



pro-K Fluoropolymergroup

Technical brochure 09
PTFE-Expansion Joints

Preamble

Due to their extraordinary properties expansion joints made with Polytetrafluoroethylene (PTFE) bellow material are used particular in applications with aggressive media and elevated temperatures. The designs as well as the operation conditions differ widely. This is the case especially for specifications concerning overall length, flange layout, diameter of support rings, movement range, guiding elements, wall thickness of the PTFE bellow and the minimal requirements of operating parameters like pressure/vacuum ratings.

This brochure provides information on standardized specifications regarding the design and operation limits and hence provides qualitative guidelines for the improvement of the operation reliability and prevention of sizing errors. The brochure is restricted to expansion joints whose bellows made of paste-extruded and sintered PTFE and contains recommendations of the Technical Guideline 12-0040 issued by the German "Interessengemeinschaft Regelwerke" (IGR).

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Fluoropolymergroup

The Fluoropolymergroup is a product group of "pro-K Industrieverband Halbzeuge und Konsumprodukte aus Kunststoff e.V.", Mainzer Landstraße 55, D-60329 Frankfurt am Main; Tel.: 069 - 408955540
E-Mail: info@pro-kunststoff.de; www.pro-kunststoff.de

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1 INTRODUCTION

PTFE expansion joints have a unique combination of outstanding properties, and are suitable for very diverse applications. Because of their near-universal corrosion resistance, they are used particularly as components in chemical plants.

They are installed in steel and PTFE-lined steel pipelines, and especially, thanks to their large adjustment range, both in plastic and FRP pipelines. Because of their flexibility and low spring rates, they are also used for sensitive plant components with enameled finishes, graphite process equipment, and graphite heat exchangers.

2 FUNCTION OF EXPANSION JOINTS

The thermal expansion is usually an unintended phenomenon when operating pipes. It requires compensation measures that have to be taken into account during planning and are state of the art.

Expansion joints compensate thermal expansion of the pipeline and thus prevent stresses, so offering a compact alternative to material-intensive horseshoe bends. They are also used to absorb oscillations and vibrations, for example those generated by pumps. Here, the very special properties of PTFE are utilized, e.g. the low tendency to material fatigue and complete absence of brittle fracture compared to other polymers, elastomers or certain metals.

The allowable movements depend on the design of the bellow and its material related properties.

The resistance to deformation of the bellow material is expressed by the spring rate, which is usually listed for both compression and expansion. PTFE expansion joints in piping systems are regarded as easy flexible. By multiplication of the spring rates with the related stroke, the resulting forces at the flange connections can be calculated.

Another important criterion for application of these expansion joints is the universal resistance of PTFE which allows the operation with nearly all kinds of aggressive media.

Depending on the operation conditions and pipeline isometrics various expansion joint types are available which differ in their design, the number of convolutions and even the manufacturing process.

The most commonly used types are described in this brochure.

3 DESIGN FEATURES

3.1 General

PTFE expansion joints mainly consist of a PTFE bellow and the flanges for the assembly in pipelines. The flanges comply with international regulations and standards. The PTFE bellow liner is flared at the flange surface and thus serves as a sealing. If connected to a PTFE lined pipe, no further gaskets should be used. The number of convolutions generally depends on the required movements, where on the one hand less number of convolutions allow a little higher pressure resistance and on the other more convolutions a higher flexibility.

The possibility of the bellow to move is a result of the convoluted shape of the PTFE liner with its depth and angle of the individual fold flanks. Metal support rings are located in the bottom of the corrugation and stabilize the bellow against deformation at high internal pressure.

Common nominal diameters of these PTFE expansion joints are ND 25 up to ND 1500 (ND 1" – ND 60").

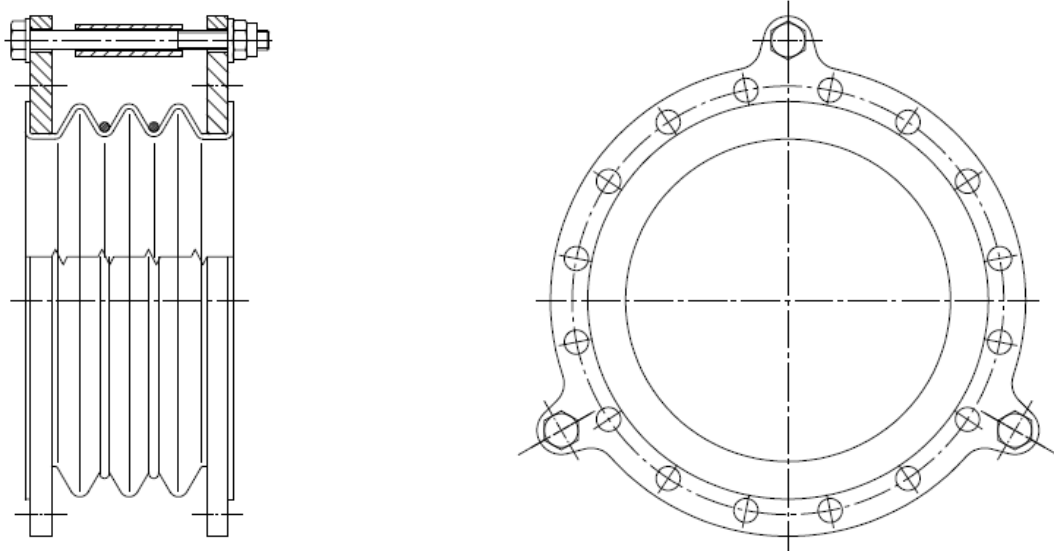


Fig. 1: Example of a three convolution expansion joint with limit bolts

To limit excessive movements, expansion joints usually have loose bolts with sleeves located between the flanges. In case of malfunction they may act as protection against overstress e.g. at full compression or expansion. This can potentially avoid damage of the bellow, however the limit bolts are not specifically designed for this purpose. At least 2 limit bolts must be available, to offer a certain safety against lateral or angular overstress, 3 limit bolts are recommended, if threaded rods are used they must have at least property class 5.6.

Even expansion joint designs for solely lateral- or angular movements are equipped with limit or guide elements.

3.2 PTFE bellow manufacturing technology and design related properties

3.2.1 Manufacturing of bellows

The shaping of the bellow geometry is done on the completely sintered virgin paste extruded PTFE-liner. Both non-modified and modified (white and dissipative) PTFE can be used as the material.

PTFE bellows which are made using isostatic or automatic compression molding processes show significantly lower performance and are not subject of this technical brochure. Wrapping of a thin PTFE film onto a tool to achieve a predefined thickness of the bellow is sometimes used too, but not a common technology. In this case there is a high probability of delamination of the different layers during operation, in particular during movement and/or if permeating media is involved. These types are not described here.

There are technological differences with respect to the shaping of the bellows depending on manufacturer. Thermal/pneumatic, thermal/hydraulic and thermal/mechanical molding processes, in which the liner material is pressed into a bellows mold after heating, are frequently used. By choosing suitable production parameters, manufacturers ensure the full functionality of the compensator and thus the required operational reliability even under extreme customer requirements.

Most important is a uniform wall thickness across (see Fig. 4) the entire bellow cross section. This avoids the accumulation of stress peaks in heavily loaded areas. An example of uneven wall thickness distribution due to inadequate shaping is shown in Fig. 2.



Fig. 2: Poor shaping of the PTFE bellows with extreme wall thickness variation

For the avoidance of notch effects the surface of the PTFE bellow must be smooth. There must not be defects like the following:

- Porosities / voids
- Inclusions / contaminations
- Scratches / surface defects
- Micro-sized cracks / crazes inside the cross section
- Notches or sharp bended transitions
- Stress whitening in deformed areas
- Indentations of the support rings causing notch effects
- Structural inhomogeneities

Geometries as shown in figure 2 and 3 are not acceptable as they may cause premature failure of the expansion joint even at low stress.

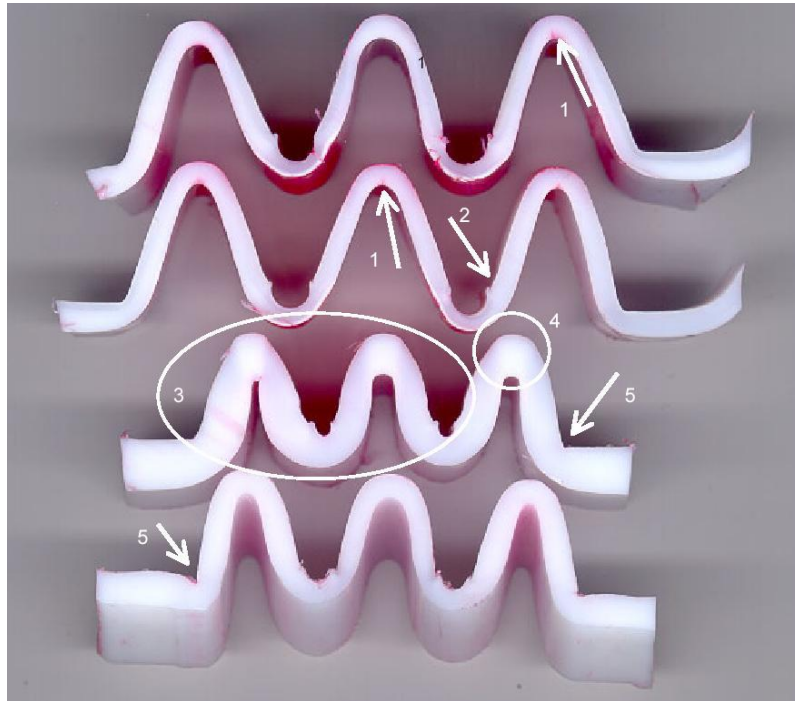


Fig. 3: Unacceptable defects that reduce the performance of the PTFE bellow

1. Micro-cracks on the inside of the convolute
2. sharp indentations of the support rings and bulging with notches
3. Inhomogeneous shape partly with folding at the peaks (pointed inlet significantly increases the notch effect)
4. Plastic deformation with stress whitening
5. Sharp edged transitions with notches

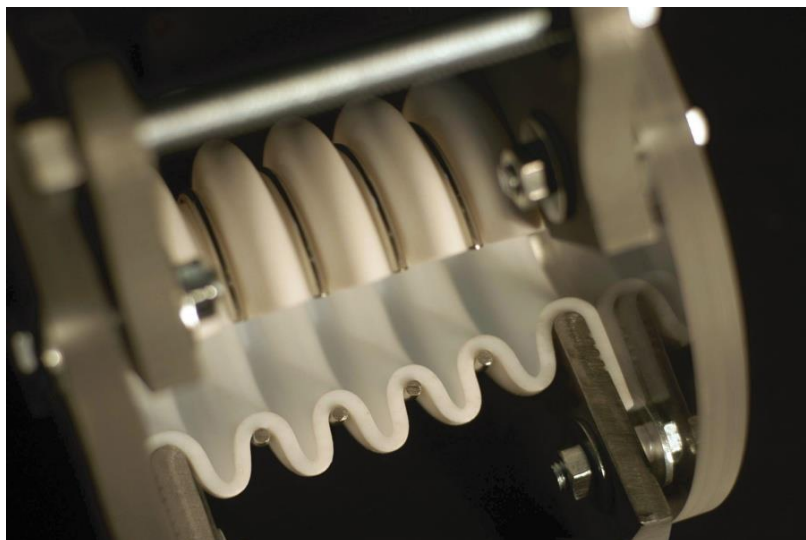


Fig. 4: Homogeneous distribution of wall thickness of a POLYFLURON

3.2.2 Construction dimensions and bellows geometry

The bellows geometry of PTFE expansion joints is determined by the structural dimension specified in IGR12-0040, the number of shafts, the thickness of the flange and the thickness of the support ring. Depending on the shaping process and forming parameters, there may be considerable deviations (see Figs. 2 and 3.) in the wall thickness distribution. A healthy movement clearance of the bellows can only take place (see below) if the bellows can move within the specified grid dimension (see Fig. 5a).

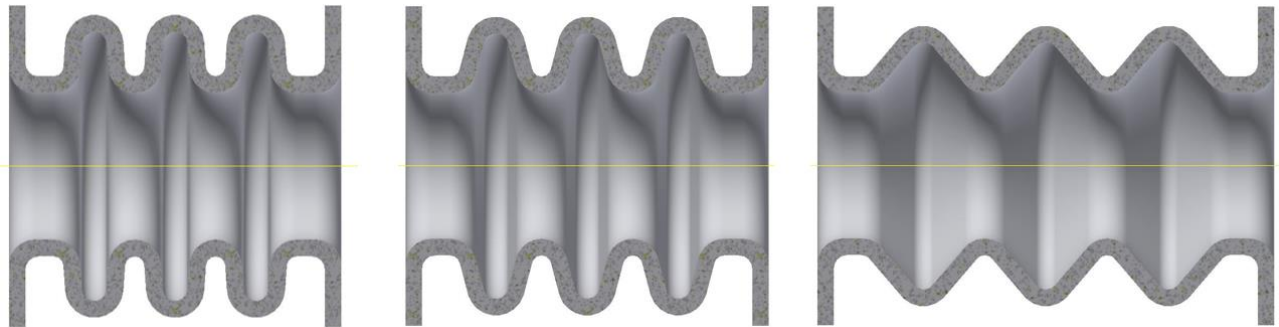


Fig. 5a: Balanced axial – backlash through optimized matching of liner thickness and shaft geometry.

In the case of poorly matched manufacturing processes (uneven wall thickness) and unfavorable shaft contour, an attempt can be made to increase the minimum wall thickness of the IGR by increasing the wall thickness within the IGR specification. This can lead to excessive adjustment forces and bellows running on block (see Fig. 5.b).

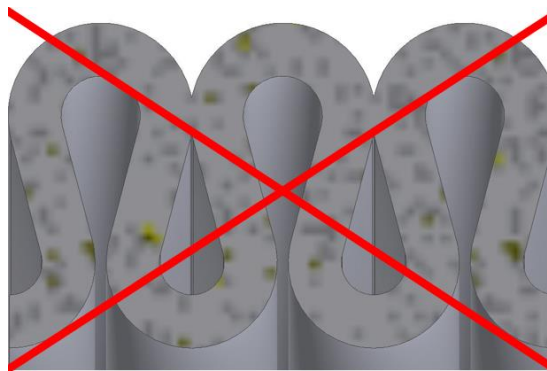


Fig. 5b: Exceeding the min. overall length (axial movement) due to too thick liner and unfavorable shaft contour

3.2.3 Influence of the bellow geometry

For the safe operation of an expansion joint a careful balance between wall thickness and convolute geometry is essential. A low wall thickness offers high flexibility but also a low operating pressure. Only an increase of the wall thickness without a change of the wave geometry does not necessarily result in higher pressure/temperature resistance as higher moving forces can cause additional stress.

FEM-calculations may help to optimize the geometry and wall thickness of the bellow. The analysis clearly shows that the maximal stress in the PTFE liner occurs during axial stress on the inner side of the convolute crest and during tangential stress in the range of the support rings in the convolute trough (yellow/red area of figure 6a and 6b).

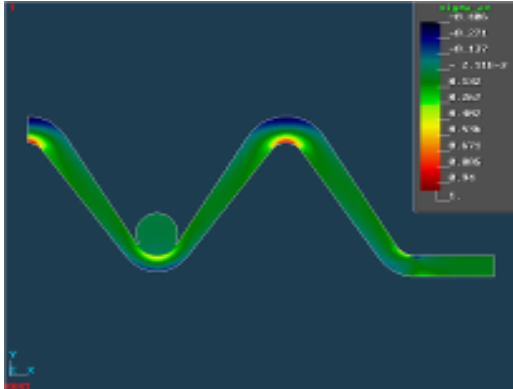


Fig. 6a: FEM Calculation of axial stress

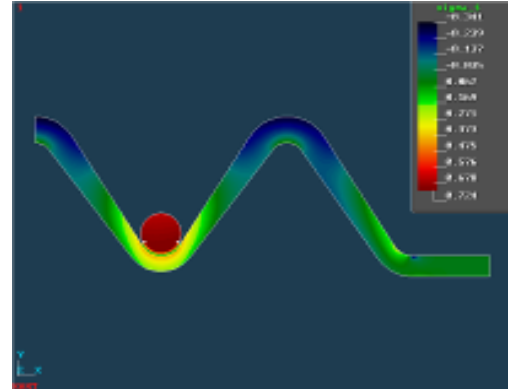


Fig. 6b: FEM Calculation of tangential stress

The stress gradient can be influenced respectively reduced by the geometry of the bellow. The simulation also confirms the results of empiric tests according to which bellow cracks in most cases start from the convolute crest (see figure 7).

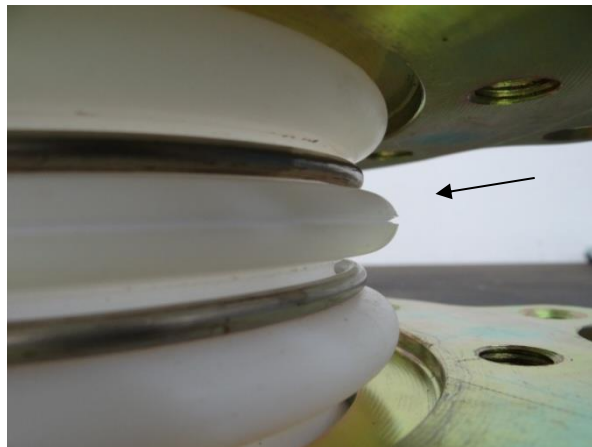


Fig. 7: Crack initiation after <5000 axial movement cycles due to an inhomogeneous distribution of the wall thickness

In this context it is noteworthy that in case of an excessive load of the bellow (above the allowable operation pressure) the PTFE convolute starts a plastic deformation (creeping above the yield stress) and bulges before it bursts after hours or days depending on the size and time of overload. An upcoming damage by overload therefore can be detected somehow visually on the part. A too low radius in the convolutions resp. steep flank angles may cause an increase in pressure rating but on the other hand the stress level in the crest of convolution further increases. Thus the risk of crack generation resp. bursting increases.

The simulation of the tangential stress (Fig. 6b) clearly shows the importance of the support rings. They are the load bearing part of the bellow. In contrast the distribution of the wall thickness at the support ring plays only a minor role for the pressure resistance. The wall thickness however has an influence on the permeation of certain media and thus the risk of damaging the support rings by corrosion.

3.3 Construction materials

3.3.1 PTFE bellows

Table 1: Material properties for electrostatically chargeable or antistatic PTFE (based on DIN 2874)

Liner material	Liner manufacturing process	Properties of liner material		
		Tear strength [N/mm ²]	Elongation at break [%]	Density [g/cm ³]
PTFE virgin, unfilled	paste extruded	≥24,0	≥275	2,14 to 2,17
PTFE virgin, antistatic	paste extruded	≥24,0	≥275	2,13 to 2,16

Another important parameter is the void content, which for example can be measured as Stretch Void Index (SVI) according to ASTM D4895 resp. DIN EN ISO 12086-2 or optically via microtome sections. A low void content is important for the flexural fatigue strength as voids may expand to micro cracks up to rupture by alternating load. The SVI should not exceed the value of 200.

Antistatic versions

If media with low conductivity and correspondingly high tendency to electrostatic charging are used antistatic / conductive equipped paste extruded material is recommended. According to DIN 2874, materials, e.g. PTFE, are considered to be non-chargeable whose surface resistivity should not exceed 10^9 Ohm and whose resistance to earth should not exceed minimum one spot 10^8 Ohm.

The applied test standards should be named when specifying the leakage resistance.

Oxidizing media like nitric acid may reduce over time the antistatic effect, what can be seen by a decrease of the dark color on the inside.

In antistatic modified PTFE expansion joints the filler must be distributed homogeneously and there must not be any local filler concentration or separations (fig. 8 and 9).

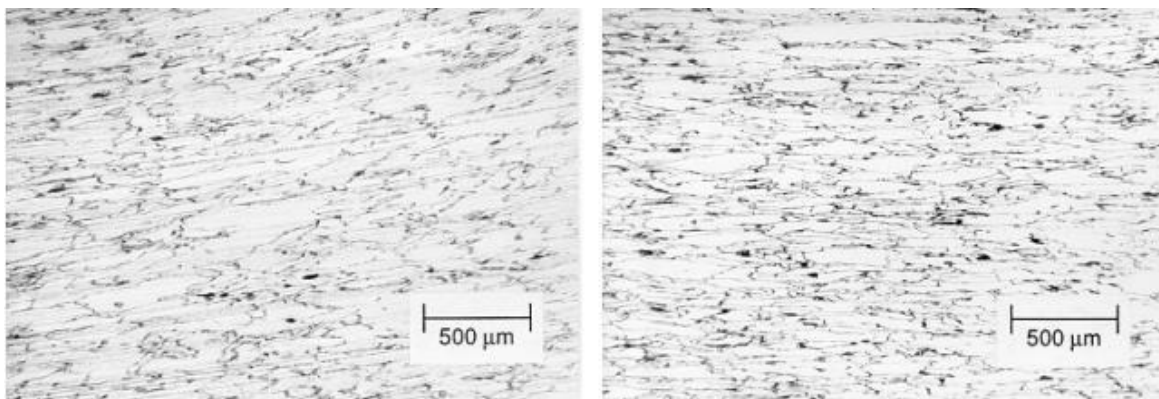


Fig. 8a and 8b: Homogeneous distribution of antistatic modifier

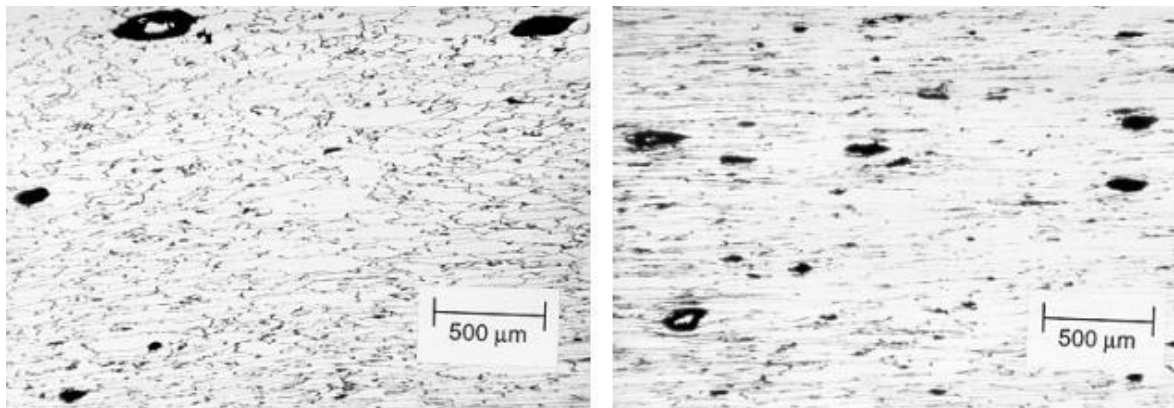


Fig. 9a and 9b: Inhomogeneous distribution, does not comply with the requirements

3.3.2 Flanges

Flanges have to be made from construction materials according to table 2. For a correct design of the flange sheet thickness a calculation is necessary. Based on these calculations the flange thickness data can deviate from DIN EN 1092-1.

Table 2: Examples of materials for loose flanges (for comparable ANSI materials, see double assignment table according to relevant literature)

Construction material	Constr. No.	Mat.	Technical specification
S235JRG2	1.0038		DIN EN 10025-2
P250GH	1.0460		DIN EN 1092-1
P235GH/P265GH/ P355GH	1.0425/ 1.0473	0345/	DIN EN 13480-2
Stainless steels	1.4571, 1.4541		DIN EN 10028-7

The flanges must have blasted surfaces (preparation level min. Sa 2 1/2) according to DIN EN ISO 12944-3 resp. 12944-4 and corrosion protection. The corrosion protection should consist of a zinc-rich epoxy primer according to DIN EN ISO 12944-5 (thickness min. 40 μm) or a galvanic cover coat with an iridescent chromate coating Fe/Zn12/C (thickness min. 12 μm) according to DIN 50961 resp. DIN EN ISO 2081.

3.3.3 Support rings

Support rings are made of the construction material 1.4571 (or equivalent 1.4404 resp. 316L) according to DIN EN 10088-3. The weld seam must have a weld factor of minimum 0,85. If another construction material is required because of permeation or corrosion reasons, it has to be jointly agreed upon and made sure that the temperature/pressure operation limits according to chapter 4.2 are met. This is especially relevant if chlorine containing media are used that might cause stress-cracking with stainless steels (see chapter 9.1).

4 OPERATION CONDITIONS

4.1 Movement absorption

Generally PTFE-expansion joints can be used for axial, lateral and angular movements. According to their application guiding elements must be designed.

During operation different movement patterns may occur at the same time. As a first approximation, the different movement clearances can be summed up proportionally in linear correlation to 100% of the allowable movement clearance. This has to be taken into account during the piping design and the manufacturer should be able to verify the reduction of movement absorption when different movement patterns occur simultaneously.

The flexibility of PTFE bellows is expressed by spring rates. They are specified for axial, lateral and angular movements and are depending on temperature. Spring rates have to be provided by the supplier. Apart from the influence of the temperature the wall thickness of the bellow also influences the flexibility of standard expansion joints. This is only of marginal importance for the compensation of thermal expansion on a pipe bridge, it is however most important for connection of expansion joints with equipment for example in graphite or FRP or with pumps where the spring rate is the crucial design parameter for the strain at pipe nozzles or for vibration absorption.

4.2 Pressure/temperature related application limits

Expansion joints with less convolutions provide a higher temperature/pressure rating but also absorb less movements compared to expansion joints with higher number of convolutions. This means the more convolutions the bigger the movement absorption but the less the temperature/pressure rating.

The limits of pressure/temperature resistance are usually measured by burst pressure tests. However, the burst pressure is primarily dependent on the operating time and temperature and secondarily on the service life of the component, so that the inclusion of creep tests in the evaluation is necessary. The bursting pressure is a technical term and represents an important quality characteristic for pipes, tubes, expansion joints and other components. It is many times greater than the permissible operating pressure.

The limit values determined in bursting pressure tests are strongly dependent on the temperature and the rate of pressure increase. They must therefore be evaluated by the manufacturer, particularly with regard to long-term stability in service, and a safety factor must be applied. This factor must cover dynamic load cases (axial, lateral and angular movement clearance), component tolerances, material characteristics and long-term load capacity.

The pressure/temperature application limits in Fig. 10 for overpressure and in Fig. 12 for underpressure stresses are shown schematically and must be prepared individually by the respective manufacturer.

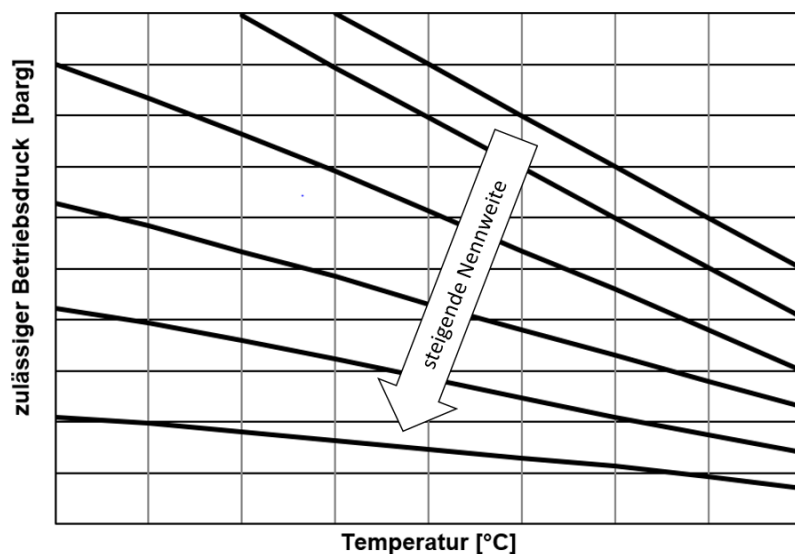
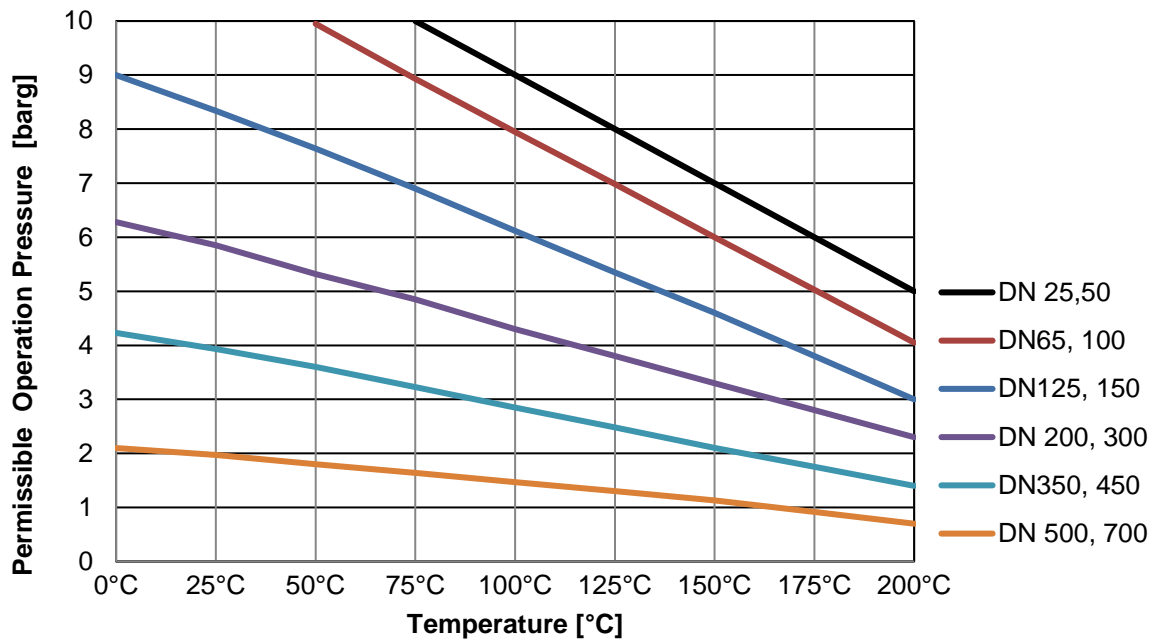


Fig. 10: Schematic representation of the maximum permissible operating pressure in relation to the temperature for various nominal sizes with a constant number of shafts.

Latest FEM pressure simulations that take into account the real tensile/elongation performance of PTFE depending on temperature provide results that correspond well with practical tests. (The real tensile/elongation behavior shows that the strain in a test specimen increases during elongation due to the change of thickness.) Thus the strain limits of expansion joints with large diameters can now be determined precisely, which hitherto could only be estimated based on the data derived from testing small diameters.

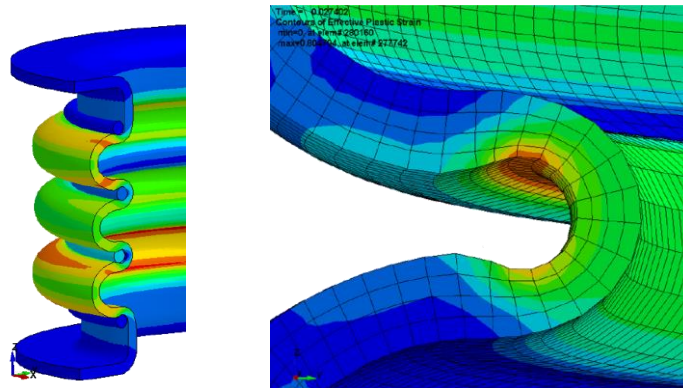


Fig. 11a and b: Simulation of the maximal operation pressure before plastic deformation

Resistance to vacuum

Pipes, especially in chemical plants, are permanently exposed to changing stress. If this is not caused by process conditions draining processes in facilities may cause vacuum strain. Expansion joints in pipes must absorb these partially high pressure fluctuations. The vacuum resistance is shown schematical in figure 12.

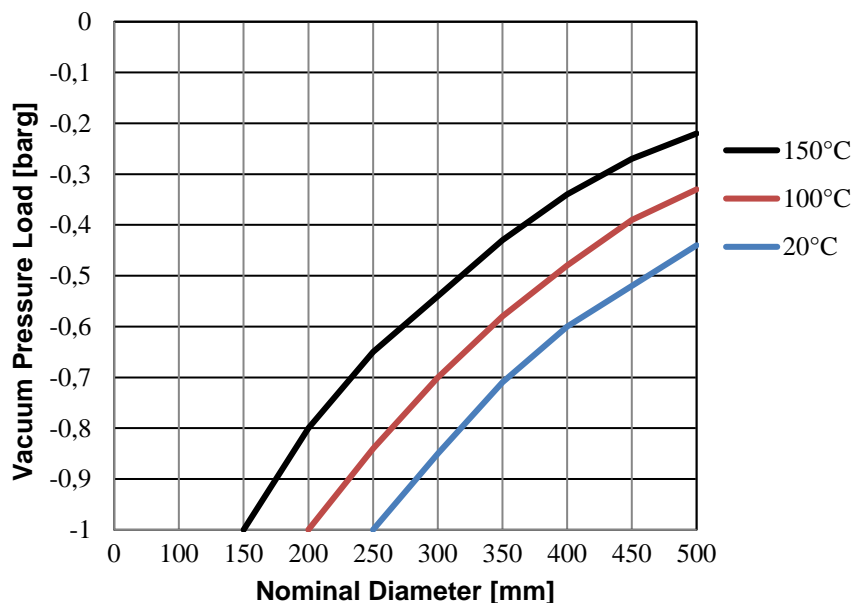


Fig. 12: Schematic vacuum resistance of PTFE-expansion joints

4.3 Load alternation

Load limits raise the question about limit values for numbers of load alternations. In this case PTFE differs significantly from metallic construction materials by its extraordinary flexural fatigue strength which is due to its high molecular weight.

Practical load alternation tests indicate a high influence of the bellow geometry on the long-term stability (see chapter 3.2.2).

Using the complete stroke and a frequency of 0.1 to about 0.3 Hz without pressure POLYFLURON® expansion joints reached load alternation cycle numbers of > 2 million. The end of the test was defined by interruption not by failure of the bellow. The stiffness rate which was detected at the same time only showed a small change (< 3%) which proves the long-term stability.

4.4 Dimensions

The minimum wall thickness s_{\min} of the PTFE liner and the diameter of the support rings d_D have to be assured at every position according to table 3.

4.4.1 Bellow and support rings

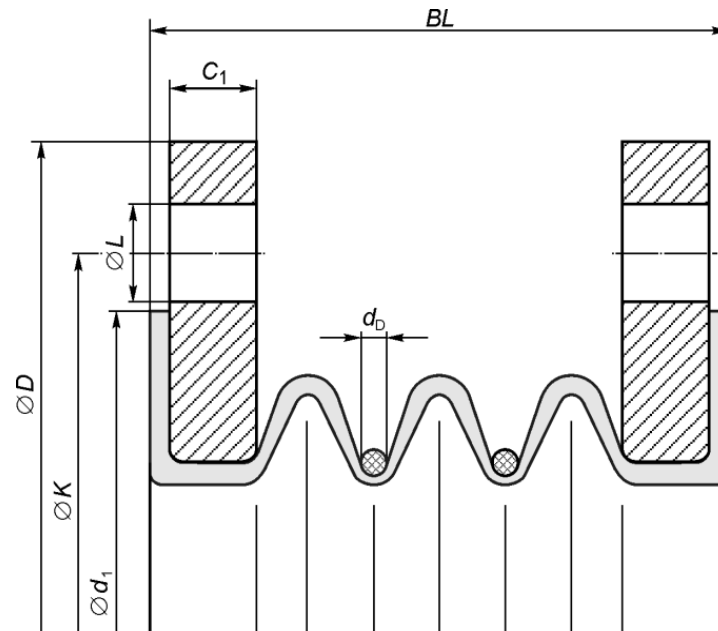


Fig. 13: Design of a PTFE-axial expansion joint; example for a three convolution layout

Table 3: Dimensions for PTFE axial expansion joints in 2-, 3- and 5-wave design (the wall thickness limits are within IGR 12-040) (s_{\min} : minimum wall thickness)

DN	2-wellig		3-wellig		5-wellig		d_D h +/- [mm]	s_{\min}		
	ANS I	BL [mm]	h +/- [mm]]	BL [mm]]	h +/- [mm]	BL [mm]		[mm]	[mm]	[mm]
25	1"		54	6	70	10	100	15	3	2
32	1-1/4"		56	6	75	10	105	15	3	2
40	1-1/2"		56	6	80	15	115	20	3	2
50	2"		68	10	85	15	125	25	4	2
65	2-1/2"		78	12	100	20	145	30	4	2
80	3"		88	15	110	20	160	35	5	2,3
100	4"		88	15	110	25	165	40	5	2,3

125	5"	95	15	120	25	170	40	5	2,3
150	6"	105	15	130	25	180	40	6	2,3
200	8"	110	15	140	30	210	40	6	3,5
250	10"	128	20	165	30	240	50	8	4
300	12"	140	20	175	30	250	50	8	4
350	14"	145	20	190	35	265	50	8	4
400	16"	145	20	190	35	265	50	8	4

The values given for the movement stroke (h) in table 3 are valid for axial direction only. If PTFE-expansion joints are used as "universal expansion joints", different movement directions like axial, angular and/or lateral may occur at the same time. The specifications given by the supplier for axial, angular or lateral movements correspond to the particular direction only as maximal value "100 %". If combined movements occur, the specified limits have to be reduced to make sure that the sum of simultaneous movements does not exceed the maximum stress. These reductions or limitations are given by the supplier.

5.1.2 Loose flanges

Table 4: Dimensions for loose flanges according to DIN EN 1092-1

DN	Outside Ø*	Diameter Ø	Hole Ø**	Screws	
	D	K	L	Number	Size
25	115	85	M12	4	M12
32	140	100	M16	4	M16
40	150	110	M16	4	M16
50	165	125	M16	4	M16
65	185	145	M16	4	M16
80	200	160	18	8	M16
100	220	180	18	8	M16
125	250	210	18	8	M16
150	285	240	22	8	M20
200	340	295	22	8	M20
250	395	350	22	12	M20
300	445	400	22	12	M20
350	505	460	22	16	M20
400	565	515	26	16	M24

4.5 Special designs

Special designs of PTFE-expansion joints may be necessary if special combinations of loads occur.

High pressure loads

If increased pressure ratings than for pure PTFE expansion joints are required multi-layer metal bellows may be used, which for corrosion protection reasons are lined with PTFE (see figure 14). These types may be designed or used for the pressure range PN10, PN16 and PN25. It combines the chemical resistance of PTFE

with the high stability of metal constructions. If the metal layer is built up of several thin layers the spring rate is typically reduced.

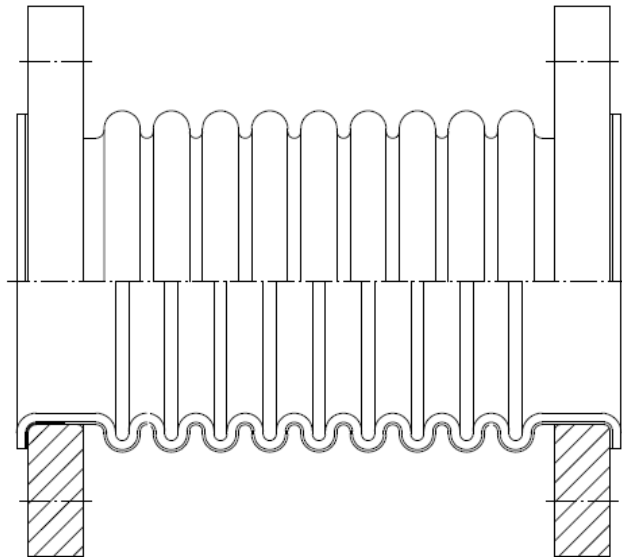


Fig. 14: High pressure expansion joint with internal PTFE liner

Negative pressure loads

For vacuum loads, beyond the limits given in figure 10, internal vacuum rings may be applied to provide full vacuum resistance. Specific data with regard to negative pressure loads and movement clearances should be required from the supplier.

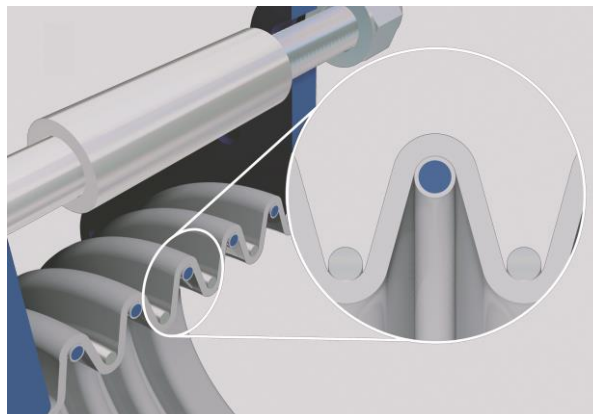


Fig. 15: Vacuum rings to increase the vacuum resistance

For long-term vacuum operation at elevated temperatures specific vacuum expansion joints starting from DN 200 are available (see figure 16). They are characterized by a clamping ring that fixes the PTFE convolution on the outside. Thus the collapse of the PTFE liner is prevented. These vacuum expansion joints are designed for axial movements only.

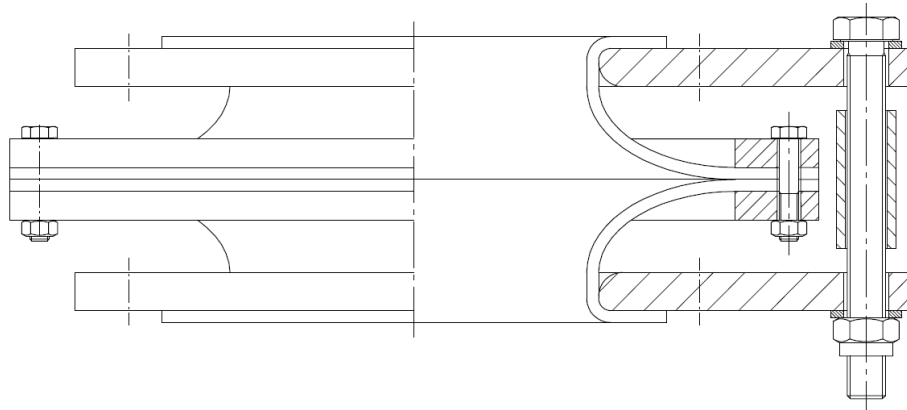


Fig. 16: PTFE vacuum expansion joint FLUROFLEX® FX-0

Abrasive loads

Due to the waveform of the bellow, expansion joints can be impacted by abrasion if erosive media at high speed are involved. Especially in chemical plants solid containing media are often used. To prevent abrasion the expansion joints can be equipped with metal or PTFE protective sleeves. These smoothbore sleeves do not interfere with the mostly appearing axial movements.

Furthermore these protective sleeves can be used as abrasion detector, which helps to early identify potential damages of the convoluted liner. The smooth bore sleeves as preventing measures can ensure safe operation even under erosive conditions.

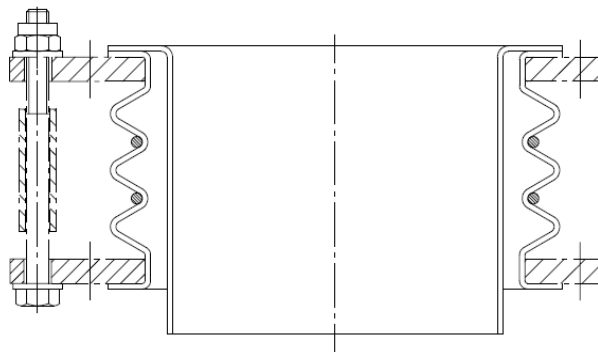


Fig 17: Expansion joint with smoothbore protection sleeve

5 TESTING

5.1 General (scope of testing)

Expansion joints as components of pipe systems are subject to inspection according to the Pressure Vessel Directive (PVD). They are delivered by the supplier with a CE-code, a declaration of conformity and an instruction for their installation and use. Independently from the PVD classification the final tests have to be certified.

The number of tests on the semi-finished article and on the finished product according to chapter 6.3 and 6.4 has to be agreed between the contracting parties. The requirements of the PVD must be met.

5.2 Testing body

If nothing else has been agreed on in the order, the tests as described in the following chapters have to be conducted by a notified body at the manufacturer during production.

5.3 Test of support rings

On a relevant number of support rings tensile tests have to be performed. The yield point, the tensile stress and the elongation at break must be within the limits of the used construction material / within the standard. The evaluation of the weld seam for the support rings can, for example, be based on DIN EN ISO 5817.

5.4 Tests of PTFE semi-finished product (liner)

The test of semi-finished products has to be performed on at least one extruded pipe per sinter process, raw material lot and manufacturing lot. The test must be performed according to DIN 2874.

5.4.1 Density

The requirements must be evaluated according to DIN EN ISO 1183.

5.4.2 Tensile strength and elongation

The requirements according to table 1 have to be verified by a tensile test according to DIN EN ISO 527-1. The shape of the test specimen (standard bar type A) and the test speed (50 mm/min) are defined by DIN EN ISO 13000-2.

5.5 Tests on finished products (expansion joint)

5.5.1 Test of appearance and workmanship

The expansion joint and especially the PTFE bellow is tested for recognizable defects. The test is performed visually and if necessary with the help of optic instruments. The distribution of additives is evaluated on microtome sections. The requirements according to chapter 3.3.1 have to be met.

5.5.2 Dimensional check

The check of the wall thickness is done by an ultrasonic measurement or by cutting the bellow and measuring with a slide gauge.

The requirements of table 3 must be met.

5.5.3 Test of electrical charging

The assessment of the electrical charging is performed by the surface resistance on the ready to install component. The measurement of the surface resistivity and the discharge resistance has to be performed according to DIN IEC 60093 und DIN IEC 60167. The test voltage must be 100 or 1000 V direct current. The test report must be compiled according to DIN IEC 60093 and DIN IEC 6016. The measurement of the discharge resistance must be performed with 100 V direct current according DIN EN 1081.

5.5.4 Prototype test of PTFE-expansion joints

To prove the long term stability creep-depending on-time tests under internal pressure must be performed. This has to be done as follows: the creep-depending on-time pressure test is performed on expansion joints of diameter DN 80 at 150°C over a period of one year. With the results of this test a time to rupture curve is established and extrapolated to 20 years. For other diameters it must be checked by a punctual test (three test points) if the values are above or below this curve. If this is not the case the curve of the DN 80 joint must be shifted in a way that the three test points are on resp. above the curve. This conclusion by analogy may be drawn only for diameters that are manufactured with the same process as the tested DN 80 joint. If other processes or other versions have been used a new time-to-rupture curve must be established.

5.5.5 Alternating load

Since sufficient experience is missing it is very extensive to establish general conditions for a test of alternating load. Therefore a suitable verification must be agreed on between supplier and user if necessary.

6 PACKAGE, STORAGE, TRANSPORT

The expansion joints must be closed on the sealing surface with a stable caps by the supplier. These caps should be removed only directly before installation.

The expansion joints should be stored in the original packaging until they are used. The following demands must be met:

- Storage on a plane area
- Do not stack expansion joints on each other
- Expansion joints may be stored only completely emptied, dried and protected from frost since icing inside the convolutions might damage them
- Protect expansion joints against contaminations by water, dirt or any other damage
- Protect expansion joints against direct sunlight exposure and elevated temperatures

7 LABELING

Expansion joints are delivered by the supplier together with CE-labeling, EG-declaration of conformity and instructions for use. Each part has to be labeled clearly and permanently as follows:

- CE-label required according to PVD
- Supplier label of liner manufacturer
- Nominal diameter
- Overall length
- Nominal pressure (flange)
- Maximal allowable pressure at 20 °C
- Abbreviation of the liner material
- Date of manufacture

If the delivery comprises an inspection certificate according to DIN EN 10204 additional requirements for the flanges apply:

- Melt number or abbreviation
- Sign of the tester (authorized inspector of manufacturer)

The label must be clearly readable when integrated. The pressure- /temperature characteristics of the manufacturer must be taken into account.

8 OPERATION

8.1 Intended use

The expansion joint may only be used if it is in proper condition and under the operation limits which are specified on the drawing, the supplier label, the technical documentation and the operation instruction. The temperature-/pressure diagrams that define the maximal/minimal allowable operating pressures and temperatures as well as the allowable movements have to be taken from the product description and must be followed.

Expansion joints may absorb or transmit forces from the pipe system resp. the installation up to a limited level. However they are not intended to transmit torsion forces.

If chlorine containing media are used (e.g. hydrochloric acid) support rings made of stainless steel 1.4571 are not suitable. In this case the choice of a suitable design has to be agreed on with the supplier.

PTFE is not resistant against chloro-tri-fluoride, monomers like butene or styrene may be critical because of permeation and auto-polymerization. In case of doubt the suitability of a expansion joint for a specific application or the resistance against the used media has to be clarified between operator and supplier.

Each deviation, especially the exceeding of the min/max allowable pressure or temperature as well as the use of not accepted media may cause the failing of the component and hence may cause severe damages to people or equipment and requires written approval of the supplier.

8.2 Prohibited actions

The following actions may cause severe accidents and hence are forbidden:

- Works on expansion joints that are under pressure or are operating.
 Before maintenance works the expansion joint has to be taken out of operation, depressurized, cooled down and decontaminated.
- Change of the specified operation conditions.
 Modifications of expansion joint including the removal or addition of components as well as mechanical or welding work.

8.3 Residual risks

To avoid risks for the operator or damages on the expansion joints they must only be applied for the intended use and in safety related perfect condition. Safety precautions against the effects of a possible extreme fire are not part of the construction and must be defined and established by the operator.

Safety precautions in ATEX-plants

The operator has to check if operation conditions with the use of the expansion joint may occur that might cause an electrical charge and if hence a spark discharge would be a safety problem. In this case an expansion joint with antistatic PTFE according to DIN 2874 and suitable grounding components must be used.

8.4 Malfunctions

Malfunctions may cause unaccepted operation conditions that might destroy the expansion joint e.g.:

- Hydraulic shock
- Thermo shock
- Unacceptable composition of used media in the pipe system
- Deposition of solids
- Freezing of the expansion joint
- Exceeding the pressure or temperature limits
- Unacceptable movement redirection from the pipe to the expansion joint

Therefore:

- Provide facilities that make sure that even at malfunctions unacceptable conditions on the expansion joint are prevented.
- If inadmissible operating conditions occur during plant operation, the expansion joints must be replaced immediately.
- Consider the following measurements to prevent unacceptable operation conditions when malfunctions occur.

Note:

The faults listed below are a selection of possible faults. Further failures can occur in connection with plant design and/or the supplied PTFE component including all internals.

The operating organization has the responsibility to check the listed faults including causes and remedy instructions for compatibility with the plant design and, if necessary, to revise and amend the information and to determine suitable remedial measures including immediate shutdown.

Attention:

When performing corrective actions resp. works on the component itself it has to be taken out of operation, depressurized, cooled down and decontaminated.

Malfunction	Cause	Remedy
Medium escapes at the flange connection	Torque insufficient	Torque too low: Retighten screws with defined torque Torque too high: Use additional sealing and tighten with adapted torque
	Flange installed not correctly or flange connection not free of tension	Install flange connection correctly
	Sealing areas or sealing defect or contaminated	Clean sealing surfaces and check for damages If liner is damaged or there is corrosion on steel components exchange expansion joint If sealing is damaged renew sealing
Damaged PTFE bellow	.	Call for service partner
Corrosion on steel components	Leakage	Evaluate cause of leak Take suitable corrective action to prevent leak If necessary exchange expansion joint

8.5 Safety shields

Expansion joints are sensitive components in a piping system as they are mostly not covered by pressure absorbing or other protective parts. For this reason the use of splash guards, e.g. splash sleeves made of suitable material are recommended.

If irritating or caustic media are used the application of splash guards on flanges are required according to the German „Merkblatt M004 der Berufsgenossenschaft Rohstoffe und chemische Industrie (BG RCI)“

Safety shields are available in different designs. Transparent materials or integrated pH-indicators enable a very good optical inspection and detection of possible dangers.

9 LIST OF FIGURES

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Fig. 1	Three convolution expansion joint with limit bolts	SGL Carbon GmbH / Dr. Schnabel GmbH
Fig. 2	Poor shaping of the PTFE bellows with extreme wall thickness variation	Baum Lined Piping GmbH
Fig. 3	Unacceptable defects that reduce the performance of the PTFE bellow	Franz Hingott, TÜV Süd
Fig. 4	Homogeneous distribution of wall thickness of a POLYFLURON	SGL Carbon GmbH / Dr. Schnabel GmbH
Fig. 5	a. Balanced axial – backlash through optimized matching of liner thickness and shaft geometry b. Exceeding the min. overall length (axial movement) due to too thick liner and unfavorable shaft contour	Baum Lined Piping GmbH
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		Dr. Schnabel GmbH
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