrolysis resistance, making it one of the most advanced engineering polymers for demanding industrial applications.

PEEK maintains its excellent mechanical properties at continuous operating temperatures even up to 250 °C, while exhibiting a very low thermal expansion and high dimensional stability.

For high-purity applications, PEEK offers an exceptionally low extractables profile regarding TOC and ionic contamination as the material can be processed and used without additives. These properties make it particularly suitable for ultrapure water (UPW) and hot ultrapure water (HUPW) systems used in semiconductor manufacturing, where the highest purity standards must be maintained even at elevated temperatures and pressures.

Advantages of PEEK

- Additive-free, unpigmented material for maximum purity
- Suitable for hot ultrapure water applications
- Outstanding leachout performance and very fast rinse-up in (H)UPW
- Exceptional combination of mechanical strength, stiffness and ductility, also at elevated temperatures
- High dimensional stability and low thermal expansion
- Excellent long-term pressure performance
- Secure jointing by infrared welding
- Excellent flame retardant properties

UV and weather resistance

PEEK exhibits a good resistance to ultraviolet radiation and weathering. For high-purity semiconductor applications, however, SYGEF Ultra PEEK systems are intended for indoor installation and should be protected from unnecessary environmental exposure during storage and installation. Contact the responsible GF Industry & Infrastructure Flow Solutions representative for more detailed information.

Chemical resistance

Though PEEK offers a good resistance to a wide range of chemicals, SYGEF Ultra PEEK is primarily intended for use with ultrapure water. For detailed information on the use of chemicals for sanitization contact the responsible GF Industry & Infrastructure Flow Solutions representative.

Abrasion resistance

PEEK offers excellent wear and abrasion resistance combined with high mechanical strength and stiffness. These properties contribute to the long service life of components exposed to dynamic loading or flowing media.

Application limits

The application limits depend on operating temperature, pressure, media and expected service life. PEEK as a polymer can be used up to 250°C. The SYGEF Ultra PEEK piping system is specifically designed for Hot Ultra Pure Water applications with continuous operating temperatures up to 140 °C. Pressure-temperature ratings are provided in the corresponding pressure-temperature diagrams.

Combustion behavior

PEEK exhibits excellent intrinsic flame resistance and belongs to the highest-performing thermoplastics regarding fire behaviour. It has a high limiting oxygen index (LOI) and is inherently self-extinguishing without the use of flame-retardant additives. If exposed to a fire from other materials burning, decomposition products of PEEK depend on the fire conditions. Please consider that fire fighting methods have to be adapted to the burnig material. For PEEK, powder, foam, water, water spray and CO2 can be used as extinguishing media. Please refer to the safety data sheets for appropriate fire fighting measures.

Electrical properties

Like most unmodified thermoplastics, PEEK is electrically non-conductive and therefore not susceptible to electrochemical corrosion. However, electrostatic charging may occur under certain operating conditions. Appropriate precautions should be taken where electrostatic discharge could present a hazard. Various methods are available to prevent the occurrence of electrostatic charges. GF Industry & Infrastructure Flow Solutions representatives can provide support in selecting the right one. The specific volume resistance is greater than 1.6 x10^{17} Ωcm and the surface resistivity is >1.9x10^{17} Ω.

High-purity properties

SYGEF Ultra PEEK is manufactured from unpigmented, additive-free PEEK to achieve the highest purity. The material is characterized by extremely low extractables.

These properties make SYGEF Ultra PEEK particularly suitable for Hot Ultra Pure Water (HUPW) systems in semiconductor manufacturing, where the highest purity standards are required. In addition, products made of PEEK exhibit a very smooth surface. Leach-out tests according to SEMI F40 are done regularly for quality control.

1.2 Pressure-temperature diagram for PEEK

The following pressure-temperature diagrams for PEEK pipe and fittings are valid for a service life of 25 years.

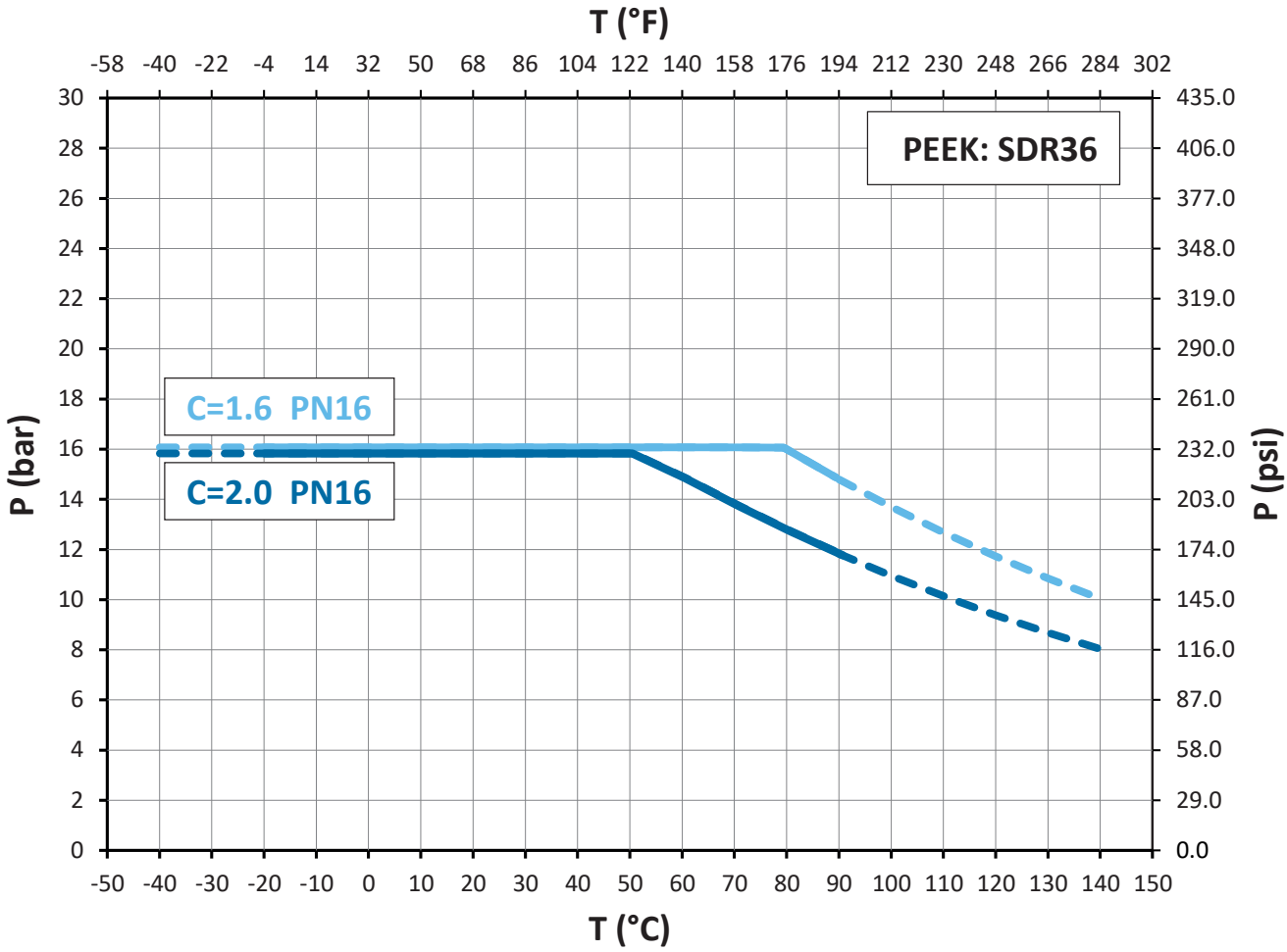
The design factor of 2.0 recommended by GF Industry & Infrastructure Flow Solutions has been incorporated. The pressure-temperature curves are valid for water or media resembling water, in other words, media that have no reduction factor for chemical resistance.

The long-term welding factor fs (or long-term joining factor) must be taken into account if relevant (e.g. stress check in longitudinal direction).

⚠ Please take into account the pressure-temperature diagrams for valves and special fittings. Because of the construction and/or sealing material used, differences are possible when compared to pipe and fittings. More information is available in the Planning Fundamentals of the relevant types of valves and special fittings.

i In case of operating in the temperature range shown in dotted lines, contact your authorized GF Industry & Infrastructure Flow Solutions representative.

PEEK, SDR36



P Permissible pressure (bar, psi)
T Temperature (°C, °F)

⚠ The permissible operating pressure can be used as a guide value for constant operating conditions (pressure, temperature). For changing operating conditions, it is recommended to perform a strength check in accordance with DVS 2210-1.

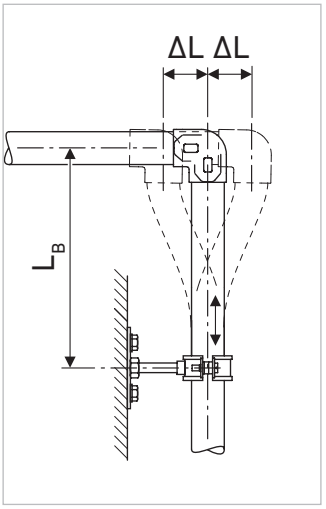
i These diagrams can only be used for applications with liquids!

1.3 Flexible sections of PEEK piping systems

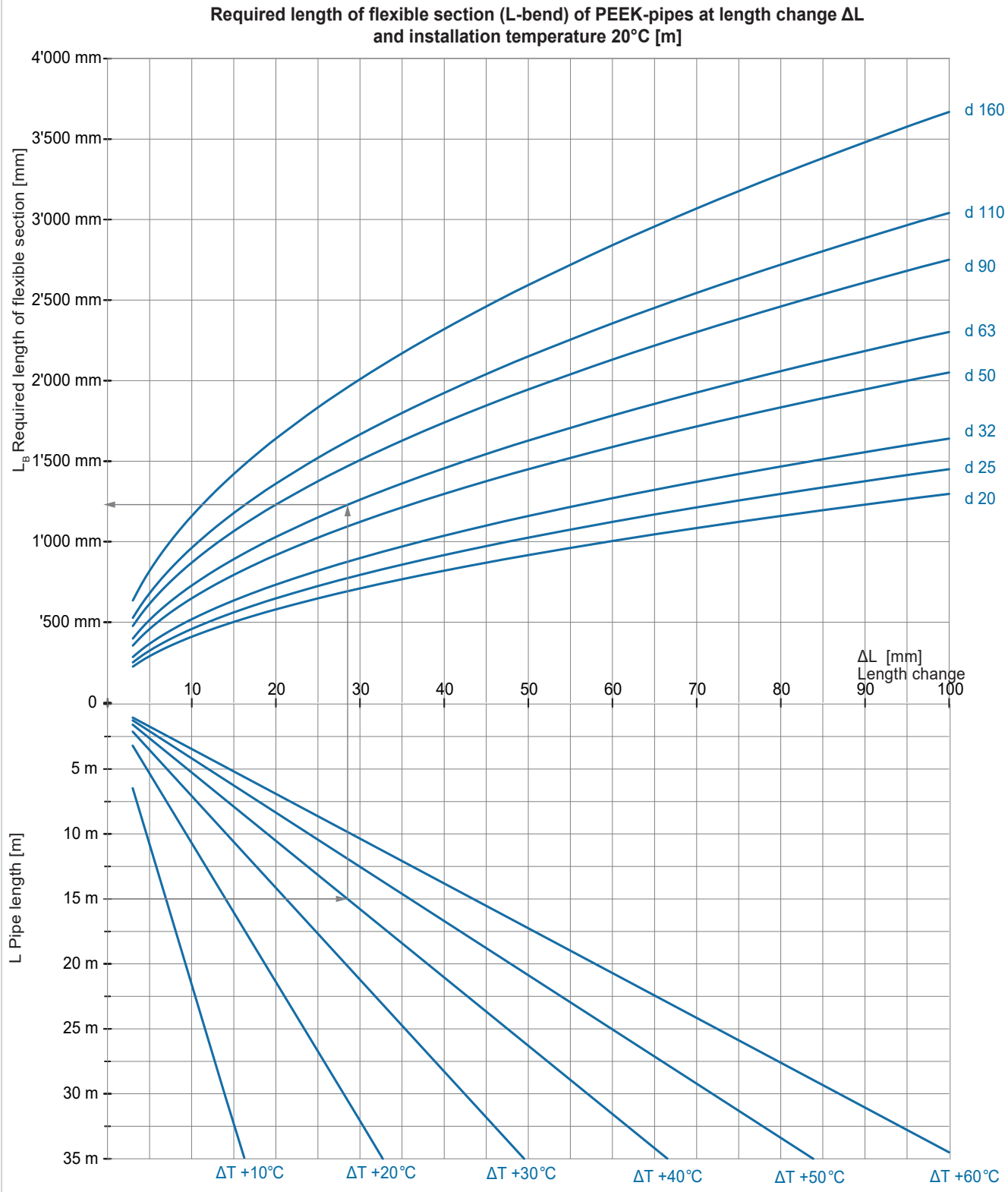
Properties of PEEK

Symbol	Designation	Value	Unit
K	Proportionality factor for flexible sections	29	-
ΔL	Length change	-	mm/inch
d	Outer pipe diameter	-	mm
L_B	Required length of flexible section (L-bend)	-	mm/inch

$L_B = K * (d * \Delta L)^{\wedge 0.5}$



Flexible sections diagram - Outer pipe diameter d20 - d160



Required length of flexible section L_B at length change ΔL, [mm]

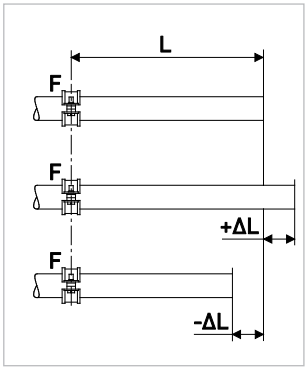
ΔL (mm)	Outer Pipe Diameter d (mm) 20 (mm)	25 (mm)	32 (mm)	50 (mm)	63 (mm)	90 (mm)	110 (mm)	160 (mm)
15	500	560	635	795	890	1050	1200	1400
30	710	795	900	1100	1250	1500	1650	2000
45	870	975	1100	1400	1550	1850	2050	2450
60	1000	1100	1250	1600	1800	2150	2350	2850
75	1100	1250	1400	1800	2000	2400	2650	3200
90	1250	1400	1550	1950	2200	2600	2900	3500
105	1350	1500	1700	2100	2350	2800	3100	3750
120	1400	1600	1800	2250	2500	3000	3350	4000
135	1500	1700	1900	2400	2650	3200	3550	4250
150	1600	1800	2000	2500	2800	3350	3750	4500
165	1650	1850	2100	2650	2950	3550	3900	4700
180	1750	1950	2200	2750	3100	3700	4100	4900
195	1800	2000	2300	2850	3200	3850	4250	5100
210	1900	2100	2400	2950	3350	4000	4400	5300
225	1950	2200	2450	3100	3450	4150	4550	5500
240	2000	2250	2550	3200	3550	4250	4700	5700
255	2050	2300	2600	3250	3700	4400	4850	5850
270	2150	2400	2700	3350	3800	4500	5000	6050
285	2200	2450	2750	3450	3900	4650	5150	6200
300	2250	2500	2850	3550	4000	4750	5250	6350

Required length of flexible section L_B at length change ΔL, [inch]

ΔL (inch)	Outer Pipe Diameter d (mm) 20 (inch)	25 (inch)	32 (inch)	50 (inch)	63 (inch)	90 (inch)	110 (inch)	160 (inch)
0.5	16.7	18.7	21.2	26.5	29.7	35.5	39.3	47.4
1.0	23.7	26.5	30.0	37.4	42.0	50.2	55.5	67.0
1.5	29.0	32.4	36.7	45.9	51.5	61.5	68.0	82.0
2.0	33.5	37.4	42.4	52.9	59.4	71.0	78.5	94.7
2.5	37.4	41.9	47.4	59.2	66.4	79.4	87.8	106
3.0	41.0	45.9	51.9	64.8	72.8	87.0	96.2	116
3.5	44.3	49.5	56.0	70.0	78.6	94.0	104	125
4.0	47.4	52.9	59.9	74.9	84.0	100	111	134
4.5	50.2	56.2	63.5	79.4	89.1	107	118	142
5.0	52.9	59.2	67.0	83.7	94.0	112	124	150
6.0	60.6	67.7	76.6	95.8	108	129	142	171
7.0	67.7	75.7	85.6	107	120	144	159	191
8.0	74.3	83.1	94.0	117	132	158	174	210
9.0	80.5	90.1	102	127	143	171	189	228
10.0	86.5	96.7	109	137	153	183	203	245
11.0	92.1	103	116	146	163	195	216	260
12.0	97.5	109	123	154	173	207	229	276
13.0	103	115	130	162	182	218	241	290
14.0	108	120	136	170	191	228	252	304
15.0	112	126	142	178	199	238	263	318

1.4 Length changes of PEEK

Properties of PEEK			
Symbol	Designation	Value	Unit
T_{min}	Temperature min.	-40 / -40	°C / °F
T_{max}	Temperature max.	+140 / +284	°C / °F
ΔT	Temperature difference	-	°C / °F
α_{min}	Linear thermal expansion coefficient @20°C/68°F	0.04	mm/m K
α_{max}	Linear thermal expansion coefficient @max. temperature	0.048	mm/m K
ΔL	Length change	-	mm
L	Pipe length	-	m/inch
F	Fix point	-	-



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

Thermal length change ΔL (mm) between 20°C and any end temperature

Pipe length L	End temperature (°C)																		
	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140
(m)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
1	-2.6	-2.2	-1.8	-1.3	-0.9	-0.5	0.0	0.5	0.9	1.4	1.9	2.4	2.9	3.4	3.9	4.5	5.0	5.5	6.1
2	-5.2	-4.4	-3.5	-2.7	-1.8	-0.9	0.0	0.9	1.9	2.8	3.8	4.8	5.8	6.8	7.9	8.9	10.0	11.0	12.1
3	-7.8	-6.5	-5.3	-4.0	-2.7	-1.4	0.0	1.4	2.8	4.2	5.7	7.2	8.7	10.2	11.8	13.4	15.0	16.6	18.2
4	-10.3	-8.7	-7.1	-5.3	-3.6	-1.8	0.0	1.9	3.7	5.7	7.6	9.6	11.6	13.6	15.7	17.8	19.9	22.1	24.3
5	-12.9	-10.9	-8.8	-6.7	-4.5	-2.3	0.0	2.3	4.7	7.1	9.5	12.0	14.5	17.0	19.6	22.3	24.9	27.6	30.4
6	-15.5	-13.1	-10.6	-8.0	-5.4	-2.7	0.0	2.8	5.6	8.5	11.4	14.4	17.4	20.4	23.6	26.7	29.9	33.1	36.4
7	-18.1	-15.3	-12.3	-9.4	-6.3	-3.2	0.0	3.2	6.5	9.9	13.3	16.8	20.3	23.9	27.5	31.2	34.9	38.7	42.5
8	-20.7	-17.4	-14.1	-10.7	-7.2	-3.6	0.0	3.7	7.5	11.3	15.2	19.2	23.2	27.3	31.4	35.6	39.9	44.2	48.6
9	-23.3	-19.6	-15.9	-12.0	-8.1	-4.1	0.0	4.2	8.4	12.7	17.1	21.6	26.1	30.7	35.3	40.1	44.9	49.7	54.6
10	-25.9	-21.8	-17.6	-13.4	-9.0	-4.6	0.0	4.6	9.4	14.1	19.0	24.0	29.0	34.1	39.3	44.5	49.8	55.2	60.7
12	-31.0	-26.2	-21.2	-16.0	-10.8	-5.5	0.0	5.6	11.2	17.0	22.8	28.8	34.8	40.9	47.1	53.4	59.8	66.3	72.9
14	-36.2	-30.5	-24.7	-18.7	-12.6	-6.4	0.0	6.5	13.1	19.8	26.6	33.5	40.6	47.7	55.0	62.3	69.8	77.3	85.0
16	-41.4	-34.9	-28.2	-21.4	-14.4	-7.3	0.0	7.4	15.0	22.6	30.4	38.3	46.4	54.5	62.8	71.2	79.7	88.4	97.2
18	-46.5	-39.2	-31.7	-24.1	-16.2	-8.2	0.0	8.3	16.8	25.5	34.2	43.1	52.2	61.3	70.7	80.1	89.7	99.4	109.3
20	-51.7	-43.6	-35.3	-26.7	-18.0	-9.1	0.0	9.3	18.7	28.3	38.0	47.9	58.0	68.2	78.5	89.0	99.7	110.5	121.4
30	-77.6	-65.4	-52.9	-40.1	-27.0	-13.7	0.0	13.9	28.1	42.4	57.0	71.9	86.9	102.2	117.8	133.5	149.5	165.7	182.2
40	-103.4	-87.2	-70.5	-53.5	-36.0	-18.2	0.0	18.6	37.4	56.6	76.1	95.8	115.9	136.3	157.0	178.0	199.3	221.0	242.9
50	-129.3	-109.0	-88.1	-66.8	-45.0	-22.8	0.0	23.2	46.8	70.7	95.1	119.8	144.9	170.4	196.3	222.5	249.2	276.2	303.6

Thermal length change ΔL (inch) between 68°F and any end temperature

Pipe length L	End temperature (°F)																		
	-40	-22	-4	14	32	50	68	86	104	122	140	158	176	194	212	230	248	266	284
(ft)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)	(inch)
3	-0.09	-0.08	-0.06	-0.05	-0.03	-0.02	0.00	0.02	0.03	0.05	0.07	0.09	0.10	0.12	0.14	0.16	0.18	0.20	0.22
6	-0.19	-0.16	-0.13	-0.10	-0.06	-0.03	0.00	0.03	0.07	0.10	0.14	0.17	0.21	0.25	0.28	0.32	0.36	0.40	0.44
10	-0.31	-0.26	-0.21	-0.16	-0.11	-0.05	0.00	0.06	0.11	0.17	0.23	0.29	0.35	0.41	0.47	0.53	0.60	0.66	0.73
15	-0.47	-0.39	-0.32	-0.24	-0.16	-0.08	0.00	0.08	0.17	0.25	0.34	0.43	0.52	0.61	0.71	0.80	0.90	0.99	1.09
20	-0.62	-0.52	-0.42	-0.32	-0.22	-0.11	0.00	0.11	0.22	0.34	0.46	0.58	0.70	0.82	0.94	1.07	1.20	1.33	1.46
25	-0.78	-0.65	-0.53	-0.40	-0.27	-0.14	0.00	0.14	0.28	0.42	0.57	0.72	0.87	1.02	1.18	1.34	1.50	1.66	1.82
30	-0.93	-0.78	-0.63	-0.48	-0.32	-0.16	0.00	0.17	0.34	0.51	0.68	0.86	1.04	1.23	1.41	1.60	1.79	1.99	2.19
35	-1.09	-0.92	-0.74	-0.56	-0.38	-0.19	0.00	0.19	0.39	0.59	0.80	1.01	1.22	1.43	1.65	1.87	2.09	2.32	2.55
40	-1.24	-1.05	-0.85	-0.64	-0.43	-0.22	0.00	0.22	0.45	0.68	0.91	1.15	1.39	1.64	1.88	2.14	2.39	2.65	2.91
45	-1.40	-1.18	-0.95	-0.72	-0.49	-0.25	0.00	0.25	0.51	0.76	1.03	1.29	1.56	1.84	2.12	2.40	2.69	2.98	3.28
50	-1.55	-1.31	-1.06	-0.80	-0.54	-0.27	0.00	0.28	0.56	0.85	1.14	1.44	1.74	2.04	2.36	2.67	2.99	3.31	3.64
60	-1.86	-1.57	-1.27	-0.96	-0.65	-0.33	0.00	0.33	0.67	1.02	1.37	1.73	2.09	2.45	2.83	3.20	3.59	3.98	4.37
70	-2.17	-1.83	-1.48	-1.12	-0.76	-0.38	0.00	0.39	0.79	1.19	1.60	2.01	2.43	2.86	3.30	3.74	4.19	4.64	5.10
80	-2.48	-2.09	-1.69	-1.28	-0.86	-0.44	0.00	0.45	0.90	1.36	1.83	2.30	2.78	3.27	3.77	4.27	4.78	5.30	5.83
90	-2.79	-2.35	-1.90	-1.44	-0.97	-0.49	0.00	0.50	1.01	1.53	2.05	2.59	3.13	3.68	4.24	4.81	5.38	5.97	6.56
100	-3.10	-2.62	-2.12	-1.60	-1.08	-0.55	0.00	0.56	1.12	1.70	2.28	2.88	3.48	4.09	4.71	5.34	5.98	6.63	7.29
125	-3.88	-3.27	-2.64	-2.00	-1.35	-0.68	0.00	0.70	1.40	2.12	2.85	3.59	4.35	5.11	5.89	6.68	7.48	8.29	9.11
150	-4.65	-3.92	-3.17	-2.41	-1.62	-0.82	0.00	0.83	1.68	2.55	3.42	4.31	5.22	6.13	7.07	8.01	8.97	9.94	10.9

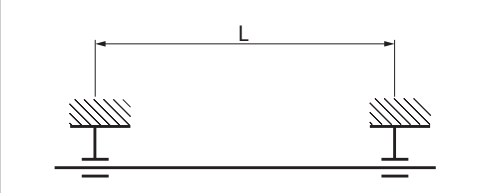
Thermal length change ΔL (mm/m) between any start temperature and any end temperature

Start temperature (°C)	End temperature (°C)																		
	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140
	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)	(mm/m)
-40	0.00	0.41	0.82	1.25	1.69	2.13	2.59	3.05	3.52	4.00	4.49	4.98	5.48	5.99	6.51	7.04	7.57	8.11	8.66
-30	-0.41	0.00	0.42	0.84	1.28	1.72	2.18	2.64	3.11	3.59	4.08	4.58	5.08	5.59	6.10	6.63	7.16	7.70	8.25
-20	-0.82	-0.42	0.00	0.43	0.86	1.31	1.76	2.23	2.70	3.18	3.66	4.16	4.66	5.17	5.69	6.21	6.75	7.29	7.83
-10	-1.25	-0.84	-0.43	0.00	0.44	0.88	1.34	1.80	2.27	2.75	3.24	3.73	4.23	4.74	5.26	5.79	6.32	6.86	7.41
0	-1.69	-1.28	-0.86	-0.44	0.00	0.45	0.90	1.36	1.84	2.32	2.80	3.30	3.80	4.31	4.83	5.35	5.88	6.42	6.97
10	-2.13	-1.72	-1.31	-0.88	-0.45	0.00	0.46	0.92	1.39	1.87	2.36	2.85	3.35	3.86	4.38	4.91	5.44	5.98	6.53
20	-2.59	-2.18	-1.76	-1.34	-0.90	-0.46	0.00	0.46	0.94	1.41	1.90	2.40	2.90	3.41	3.93	4.45	4.98	5.52	6.07
30	-3.05	-2.64	-2.23	-1.80	-1.36	-0.92	-0.46	0.00	0.47	0.95	1.44	1.93	2.43	2.94	3.46	3.99	4.52	5.06	5.61
40	-3.52	-3.11	-2.70	-2.27	-1.84	-1.39	-0.94	-0.47	0.00	0.48	0.97	1.46	1.96	2.47	2.99	3.52	4.05	4.59	5.14
50	-4.00	-3.59	-3.18	-2.75	-2.32	-1.87	-1.41	-0.95	-0.48	0.00	0.49	0.98	1.48	1.99	2.51	3.04	3.57	4.11	4.66
60	-4.49	-4.08	-3.66	-3.24	-2.80	-2.36	-1.90	-1.44	-0.97	-0.49	0.00	0.49	1.00	1.51	2.02	2.55	3.08	3.62	4.17
70	-4.98	-4.58	-4.16	-3.73	-3.30	-2.85	-2.40	-1.93	-1.46	-0.98	-0.49	0.00	0.50	1.01	1.53	2.05	2.59	3.13	3.68
80	-5.48	-5.08	-4.66	-4.23	-3.80	-3.35	-2.90	-2.43	-1.96	-1.48	-1.00	-0.50	0.00	0.51	1.03	1.55	2.09	2.63	3.17
90	-5.99	-5.59	-5.17	-4.74	-4.31	-3.86	-3.41	-2.94	-2.47	-1.99	-1.51	-1.01	-0.51	0.00	0.52	1.04	1.58	2.12	2.66
100	-6.51	-6.10	-5.69	-5.26	-4.83	-4.38	-3.93	-3.46	-2.99	-2.51	-2.02	-1.53	-1.03	-0.52	0.00	0.53	1.06	1.60	2.15
110	-7.04	-6.63	-6.21	-5.79	-5.35	-4.91	-4.45	-3.99	-3.52	-3.04	-2.55	-2.05	-1.55	-1.04	-0.53	0.00	0.53	1.07	1.62
120	-7.57	-7.16	-6.75	-6.32	-5.88	-5.44	-4.98	-4.52	-4.05	-3.57	-3.08	-2.59	-2.09	-1.58	-1.06	-0.53	0.00	0.54	1.09
130	-8.11	-7.70	-7.29	-6.86	-6.42	-5.98	-5.52	-5.06	-4.59	-4.11	-3.62	-3.13	-2.63	-2.12	-1.60	-1.07	-0.54	0.00	0.55
140	-8.66	-8.25	-7.83	-7.41	-6.97	-6.53	-6.07	-5.61	-5.14	-4.66	-4.17	-3.68	-3.17	-2.66	-2.15	-1.62	-1.09	-0.55	0.00

Thermal length change ΔL (inch/ft) between any start temperature and any end temperature

Start temperature (°F)	End temperature (°F)																		
	-40	-22	-4	14	32	50	68	86	104	122	140	158	176	194	212	230	248	266	284
	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)	(inch/ft)
-40	0.000	0.005	0.010	0.015	0.020	0.026	0.031	0.037	0.042	0.048	0.054	0.060	0.066	0.072	0.078	0.084	0.091	0.097	0.104
-22	-0.005	0.000	0.005	0.010	0.015	0.021	0.026	0.032	0.037	0.043	0.049	0.055	0.061	0.067	0.073	0.080	0.086	0.092	0.099
-4	-0.010	-0.005	0.000	0.005	0.010	0.016	0.021	0.027	0.032	0.038	0.044	0.050	0.056	0.062	0.068	0.075	0.081	0.087	0.094
14	-0.015	-0.010	-0.005	0.000	0.005	0.011	0.016	0.022	0.027	0.033	0.039	0.045	0.051	0.057	0.063	0.069	0.076	0.082	0.089
32	-0.020	-0.015	-0.010	-0.005	0.000	0.005	0.011	0.016	0.022	0.028	0.034	0.040	0.046	0.052	0.058	0.064	0.071	0.077	0.084
50	-0.026	-0.021	-0.016	-0.011	-0.005	0.000	0.005	0.011	0.017	0.022	0.028	0.034	0.040	0.046	0.053	0.059	0.065	0.072	0.078
68	-0.031	-0.026	-0.021	-0.016	-0.011	-0.005	0.000	0.006	0.011	0.017	0.023	0.029	0.035	0.041	0.047	0.053	0.060	0.066	0.073
86	-0.037	-0.032	-0.027	-0.022	-0.016	-0.011	-0.006	0.000	0.006	0.011	0.017	0.023	0.029	0.035	0.042	0.048	0.054	0.061	0.067
104	-0.042	-0.037	-0.032	-0.027	-0.022	-0.017	-0.011	-0.006	0.000	0.006	0.012	0.018	0.024	0.030	0.036	0.042	0.049	0.055	0.062
122	-0.048	-0.043	-0.038	-0.033	-0.028	-0.022	-0.017	-0.011	-0.006	0.000	0.006	0.012	0.018	0.024	0.030	0.036	0.043	0.049	0.056
140	-0.054	-0.049	-0.044	-0.039	-0.034	-0.028	-0.023	-0.017	-0.012	-0.006	0.000	0.006	0.012	0.018	0.024	0.031	0.037	0.043	0.050
158	-0.060	-0.055	-0.050	-0.045	-0.040	-0.034	-0.029	-0.023	-0.018	-0.012	-0.006	0.000	0.006	0.012	0.018	0.025	0.031	0.038	0.044
176	-0.066	-0.061	-0.056	-0.051	-0.046	-0.040	-0.035	-0.029	-0.024	-0.018	-0.012	-0.006	0.000	0.006	0.012	0.019	0.025	0.032	0.038
194	-0.072	-0.067	-0.062	-0.057	-0.052	-0.046	-0.041	-0.035	-0.030	-0.024	-0.018	-0.012	-0.006	0.000	0.006	0.013	0.019	0.025	0.032
212	-0.078	-0.073	-0.068	-0.063	-0.058	-0.053	-0.047	-0.042	-0.036	-0.030	-0.024	-0.018	-0.012	-0.006	0.000	0.006	0.013	0.019	0.026
230	-0.084	-0.080	-0.075	-0.069	-0.064	-0.059	-0.053	-0.048	-0.042	-0.036	-0.031	-0.025	-0.019	-0.013	-0.006	0.000	0.006	0.013	0.019
248	-0.091	-0.086	-0.081	-0.076	-0.071	-0.065	-0.060	-0.054	-0.049	-0.043	-0.037	-0.031	-0.025	-0.019	-0.013	-0.006	0.000	0.006	0.013
266	-0.097	-0.092	-0.087	-0.082	-0.077	-0.072	-0.066	-0.061	-0.055	-0.049	-0.043	-0.038	-0.032	-0.025	-0.019	-0.013	-0.006	0.000	0.007
284	-0.104	-0.099	-0.094	-0.089	-0.084	-0.078	-0.073	-0.067	-0.062	-0.056	-0.050	-0.044	-0.038	-0.032	-0.026	-0.019	-0.013	-0.007	0.000

1.5 Pipe support spacing for PEEK pipes



Liquids with a density of 1 g/cm³

d (mm)	Pipe support spacings L in mm for pipe PN16 / SDR36 (mm)												
	≤ 20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	90 °C	100 °C	110 °C	120 °C	130 °C	140 °C
20	1'400	1'350	1'350	1'300	1'300	1'300	1'250	1'200	1'200	1'150	1'100	1'000	900
25	1'500	1'450	1'450	1'400	1'400	1'400	1'350	1'300	1'300	1'250	1'200	1'100	1'000
32	1'600	1'600	1'550	1'550	1'500	1'500	1'450	1'450	1'400	1'350	1'300	1'250	1'100
50	1'950	1'900	1'900	1'850	1'800	1'800	1'750	1'700	1'650	1'650	1'600	1'500	1'350
63	2'100	2'050	2'000	2'000	1'950	1'900	1'900	1'850	1'800	1'750	1'700	1'600	1'500
90	2'300	2'250	2'250	2'200	2'150	2'150	2'100	2'050	2'000	1'950	1'900	1'800	1'650
110	2'550	2'500	2'500	2'450	2'400	2'350	2'300	2'250	2'200	2'150	2'100	1'950	1'800
160	3'100	3'050	3'000	2'950	2'900	2'850	2'800	2'750	2'650	2'600	2'550	2'400	2'200

Liquids with a density other than 1 g/cm³

If the liquid to be transported has a density not equal 1 g/cm³, then the Pipe support spacing in the table above should be multiplied by the factor given in the following table to obtain different support spacings.

Density of medium (g/cm³)	Type of medium	Factors for pipe support spacing
1.00	Water	1.00
1.25	Other media	0.96
1.50		0.92
1.75		0.88
2.00		0.84

1.6 Creating flange connections

When making a flange connection, the following points have to be taken into account:

Usage information

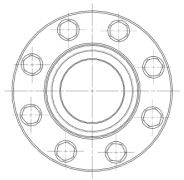
Backing flanges are identified with the following pictograms of the usable flanges:

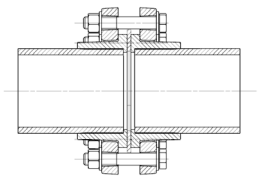
Socket fusion

Butt fusion

Orientation of bolts beyond the two main axes

- For horizontal piping systems, the orientation shown of the bolts beyond the main axes (see the following figure) is preferred since possible leaks at the flange connection do not cause the medium to run directly onto the bolts.





Flange with main axes (centered, crosswise)

- Flange adapter, valve end or fixed flange, gasket, as well as backing flange, must be aligned centered on the pipe axis.
- Before pre-tightening the bolts, the jointing faces must be flush with each other and must fit tightly against the gasket. Pulling badly aligned flanges together within the flange connection must to be strictly avoided because of the resulting tensile stress.

Selecting and handling bolts

- The length of the bolts should be selected in such a way that the bolt thread does not protrude more than 2 to 3 turns of the thread at the nut. Washers must be used at the bolt head as well as the nut.
  - To ensure that the connecting bolts can be easily tightened and removed after a lengthy period of use, the thread should be lubricated, e.g. with molybdenum sulphide.
  - Tightening the bolts by using a torque wrench
- The bolts must be tightened diagonally and evenly: First, tighten the bolts by hand so that the gasket is evenly contacting the jointing faces. Then tighten all bolts diagonally to 50 % of the required torque, followed by 100 % of the required torque. The recommended bolt tightening torques are listed in the table “Bolt tightening torque guidelines for ISO flange connections”. However, deviations may occur in practice, e.g. through the use of stiff bolts or pipe axes that are not aligned. The Shore hardness of the gasket can also influence the necessary tightening torque.
- We recommend checking the tightening torques 24 hours after assembly according to the specified values and, if necessary, retighten them. Always tighten diagonally here, as well.
- After the pressure test, the tightening torques must be checked in any case and, if necesary, retightened.

i For more information on flange connections, see DVS 2210-1 Supplement 3.

Tightening the bolts using a torque wrench

However, deviations may occur in practice, e.g. through the use of stiff bolts or pipe axes that are not aligned. The Shore hardness of the gasket can also influence the necessary tightening torque.

i In the area of flexible sections and expansion loops, no bolt connections or flange connections should be used since the bending stress may cause leaks.

Bolt tightening torque guidelines for metric (ISO) flange connections with PP-V, PP- steel and PVC flanges

The indicated torques are recommended by GF Industry & Infrastructure Flow Solutions. These torques already ensure a sufficient tightness of the flange connection. They deviate from the data in the DVS 2210-1 Supplement 3, which are to be understood as upper limits. The individual components of the flange connection (valve ends, flange adapters, flanges) by GF Industry & Infrastructure Flow Solutions are dimensioned for these upper limits.

Pipe outer diameter d (mm)	Nominal diameter DN (mm)	No. of bolts	For SYGEF Ultra metric systems, with PP-Steel flanges (Nm)	
			O-ring, unlubed	SYGEF Ultra gasket unlubed
d20	DN15	4	13	
d25	DN20	4	13	14
d32	DN 25	4	13	16
d40	DN 32	4	20	20
d50	DN 40	4	20	26
d63	DN 50	4	26	34
d75	DN 65	4	33	38
d90	DN 80	8	20	45
d110, 125	DN 100	8	26	30
d140	DN 125	8	33	
d160	DN 150	8	39	49

1.7 Pressure and leak test

1.7.1 Introduction to pressure testing

Overview of the different testing methods

Testing method	Pressure test			Leak test	
Medium	Water	Gas[1)]	Compressed air[1)]	Gas/air (oil-free)	Gas/air (oil-free)
Type	Incompressible	Compressible	Compressible	Compressible	Compressible
Test pressure (overpressure)	$P_{p\,(perm)}$ or $0.85 \cdot P_{p\,(perm)}$	Operating pressure + 2 bar	Operating pressure + 2 bar	0.5 bar	1.5 bar
Hazard potential during pressure test	Low	High	High	Low	Medium
Material	All plastics	ABS, PE	PB, PE	All plastics	ABS
Informative value	High: Proof of resistance to pressure including tightness against test medium	High: Proof of resistance to pressure including tightness against test medium	High: Proof of resistance to pressure including tightness against test medium	Low	Medium

1) Observe the applicable safety precautions. More information is available in DVS 2210-1 addendum 2.

A number of international and national standards and guidelines are available for leak and pressure tests. Therefore, it is often not easy to find the applicable test procedure and for example the test pressure.

The purpose of a pressure test is:

- Ensure the resistance to pressure of the pipeline, and
- Show the leak-tightness against the test medium

Usually, the pressure test is done as a water pressure test and only in exceptional cases (under consideration of special safety precautions) as a gas pressure test with air or nitrogen.

The following comparison attempts to point out the difference between water and air as a test medium:

Water is an incompressible medium, i.e. setting a 1 m PVDF pipe with a diameter of d160 under a pressure of 3 bar results in an energy of approx. 1 joule. In contrast, air is a compressible medium. The same pipe with test pressure of 3 bar already stores an energy of 5,000 joule. If there were a failure during the pressure test, the water-filled pipe would jump up 0.02 m, the air-filled pipe 110 m.

Fracture behavior of plastics

In case of a failure, thermoplastic materials show different behaviors. Hence, PE and PB exhibit a ductile behavior (and ABS slightly lower), so that brittle fracture cannot occur.

Nevertheless, the following safety precautions must be taken into consideration during the pressure test. As mentioned before, the pressure test is the first loading placed on the pipeline and is intended to uncover any existing processing faults (e.g. insufficient fusioning).

Gas leak-tightness cannot be demonstrated by a water pressure test, not even with increased test pressure!

1.7.2 Pressure test with water or a similar incompressible test medium for PEEK

Pressure drop

The guidelines for an expansion-related pressure decrease in pipe are:

Material	Pressure drop (bar/h)
PEEK	0.8

*According to DVS 2210-1ff

Determining the test pressure

The permissible test pressure is calculated according to the following formula:

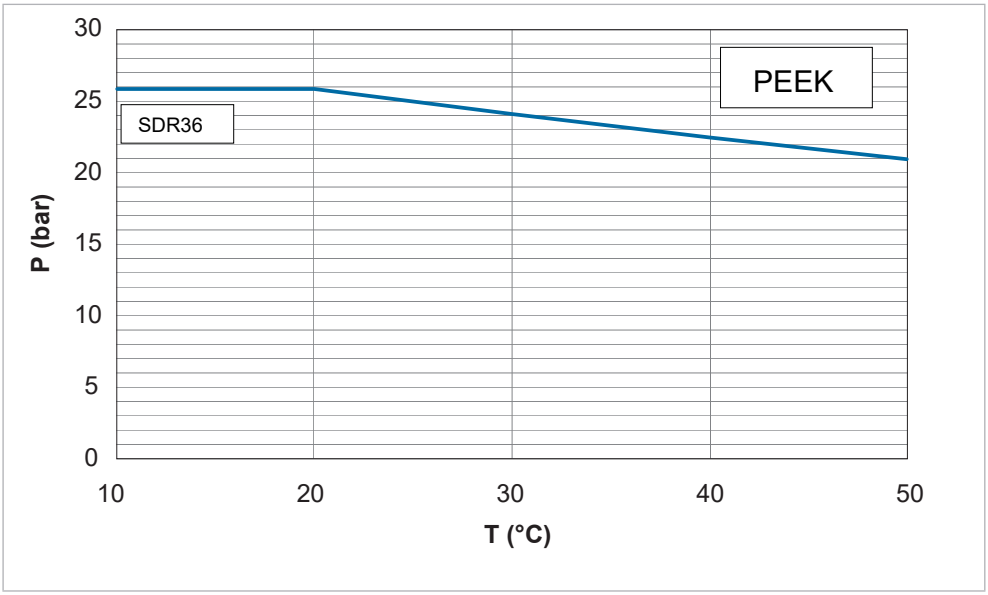
$$P_{p(zul)} = \frac{1}{SDR} \cdot \frac{20 \cdot \sigma_{v(T,\,100\,h)}}{S_p \cdot A_G}$$

$\sigma_{v(T,\,100\,h)}$	Long-term creep strength for pipe wall temperature T_R (at t = 100 h)
S_p	Minimum safety factor for long-term creep strength
A_G	Processing or geometry-specific factor that reduces the allowable test pressure
T_R	Pipe wall temperature: average value of test medium temperature and pipe surface temperature

⚠ In general, the weakest link in the system (in terms of PN rating) determines the maximum test pressure. If valves are installed in the system, the maximum test pressure shall not exceed the nominal pressure (PN) of the valves. At test temperatures above 20 °C, the maximum test pressure shall be limited according to the valve-specific pressure-temperature diagrams.

Material	S_p Minimum safety factor DVS 2210-1 Suppl.2
PEEK	1.4

Test pressure diagram for PEEK



P Permissible test pressure (bar)
T Pipe wall temperature (°C)

1.7.3 Pressure test with water or a similar incompressible test medium

Overview

The pressure test is done when installation work has been completed and presupposes an operational pipeline or operational test sections. The test pressure load is intended to furnish experimental proof of operational safety. The test pressure is not based on the operating pressure, but rather on the internal pressure load capacity, based on the pipe wall thickness.

Addendum 2 of DVS 2210-1 forms the basis for the following information. This replaces the data in DVS 2210-1 entirely. The modifications became necessary because the reference value "nominal pressure (PN)" is being used less and less to determine the test pressure (1.5 x PN, or 1.3 x PN) and is being replaced by SDR. In addition, a short-term overload or even a reduction in the service life can occur if the pipe wall temperature TR = 20 °C is exceeded by more than 5 °C in the course of the pressure test based on the nominal pressure.

Test pressures are, therefore, determined in relation to SDR and the pipe wall temperature. The 100-h value from the long-term behavior diagram is used for the test pressure.

Test parameters

The following table provides recommended methods for performing the pressure test.

Object	Pre-test	Main test
Test pressure $_{pp}$ (depends on the pipe wall temperature and the permissible test pressure of the built-in components, see the section "Determining the test pressure")	≤ $P_{p\,(perm)}$	≤ 0.85 $P_{p\,(perm)}$
Test duration (depends on the length of the pipeline sections)	L ≤ 100 m: 3 h 100 m < L ≤ 500 m: 6 h	L ≤ 100 m: 3 h 100 m <L ≤ 500 m: 6 h
Checks during the test (test pressure and temperature progression must be recorded)	At least 3 checks, distributed over the test duration with restoring the test pressure	At least 2 checks, distributed over the test duration without restoring the test pressure

Pre-test

The pre-test serves to prepare the piping system for the actual test (main test). In the course of pre-testing, a tension-expansion equilibrium in relation to an increase in volume will develop in the piping system. A material-related drop in pressure will occur which will require repeated pumping to restore the test pressure and also frequently a re-tightening of the flange connection bolts.

The guidelines for an expansion-related pressure decrease in pipe are:

Material	Pressure drop (bar/h)
PVC-U	0.5
PVC-C	0.5
ABS	0.6
PP	0.8
PE	1.2
PB	1.4
PVDF	0.8
PEEK	0.5
ECTFE	0.9
PA-U*	0.8

*According to DVS 2210-1ff

Main test

In the context of the main test, a much smaller drop in pressure can be expected at constant pipe wall temperatures so that it is not necessary to pump again. The checks can focus primarily on leak detection at the flange joints and any position changes of the pipe.

Observe if using compensators

If the pipeline to be tested contains compensators, it has an influence on the expected axial forces on the fixed points of the pipeline. Because the test pressure is higher than the operating pressure, the axial forces on the fixed points increase proportionately. This has to be taken into account when designing the fixed points.

Observe if using valves

When using a valve at the end of a pipeline (end or final valve), the valve and the pipe end should be closed by a dummy flange or cap. This prevents an inadvertent opening of the valve and exit of the medium or any pollution of the inside of the valve.

1.7.4 Filling the pipeline

Before starting with the pressure test, the following points must be checked:

- Was installation done according to the available plans?
- All pressure relief devices and flap traps mounted in the flow direction?
- All end valves shut?
- Valves in front of other devices are shut to protect against pressure?
- Visual inspection of all joints, pumps, measurement devices and tanks?
- Has the waiting period after the last fusion/cementing been observed?

Now the pipeline can be filled from the geodetic lowest point. Special attention should be given to the air vent. If possible, vents should be provided at all the high points of the pipeline and these should be open when filling the system. Flushing velocity should be at least 1 m/s.

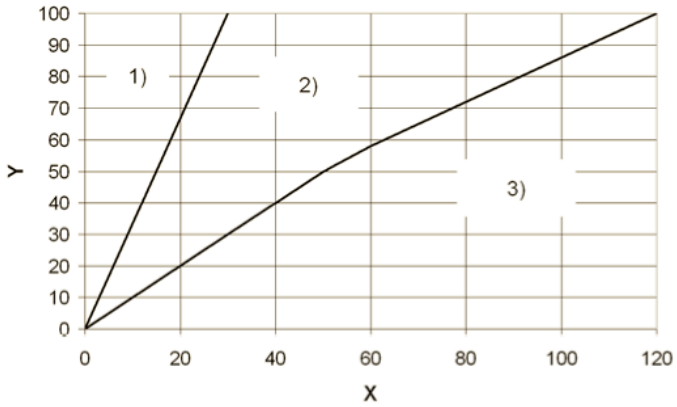
Reference values for the filling volume are given in the table below.

DN (mm)	V (l/s)	DN (mm)	V (l/s)
≤ 80	0.15	250	2.0
100	0.3	300	3.0
150	0.7	400	6.0
200	1.5	500	> 9.0

Adequate time should be allowed between filling and testing the pipeline, so that the air contained in the piping system can escape via the vents: approx. 6 - 12 h, depending on the nominal diameter.

Applying the test pressure

The test pressure is applied according to the diagram. Here it is important that the pressure increase rate does not cause any water hammering!



Y Test pressure (%)
X Time for pressure increase (min)
1) Pressure increase rate up to DN100 mm
2) Range of pressure increase rates between DN100 and DN400 mm
3) Values for pressure increase rate DN500 and greater is: 500/DN (bar/10 min)

Determining the test pressure

The permissible test pressure is calculated according to the following formula:

$$P_{p(zul)} = \frac{1}{SDR} \cdot \frac{20 \cdot \sigma_{v(T,\,100\,h)}}{S_p \cdot A_G}$$

$\sigma_{v(T,\,100\,h)}$ Long-term creep strength for pipe wall temperature T_R (at t = 100 h)
S_p Minimum safety factor for long-term creep strength
A_G Processing or geometry-specific factor that reduces the allowable test pressure
T_R Pipe wall temperature: average value of test medium temperature and pipe surface temperature

If the piping system contains valves, the maximum allowable test pressure is limited to the nominal pressure of the valves.

For the pressure test of valves in open position, the same instructions apply as for the piping system (max. 1.5 x PN, or max. PN + 5 bar), but the test pressure in closed valve position must not exceed max. 1.1 x PN.

Material	S_p Minimum safety factor DVS 2210-1 Suppl.2
ABS	1.6
PE80, PE100	1.25
PP-H	1.8
PP-R	1.4
PVC-U, PVC-C	2.5
PVDF	1.4
PEEK	1.3
ECTFE	1.6

Checks during testing

The following measurement values must be recorded consistently during testing:

- Internal pressure at the absolute lowest point of the pipeline
- Medium and ambient temperature
- Water volume input
- Water volume output
- Pressure drop rates

1.7.5 Pressure test of compressed-air piping systems

Overview

For practical reasons, this testing is done with compressed air. The pressure test follows DVGW G 469. The pressure test for pipeline lengths less than 500 m using air A3 based on visual inspection is described below. More details are available in the DVGW guideline.

⚠ Compressible media like compressed air under internal pressure.
In case of failure: life-threatening danger during pressure testing due to explosive escape of the medium.
→ The area around the pipeline under test pressure is to be clearly restricted for access only by persons assigned with the testing.
→ Required control equipment is to be placed at a safe distance.
→ The testing should be timed so that there are as few persons as possible in the immediate blocked-off area.
→ Additional signs (e.g. Do Not Enter or Warning! Gas pressure tests!) should be placed particularly at the entrances to the hazard area. If necessary, persons in neighboring buildings should be informed.

Testing procedure

The test pressure shall be least 2 bar higher than the permissible operating pressure. If this is not possible because of insufficient compressor output, then the maximum compressor pressure shall be used.

The piping systems must be free from any grease or paint.

The test pressure is applied to the installed pipeline with a maximum increase in pressure of 3 bar/min (risk of water hammer!). Hold the pipeline under the test pressure until all connection parts of the pipeline like flanges, unions, valves, etc. are inspected for tightness using a foam-building agent. A soap solution, which can be removed simply with water after the test, is best. It is recommended to subsequently reduce the test pressure to 2 bar and repeat the test using a foam-building agent.

Leak test with gas as test medium (compressible medium) and maximum test pressure of 0.5 bar

If it is not possible to do an pressure test with water (e.g., pipeline must be kept dry), a leak test can be carried out with slight overpressure. For safety reasons, the test pressure must then be limited to maximum 0.5 bar overpressure. During the leak test, all joints must be sprayed with a foam-building agent and checked. A soap solution, which can be removed simply with water after the test, is best. Since the efficiency of the leak test is significantly limited due to the low load, it is recommended to use it preferably for systems with operating pressures below 0.5 bar.

1.8 Relevant standards and guidelines for pipe and fittings made of PEEK

Standard	Name
DIN 28000-4	Chemical apparatus - Documentation in the life cycle of process plants - Part 4: Graphical symbols of valves, pipe and actuators
DVS 2207-6	Fusioning of thermoplastics - Non-contact heated tool butt fusion of pipe, piping system components and sheets - Methods, equipment, parameters
DVS 2210-1	Industrial piping systems made of thermoplastics - Planning and execution - Above-ground pipe systems
DVS 2210-1 Supplement 1	Industrial piping made of thermoplastics - Design and execution - Above-ground pipe systems - Calculation example
DVS 2210-1 Supplement 2	Industrial piping made of thermoplastics - Design and execution - Above-ground pipe systems - Recommendations for the internal pressure and leak tests
DVS 2210-1 Supplement 3	Industrial piping made of thermoplastics -Design and execution - Above-ground pipe systems - Flange connections: Description, requirements and assembly
DVS 2210-2	Industrial piping made of thermoplastics - Design, structure and installation of two-pipe systems
PEEK standards and guidelines based on	
ISO 10931	Plastics piping systems for industrial applications - Poly (vinylidene fluoride) (PVDF) - Specifications for components and the system
EN ISO 10931	Plastics piping systems for industrial applications - Poly (vinylidene fluoride) (PVDF) - Specifications for components and the system
ASTM F1673	Standard specification for polyvinylidene fluoride (PVDF) corrosive waste drainage systems
ASTM D3222	Standard specification for unmodified poly(vinylidene fluoride) (PVDF) molding extrusion and coating materials
DVS 2205 Supplement 4	Calculation of tanks and apparatus made of thermoplastics - Characteristic values of the PVDF pipe
DVS 2207-15	Fusioning of thermoplastics - Heated tool fusion of pipe, piping system components and sheets made of PVDF

1.9 SYGEF Ultra System by GF

SYGEF Ultra System overview

The outstanding physical and mechanical properties of the SYGEF Ultra PEEK piping system ensure reliable long-term performance for ultra hot ultrapure water (UHPW) applications.

SYGEF Ultra combines high mechanical strength, outstanding material purity and a wide operating temperature range from –40 °C to +140 °C (–40 °F to +284 °F).

Technical data

Nominal pressure	Up to 16 bar (232 psi)
Temperature range	-40 °C to +140 °C (-40 °F to +284 °F)
Jointing technology	Infrared (IR) fusion
Standards and guidelines[1)]	ISO, EN, ASTM, BS, JIS, CE, RoHS, DIN, DVS, SEMI
Fire performance	Class B s1 d0 according to EN 13501-1[2)]

1) For additional information about standards, guidelines and approvals, see www.gfps.com

2) Tested according to EN13823 and EN ISO 11925-2

Essential system properties

- PEEK high-performance, non-PFAS material [1)]
- Wide temperature range
- High mechanical strength and dimensional stability
- Extremely smooth inner surface
- Highest purity levels, exceeding SEMI F57++
- PN16 rating for long-term operational safety

System and design advantages

- Up to 80% faster rinse-up to specification (TOC, F) [2)]
- Up to 50% wider pipe spans enabling optimized rack design
- Up to 70% reduced thermal expansion
- Elimination of expansion loops depending on layout
- Up to 20% reduction of total piping components

[1)] More information on the PFAS definition at www.gfps.com/sygef-ultra

[2)] Performance comparisons were conducted between SYGEF Ultra (PEEK) and PVDF-HP systems

Important market segments

- Microelectronics

SYGEF Ultra product overview

The following table uses metric units of measure.

Products	PN (bar)	SDR)	d (mm) / DN (mm)	20 / 12	25 / 20	32 / 25	40 / 32	50 / 40	63 / 50	75 / 65	90 / 80	110 / 100	125 / 100	140 / 125	160 / 150
Pipes	16	36		■	■	■		■	■		■	■			■
Fittings	16	36		■	■	■		■	■		■	■			■
Unions	16	36		■	■	■		■	■						
Flange connections	16	36		■	■	■		■	■		■	■			■
Diaphragm valves	16	36		■	■	■		■	■		■	■			
Gaskets	16	36		■	■	■		■	■		■	■			■
Pipe clips	16	36		■	■	■		■	■		■	■			■
Automation	16	36		■	■	■		■	■		■	■			
IR-welding machine	16	36		■	■	■		■	■		■	■			■

■ SYGEF Ultra

Pipes

Fittings

Jointing technology

Automation

Valves

Excellence in Flow

Visit our webpage to get in touch with your local specialist:
www.gfps.com/our-locations

+GF+