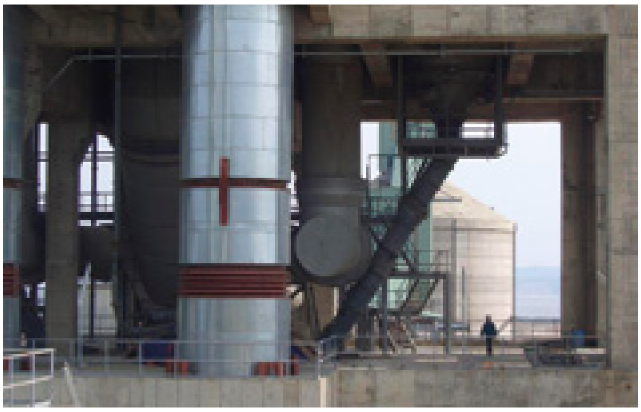
Lens expansion joints

HKS designs and manufactures lens expansion joints from the simplest standard expansion joints to highly complex expansion joints designed especially on the basis of individual customer requirements. HKS lens expansion joints are very robust, single layer expansion joints. They have proven their suitability in decades of practical use and can – in contrast to the corrugated expansion joints – also be manufactured from unalloyed or low-alloy steel (P265GH, P355NL 2, 16Mo3, 13CrMo44). Other common materials such as duplex steel, nickel-base alloys and stainless and heat resistant steel. A round design is common for heat exchangers or pipelines. In addition to this, rectangular, oval, polygonal or special shapes are also possible. Depending on movement absorption, lens expansion joints are manufactured single-convolution or multi-convolution and with a wall thickness up to 10 mm.

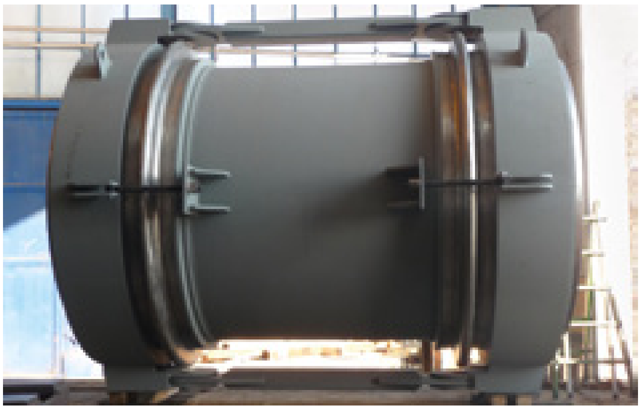
Our expansion joints are under continuous further development to meet the current state of the art and the high requirements of the industry. This results in powerful and reliable lens expansion joints with excellent properties, a long service life and the highest quality to continue meeting the highest requirements even in the future. This has been proven by numerous certifications, approvals, acceptances and customer audits. In addition to the ISO 9001 quality management system, manufacturer's qualifications such as AD2000 HP0, ISO 3834-2, PED module H and ASME U-Designator (U-Stamp) are also in place. Our development and design department is available for technical consultation for our customers, engineering and solutions for project-oriented challenges. For optimum dimensioning of the lens expansion joints, we use sets of rules such as AD2000 data sheet B13, EN 13445, EN14917, EJMA, ASME Sec. VIII Div. I or finite element method (FEM).



Areas of application

Application examples for HKS lens expansion joints are versatile and flexible. The movement options with large expansions and the highly robust design are suitable for particularly rough and extreme ambient conditions in many industries with different media and temperatures. Our high-quality lens expansion joints are used in many branches of industry such as:

- Plant engineering
- Apparatus engineering
- Power station construction
- Pipeline construction
- Mechanical engineering
- Chemical industry
- Steel and iron industry
- Cement industry

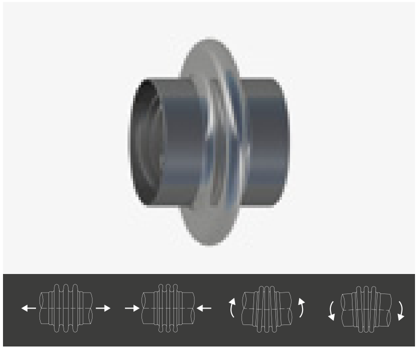


The main tasks are:

- Absorbing expansions
- Absorbing movement
- Reduction of tensions
- Compensation of installation inaccuracies
- Compensating for settling of buildings

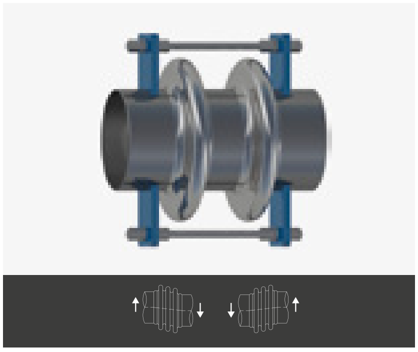
Model variants

HKS lens expansion joints have different designs (axial, lateral, angular and universal expansion joints), materials (depending on medium and temperature) and shapes (round, rectangular, oval).



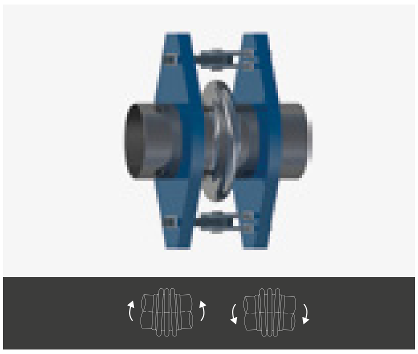
Axial expansion joints (e.g. type L-AN R-R)

- Absorption of axial and/or angular movement
- With swivel flanges, fixed flanges or welding ends
- Nominal diameters DN 32 – DN 6000 [1)]
- Pressure stages PN 1 – PN 63 [2)]
- In pipes they require fixed and floating bearings to absorb the axial reaction forces



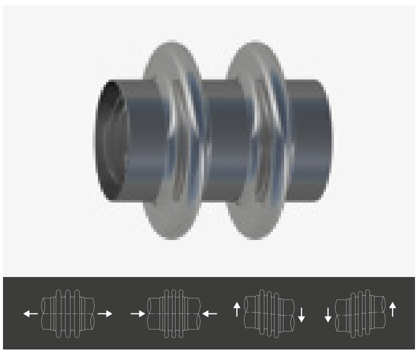
Lateral expansion joints (e.g. type L-RM R-R)

- Absorption of lateral movement
- With swivel flanges, fixed flanges or welding ends
- Nominal diameters DN 32 – DN 6000 [1)]
- Pressure stages PN 1 – PN 63 [2)]
- With tension rods or joint tensioners
- Tie rod absorbs axial reaction forces



Angular expansion joints (e.g. type L-WN R-R)

- Absorption of angular movement
- With fixed flanges or welding ends
- Nominal diameters DN 32 – DN 6000 [1)]
- Pressure stages PN 1 – PN 63 [2)]
- With single or cardan tension rod for one sided or all around movement absorption
- Large bending angles and compact length
- Tie rod absorbs axial reaction forces



Universal expansion joints (e.g. type L-AM R-R)

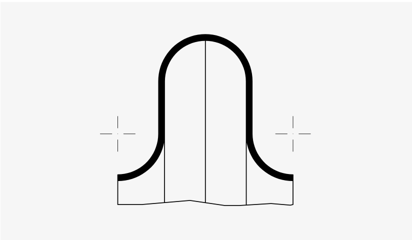
- Absorption of axial and/or lateral movement
- With swivel flanges, fixed flanges or welding ends
- Nominal diameters DN 32 – DN 6000 [1)]
- Pressure stages PN 1 – PN 63 [2)]
- In pipes they require fixed and floating bearings to absorb the axial reaction forces

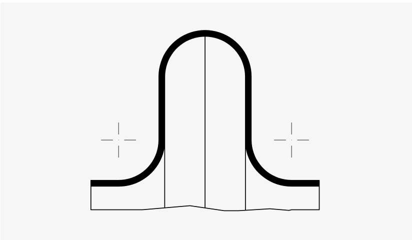
1) Nominal diameters deviating from the standard have to be individually tailored by HKS.
2) Nominal pressures and special requirements (hot air, exhaust gas) deviating from the standard have to be individually tailored by HKS.

Round lens expansion joints

Lens expansion joints have a relatively large convolution height, a singleply and a wall thickness between 2 mm and 10 mm. In contrast to corrugated expansion joints, individual convolution (lenses) on round lens expansion joints are always made from two half convolution (half shells) and joined with a continuous welding seam (circumferential weld). Half convolutions are made of circular ring plates (round blanks) by forming their outer and inner edges through rolling bending (crimping) or pressing to produce an S-shaped profile. The convolution geometry depends on the operating data, the formability of the material and the production options.

Main shapes:





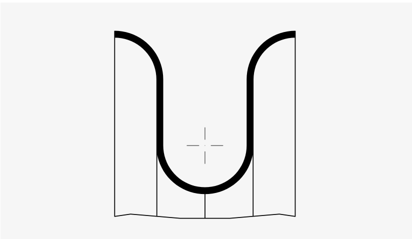
The most commonly used convolution shape for lens expansion joints consists of two joined half shells with outside convolution. They are manufactured as single-convolution or multi-convolution versions depending on movement absorption. Convolution heights and Geometrys can be designed in a great variety of ways, with service life and pressure resistance tailored to the exact operating conditions.

The manufacturing process of the half shells depends on the Nominal diameter.

DN 32 – DN 500	compression moulding (deep drawing) of the half shells
DN 550 – DN 6000	crimping (roll bending) of the half shells

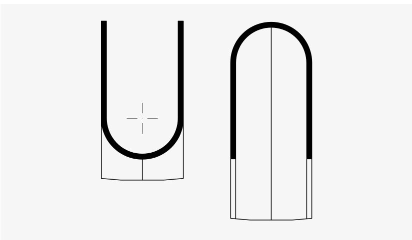
To move connecting welds on lenses on pipes or containers away from the areas with a high level of wear, cylindrical ends (L = 3×t) are additionally included. This allows the number of stress cycles (service life) to be increased with identical movement absorption.

Special shapes:

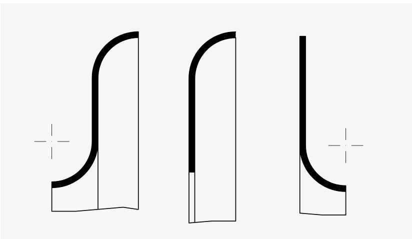


In addition to the main shape with outside convolution, different variants can be manufactured as special shapes.

If the installation conditions allow no convolution positioning on the outside, lens expansion joints can be produced with inside convolutions. In contrast to the previously described form, the continuous weld is then placed in the root of the convolution.



U-shaped convolutions without moulded pipe connection are another special design. Their opening can be placed facing inwards or outwards. This design is, for example, used on slide valves and extension valves or as a dust-free connection between two container bottoms.

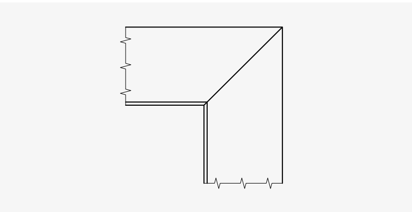


For special applications and installation situations, half shells with and without moulded pipe connections are required. For example as a sealing membrane or dust protection, in a heat exchanger shell with different outer diameters or as a collar.

Rectangular lens expansion joints

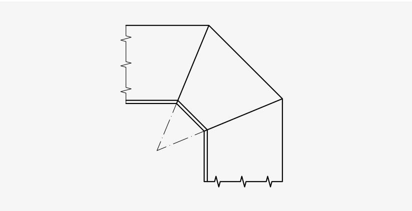
HKS rectangular expansion joints with lens design are not standardised and are individually tailored and manufactured depending on customer requirements. Convolution heights from 50 mm to 300 mm and lengths from 50 mm to 160 mm are common dimensions for individual U-shaped convolutions. The convolution dimension depends strongly on the manufacturing method, the material, the convolution radius and the wall thickness. So-called profile bars with one to three convolutions are produced with a press brake in several steps and joined to form a rectangular, square or oval expansion joint using different corner joining methods. The shape of the corner joint has a crucial influence on the existing tension condition in the critical corner areas and therefore also determines the service life of the expansion joint. The more closely the corner resembles a "round corner", the longer the service life under otherwise equal operating conditions. HKS offers five different corner joining methods.

Method I: Single mitre



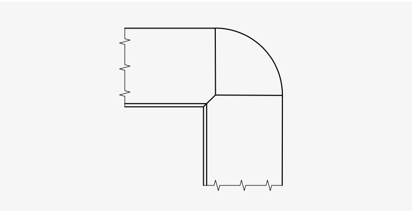
The most simple way of producing a corner joint is the single mitre with 45° mitre cuts on the profile bars. It is used for very low pressure and expansion levels.

Method II: Double mitre



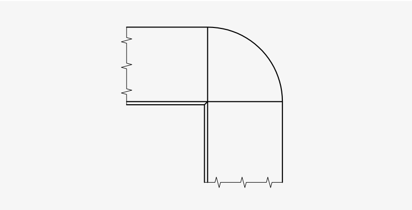
A more beneficial tension distribution in the corners compared to method II is the double mitre version with 22.5° mitre cuts. It is only rarely used, however, due to the elaborate connection.

Method III: Y mitre



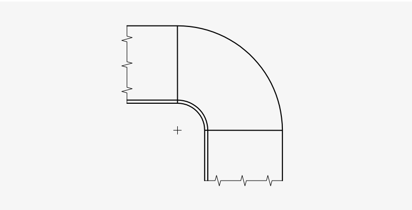
Rectangular on the inside (as method I) and rounded on the outside (inserted corner) is a very frequently applied joining method which is used for higher expansion levels. The channel connection can retain its rectangular shape here and tension distribution is better than with method I.

Method IV: Rounded outside



This version is comparable to profile III and is mainly used where small lengths are available. The disadvantage is in the area of the inner brim where only a small radius is available and where the tip of the inserted corner runs out. This creates high local tension peaks which lead to a reduced service life.

Method V: Fully rounded



With regard to tension distribution, the best choice is the version with rounded inside and outside by inserting a fully rounded corner. The disadvantage is that the channel also has to have a contour with rounded corners.

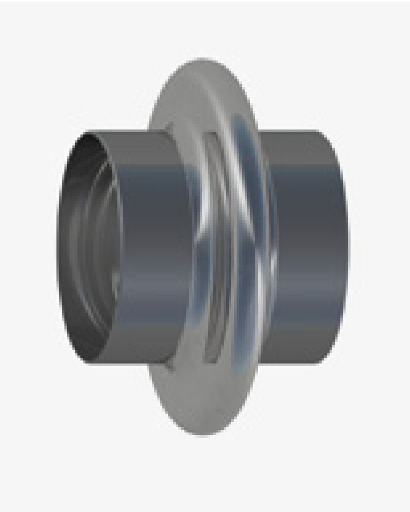
Frequently used materials in lens manufacturing

Material group	Material designation	
General structural steel	1.0038 1.0330 1.0338	S235JR DC01 DC04
High-temperature steel	1.0425 1.0473 1.5415 1.7335	P265GH P355GH 16Mo3 13CrMo4-5
Fine grained structural steel	1.0565 1.1106	P355NH P355NL2
Stainless austenitic steel	1.4301 1.4404 1.4529 1.4539 1.4541 1.4571	X5CrNi18-10 X2CrNiMo17-12-2 X1NiCrMoCuN25-20-7 X2NiCrMoCu25-20-5 X6CrNiTi18-10 X6CrNiMoTi17-12-2
Heat resistant steel	1.4828 1.4841 1.4876 1.4878	X15CrNiSi20-12 X15CrNiSi25-21 X10NiCrAlTi32-21 X8CrNiTi18-10
Duplex steel	1.4462	X2CrNiMoN22-5-3
Nickel-base alloy	2.4856 2.4858	NiCr22Mo9Nb NiCr21Mo

As a rule, lens expansion joint convolutions can be manufactured from all materials which are suitable for welding and cold forming. The table shows only a small selection of materials.

Connection types

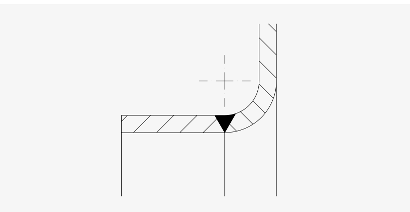
Lens expansion joints are manufactured to customer requirements, with or without connections. It is practical to include connections with flanges or welding ends for integration into heat exchangers, containers or pipelines.



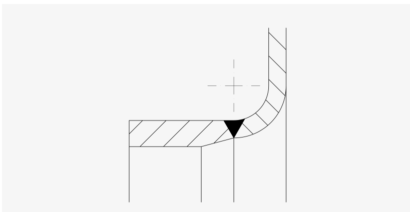
Welding ends

For most applications for lens expansion joints, the connections between the convolutions and the pipe connections are butt welded. One of the great advantages of butt welding is quality assurance. This refers to the verifiability of the welding seam quality using non-destructive testing such as X-ray, ultrasound, visual or dye penetration testing. For fillet welds, Xray testing is not possible and verification is limited to internal irregularities. If the component to be connected has a thicker wall than the lens convolution, it is usually tapered towards the connecting seam. One possible method is butt welding with a groove. The advantage of this is the geometrically available pool securing and therefore the improved and easier weldability. There is a higher risk of crevice corrosion, however. Fillet connections are also possible for lower strain areas, but the risk of crevice corrosion has to be taken into account here as well. The thickness of the walls to be connected should not be less than 2 mm.

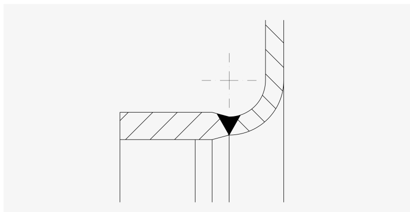
Butt welds



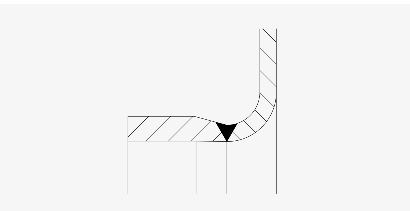
same thickness



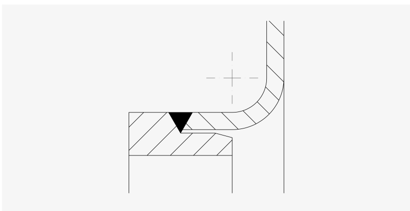
flush outside



centred

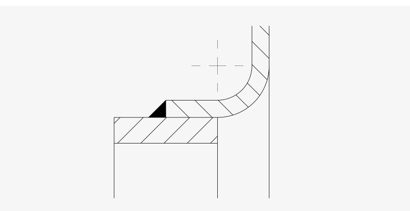


flush inside

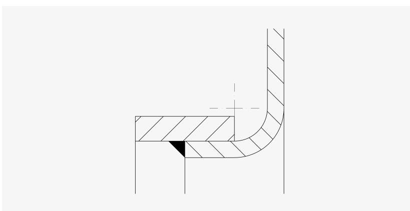


with groove

Fillet welds



outside



inside

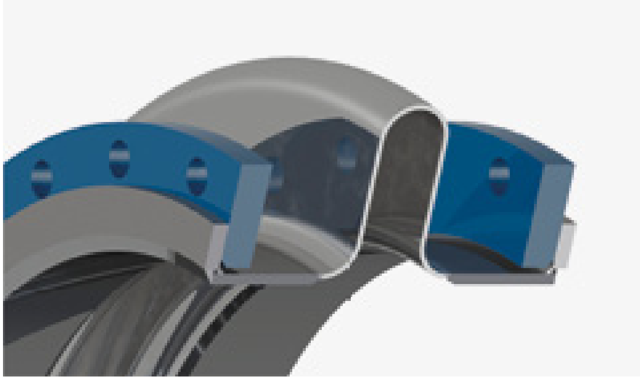
Flanges

The advantage of a flange connection is the ease of mounting. This makes it possible to replace an expansion joint regardless of the weather even under difficult installation conditions. This is significantly more complicated for expansion joints with welding ends.

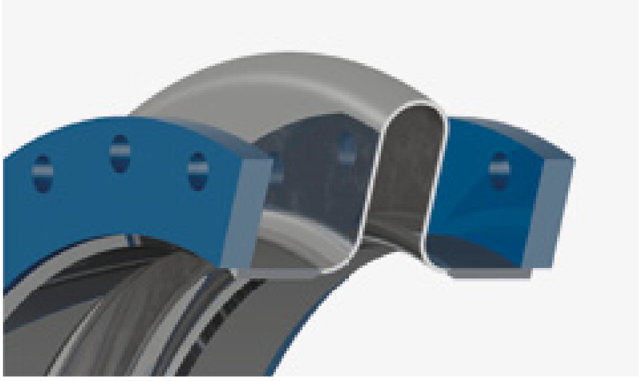
Flange connections are largely standardised through national and international standards (DIN, EN, ANSI, BS or JIS) or described by customers factory standards. On customer request, special flange connections with various requirements can be implemented. Flange types in line with EN 1092-1 are commonly used as a standard.

To ensure flange connections without screws or to create compact shapes or lengths, it is common practice to use combinations of fixed flanges with additional welding ends.

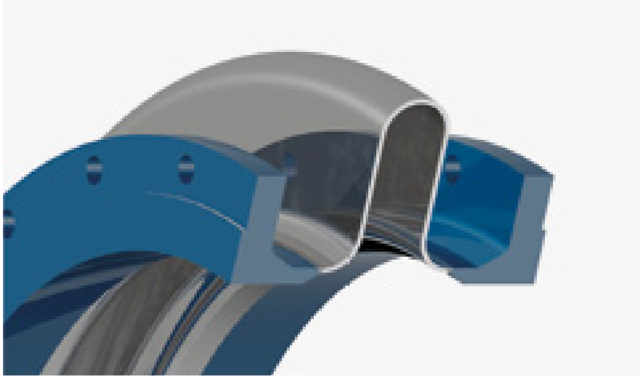
Materials are often selected in line with the bellows material used.



Swivel flange with collar and welding ends



Flat fixed flange with welding ends

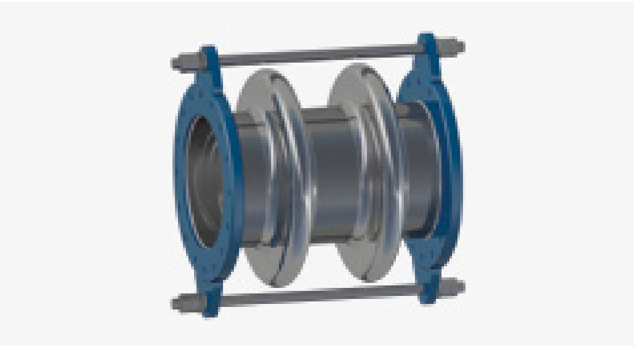


Welding neck flange

Angled flange

Tie rods

Under pressure (operating or test conditions), lens expansion joints develop an axial reaction force across the entire effective bellows cross section which puts additional stress on the neighbouring plain and fixed bearings. This bearing stress in the pipe system is drastically reduced by using lateral and/or angular expansion joints with tie rods. Only the adjustment forces and moments from the lateral or angular movement are additionally introduced into the pipe system and absorbed by lightweight fixed points.

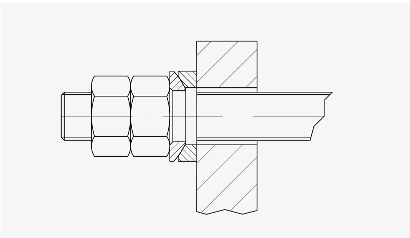


External tie rods

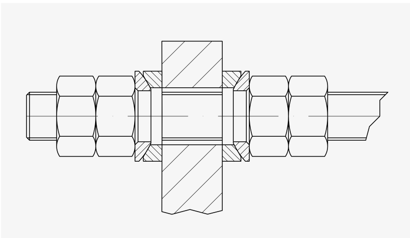
External and internal tie rods

Tension rods

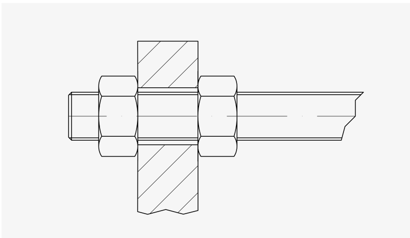
This type of tensioning is used for lateral expansion joints or can be used to limit the element length or serve as a pretensioning device on axial and universal expansion joints. Threaded rods are placed symmetrically around the circumference and supported with spherical washers, conical washers and nuts. For pretensioning or fixing the length, the version without spherical and conical washer is sufficient. For absorbing excess pressure (internal pressure), only external tensioning is required and additional internal tensioning for negative pressure (vacuum, external pressure). All metallic unalloyed or low-alloy components such as threaded rods, nuts, conical and spherical washers are galvanised or coated with an anti-rust primer. Components made of stainless highalloy steel are used where higher durability is required. Other materials, hot galvanising, special paints and coatings are possible on request.



External tensioning (without negative pressure)



External and internal tensioning
(with negative pressure)



Pretensioning or length fixing

Materials for connecting parts

Material group	Material designation			
	Moulded parts/tabs	Spherical/conical washer	Tension rods/nuts	Joints
Standard (unalloyed steel)	1.0038 (S235JR)	1.0401 (C15)	5.6, 8.8 / 5, 8	1.0038 (S235JR)
High-temperature steel	1.5415 (16Mo3)	1.7225 (42CrMo4)	1.7225 (42CrMo4)	1.5415 (16Mo3)
Stainless steel	1.4301 (X5CrNi18-10) 1.4541 (X6CrNiTi18-10) 1.4571 (X6CrNiMoTi17-12-2)	1.4305 (X8CrNiS18-9)	A2, A4	1.4301 (X5CrNi18-10) 1.4541 (X6CrNiTi18-10) 1.4571 (X6CrNiMoTi17-12-2)

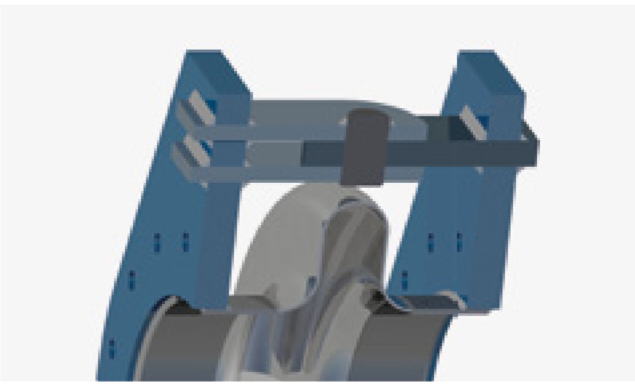
Single joint tensioners
(angular expansion joint for unilateral movement absorption)

Double joint tensioners
(lateral expansion joint for unilateral movement absorption)

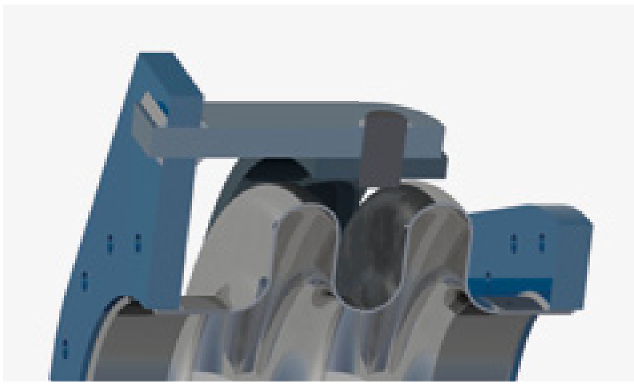
Cardan joint tensioners with ring
(angular expansion joint for all-around movement absorption)

Hinged tensioners

Single joint or cardan joint tensioners are installed on angular expansion joints for transferring axial reaction forces. The link joints are placed at the centre of the bellows axis in pairs and can absorb unilateral or allaround rotations. Single joint tensioners use an oval flange with connected tabs and bolts to form a two-shear connection which allows angular rotation only around the centre bolt axis. On cardan joint tensioners, the oval flanges are placed with tabs offset by 90° and connected with a gimbal ring or box. This allows an angular rotation around the bellows centre point in all directions. Lateral expansion joints are produced with double joint tensioners and an additional tab for unilateral movements and with cardan joint tensioners for all-around movements. The tensioning is generally placed externally and can also be placed on the inside, depending on expansion joint size, movement type, medium and ambient conditions. All metallic unalloyed components are galvanised or coated with an anti-rust primer. Versions mode from corrosion resistant materials or with special coatings are available on customer request.



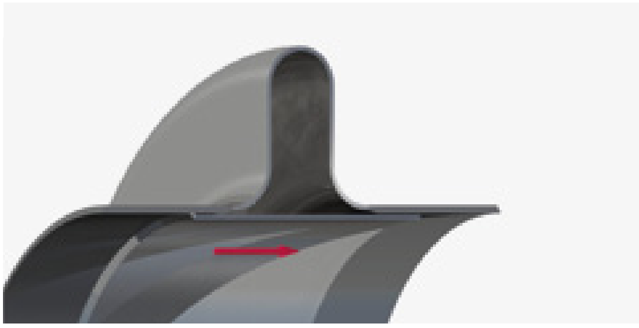
Detail of single joint tensioner



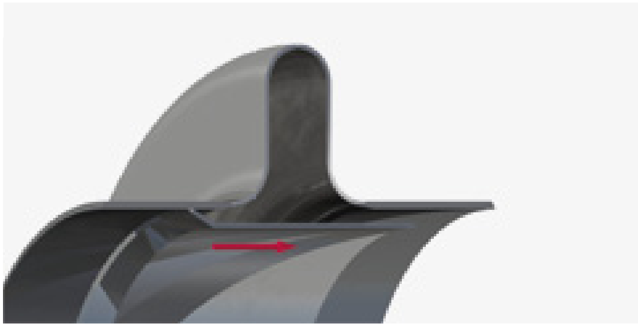
Detail of cardan joint tensioner

Inner sleeves

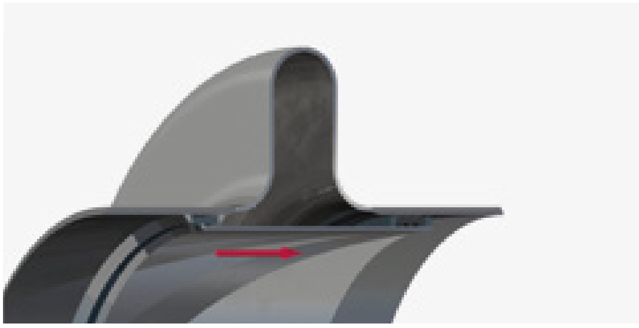
High flow velocities of the medium can cause turbulences and increased flow resistance (pressure loss) in piping with lens expansion joints. To minimise these effects and to transport the medium with as little swirling as possible, inner sleeves are placed into the expansion joint. For highly abrasive media, the lens convolution is protected by an inner sleeve with a suitable wall thickness, made from unalloyed (S235JR, P265GH), corrosion resistant (1.4541, 1.4571) or wear resistant steel (HARDOX®, XAR®), depending on the operating conditions. In operation, sufficient protection has to be ensured by covering the expansion joint convolutions and making the gap between inner sleeve and connecting pipe as small as possible. For this reason, a cylindrical inner sleeve is used for low axial movements and a telescopic inner sleeve for strong movements. Lateral and angular expansion joints are equipped with conical inner sleeves which still allow movement absorption and have a small air gap to the expansion joint even with maximum deflection. In all operating conditions, the movement absorption (axial, lateral, angular) of the lens expansion joint must not be affected by a guide pipe or inner sleeve. The cylindrical inner sleeves are fixed to the connecting parts (welding ends, welding neck flanges) with a fillet weld, directly or with a spacer ring, to ensure a continuous and even, radial clearance. Alternatively the connection can also be flared.



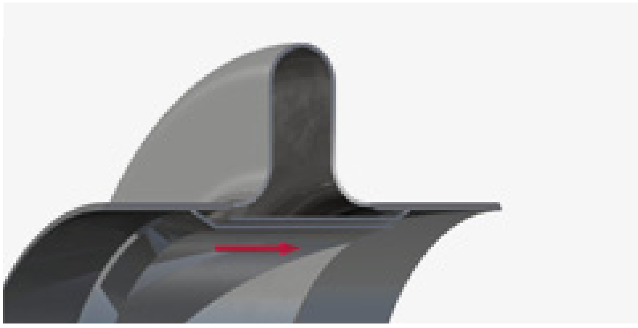
Cylindrical inner sleeve, plain



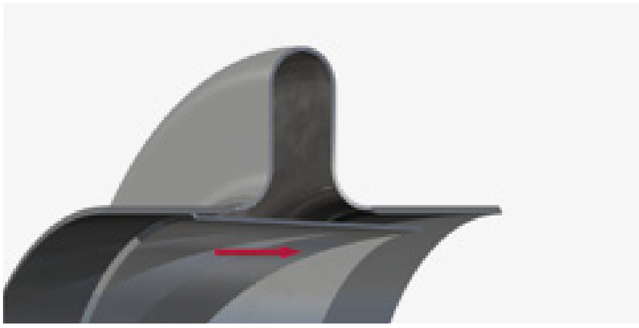
Cylindrical inner sleeve, flared



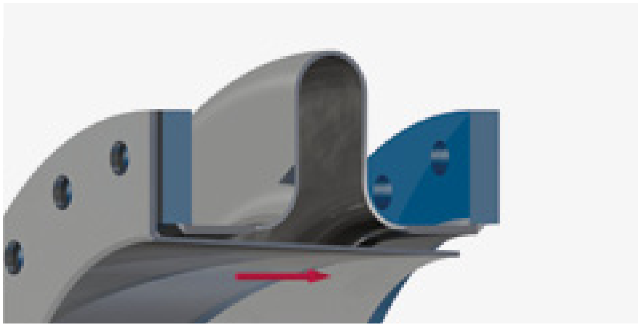
Cylindrical inner sleeve, with spacer ring



Telescopic inner sleeve



Conical inner sleeve



Superimposed inner sleeve

Quality standard

HKS has many decades of experience in the design and manufacturing of high-quality expansion joints. Experienced, trained specialist personnel and our extensive manufacturing options allows us to implement individual customer requests. A certified ISO 9001 quality management system, welder approval (AD 2000 HP0) and regular training of the welding personnel as well as over 70 different welding process tests allow us to manufacture expansion joints according to the Pressure Equipment Directive 97/23/EC. In addition to manufacturing, the testing of lens expansion joints has a high priority. Lens expansion joints which are not subject to the rules of the PED can be examined with different non-destructive test methods depending on customer requirements.

Welding seam testing by HKS and external testing bodies:

- VT visual test
- PT penetration test
- RT X-ray test
- UT ultrasound test
- MT magnetic particle test

In addition to welding seam testing, we offer various services for material testing in cooperation with a material testing association:

- Certification of resistance to intergranular corrosion (IGC)
- Certification of hot yield strength
- Notched bar impact testing at low temperatures
- UpDegreesing of quality certificate 3.1 into 3.2 (TÜV)

Dimensional tolerances

Lens expansion joints are subject to the general tolerances for welded constructions (ISO 13920) and are, as a rule, to be classified in tolerance class BF to CG. Tolerances for connection diameters are modelled on the common material standards for pipes. In this context it has to be noted that from a diameter of approx. 500 mm this is determined based on the circumference. For ovality, a tolerance of ± 0.5 % of the diameter is permitted. Lengths are defined separately and listed in the following table depending on nominal width and component length differently and following EN 14917 section 7.5.2.2. Component tolerances deviate for multi-convolution expansion joints or for very high convolutions. Smaller manufacturing tolerances can be implemented with greater manufacturing effort and are possible upon prior agreement.

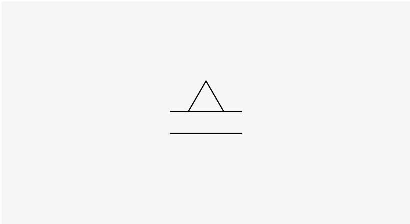
Dimensional tolerances for overall length

Nominal diameter DN	Length [mm]		
	< 400	400 - 1000	> 1000
≤ 500	± 3	± 4	± 5
550 - 1000	± 4	± 5	± 7
1100 - 2500	± 5	± 6	± 9
2600 - 4000	± 8	± 10	± 12
4100 - 6000	± 10	± 12	± 15

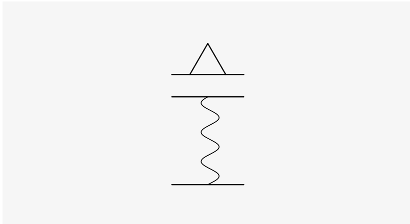
Installation in pipe systems

Expansion joints are used in piping systems to compensate for expansions. Combinations of several expansion joints for absorbing system specific movements have to be specially designed. This changes the stress on fixpoints and guides compared to an uncompensated system. On request, our HKS specialists can develop and manufacture individual system solutions as well as optimum arrangements of the system components ready for installation. The fixed bearings absorb additional reaction forces from the effective cross section and from the spring rate.

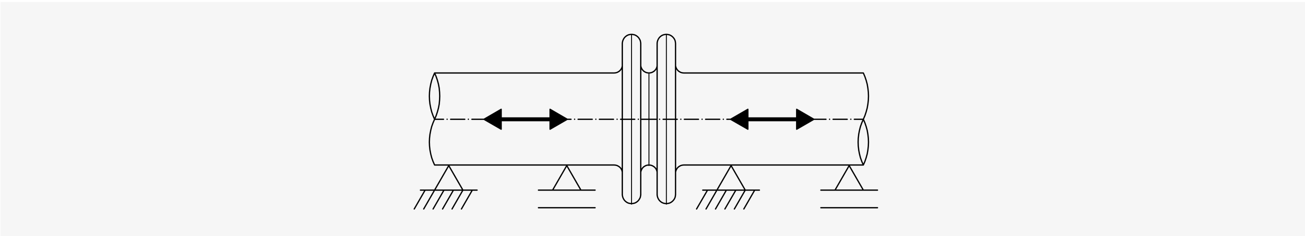
Fixed bearing



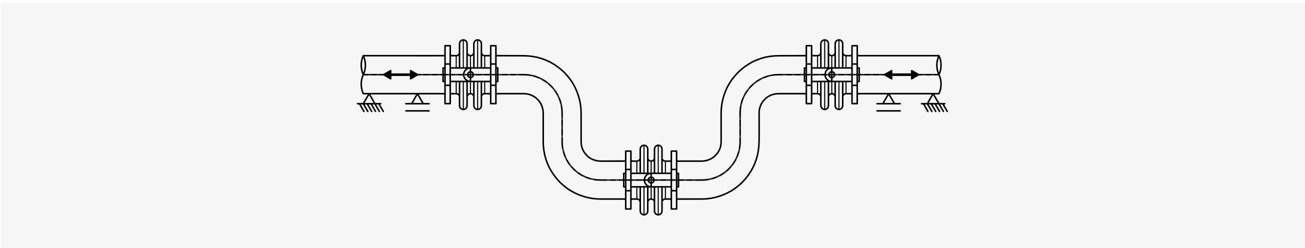
Floating bearing



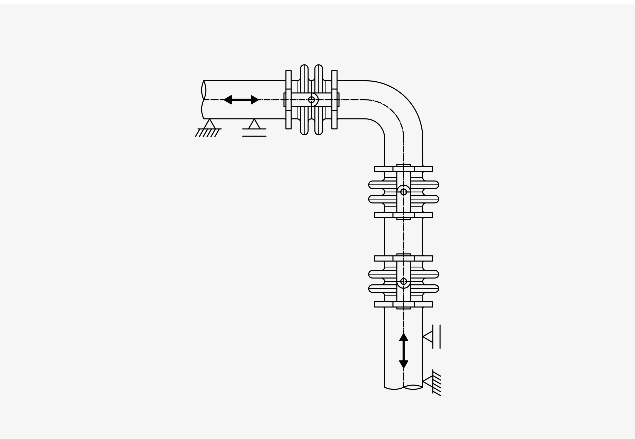
Spring bearing

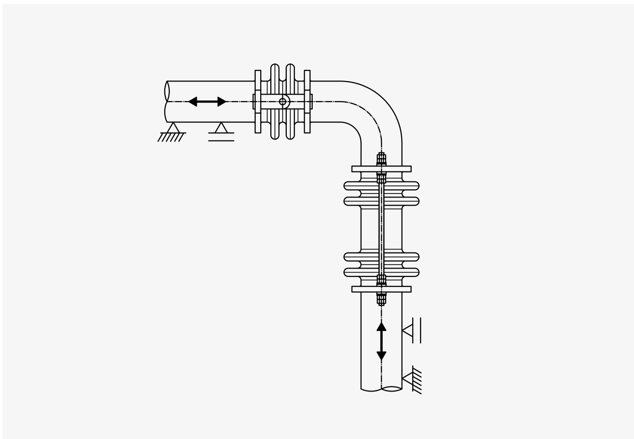


Absorption of axial expansion along the pipe axis using an axial expansion joint

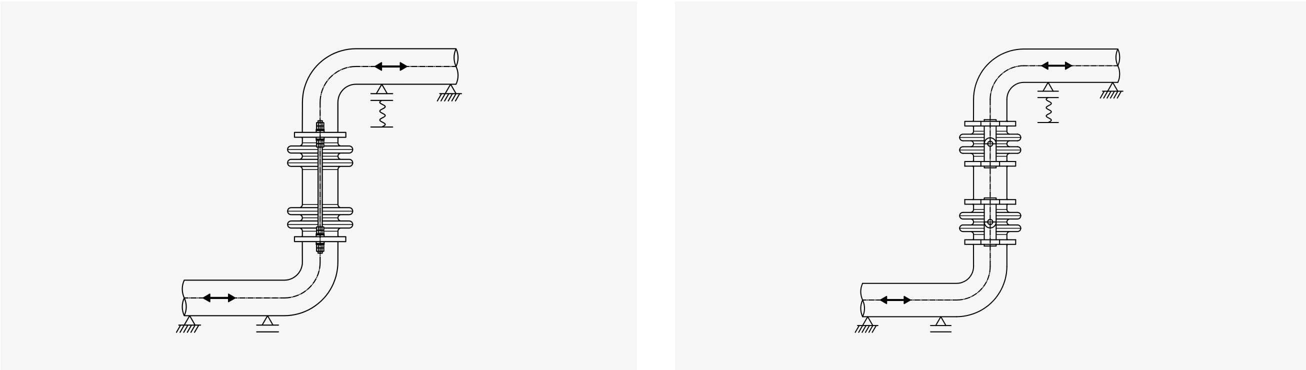


Axial expansions acting in a U-shaped arrangement are deflected in three angular movements (three hinges)**.**
This design is intended for absorbing large axial expansions in the pipe.





Axial expansions acting in an L-shaped arrangement are deflected in three angular movements (left) **or alternatively in one angular and one lateral movement** (right)**.**



Axial expansions are deflected in one lateral movement (left) **or alternatively in two angular movements** (right).
The axes of rotation have to be placed at 90 degrees to the axial direction of expansion. Correct support of the piping system has to be ensured.

Design of lens expansion joints

The selection of an expansion joint is essentially determined by the expansion, the routing of the piping and the room situation. Expansion joints have to be selected in line with the basic movement types (axial, lateral, angular). In contrast to corrugated expansion joints, lens expansion joints are already possible with one convolution as a single bellows version, but they require at least three convolutions to absorb lateral movements. The use of expansion joints produces forces and moments which have to be absorbed by the fixed bearings of the piping system. Furthermore, superimposition of movements, temperature influences and increased stress cycles can lead to individual adaptations in dimensioning. For special applications in heat exchanger shells, we always recommend contacting our HKS specialists. On request, we are happy to support you with selecting the optimum expansion joint or to offer a customised product.

Thermal expansion of pipes

The thermal expansion caused by temperature change in pipes is one of the most frequent areas of application for expansion joints. The calculation of thermal expansion depends on the materials, the length of the piping and the temperature difference. For use in the shell of a shell-and-tube heat exchanger, the temperature and length differences between shell surface and tube bundle are the decisive factors.

$$\Delta L(\Delta T) = L \times \alpha \times T$$

$\Delta L(\Delta T)$ = change in length depending on temperature difference [mm]
L = length of piping [mm]
α = coefficient of thermal expansion [1/K]
T = temperature difference [K]

Material	Length expansion coefficient α × 10-6 [1/K] between 20 °C and				
	100 °C	200 °C	300 °C	400 °C	500 °C
Ferritic steel	12.5	13.0	13.6	14.1	14.3
X6CrNiTi18-10 (1.4541)	16.0	16.5	17.0	17.5	18.0
X6CrNiMoTi17-12-2 (1.4571)	16.5	17.5	18.0	18.5	19.0
X2CrNiMo17-12-2 (1.4404)	16.0	16.5	17.0	17.5	18.0
Copper	15.5	16.0	16.5	17.0	17.5
Aluminium (AlMg3)	23.7	24.5	25.3	26.3	27.2
PE	200	-	-	-	-
PP	180	-	-	-	-
PVC	80	-	-	-	-

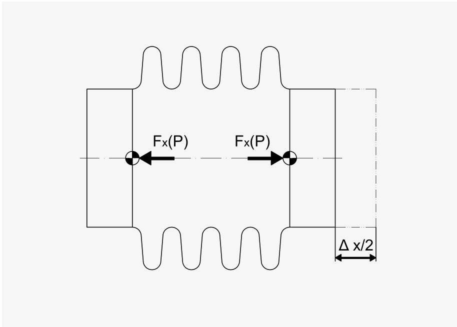
Forces and moments of expansion joints

Axial expansion joints:

The **axial reaction force** is the force in direction of the axis resulting from the operating pressure and the effective cross section.

$$F_x(P) = A_e \times P \times 10^{-2}$$

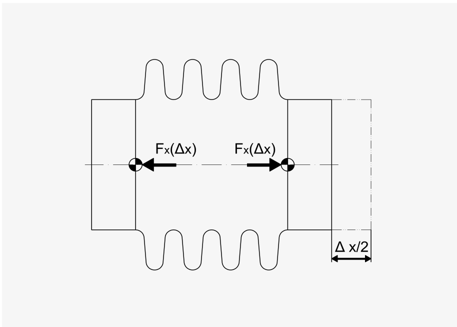
$F_x(P)$ = axial pressure force [kN]
A_e = effective cross section [cm²]
P = operating pressure [bar]



The **axial adjustment force** is the force required for axial deflection from the rest position. It is calculated from the axial adjustment force rate of the bellows and the movement absorption. The direction of stress (tensile force + or pressure force -) has to be taken into account.

$$F_x(\Delta x) = \pm C_{\Delta x} \times \frac{\Delta x}{2 \times N}$$

$F_x(\Delta x)$ = axial adjustment force [kN]
$C_{\Delta x}$ = axial adjustment force rate [kN/mm]
Δx = axial movement absorption [mm]
N = number of lens convolutions



Addition of both forces yields the axial overall force. The signs have to be taken into account.

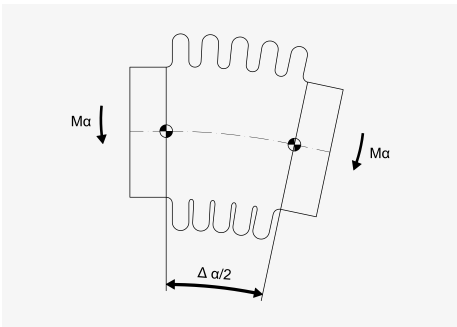
$$F_x = F_x(P) \pm F_x(\Delta x)$$

Angular expansion joints:

The **angular adjustment moment** is the force required for angular deflection from the rest position. It is calculated from the angular adjustment force rate and the angular movement absorption.

$$M_\alpha(\Delta\alpha) = C_{\Delta\alpha} \times \frac{\Delta\alpha}{2 \times N}$$

$M_\alpha(\Delta\alpha)$ = angular adjustment moment [kNm]
$C_{\Delta\alpha}$ = angular adjustment force rate [kNm/degrees
$\Delta\alpha$ = angular movement absorption [degrees]
N = number of lens convolutions



Taking into account operating conditions

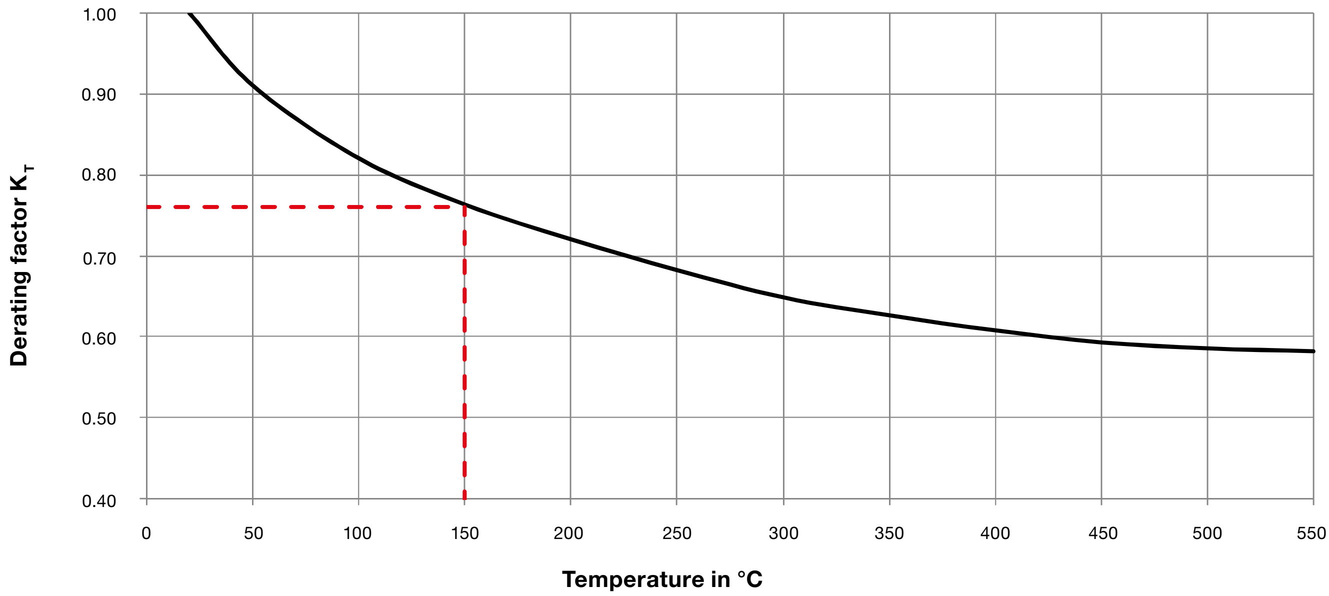
The table sheets contain the characteristic data for standard lens expansion joints. The lens selection only shows a very small part of the possible product range and is primarily intended to provide a general overview of the manufacturing options. All table values were determined with at least 1000 nominal stress cycles with a safety of SL = 1 according to AD 2000 data sheet B13, or EJMA unpressurised and the maximum operating pressure at 20 °C. The calculation was carried out with a design temperature of 20 °C for the material 1.4571 with a permitted test pressure at 20 °C corresponding to 1.43 times the maximum operating pressure. Operating conditions usually differ from these standard conditions. The table values can be adapted approximately to the actual operating conditions using derating or correction factors. For example, higher operating temperatures decrease the strength of a material and reduce the permitted operating pressure. Following the Wöhler curve (S-N curve), the movement absorption reduces as the number of stress cycles increases. The correction values are material-dependent and may only be applied to the table values.

Axial expansion joints:

$$P(T) = PS_{20\,°C} \times K_T$$

P(T) = maximum permitted operating pressure at design temperature [bar]
$PS_{20\,°C}$ = maximum permitted operating pressure at 20 °C [bar]
K_T = temperature derating factor

Temperature derating diagram



Temperature derating factor K_T for 1.4571												
Temperature [°C]	20	50	100	150	200	250	300	350	400	450	500	550
K_T	1.00	0.90	0.81	0.76	0.73	0.69	0.65	0.63	0.61	0.59	0.59	0.58

Influence of the number of stress cycles on the movement absorption

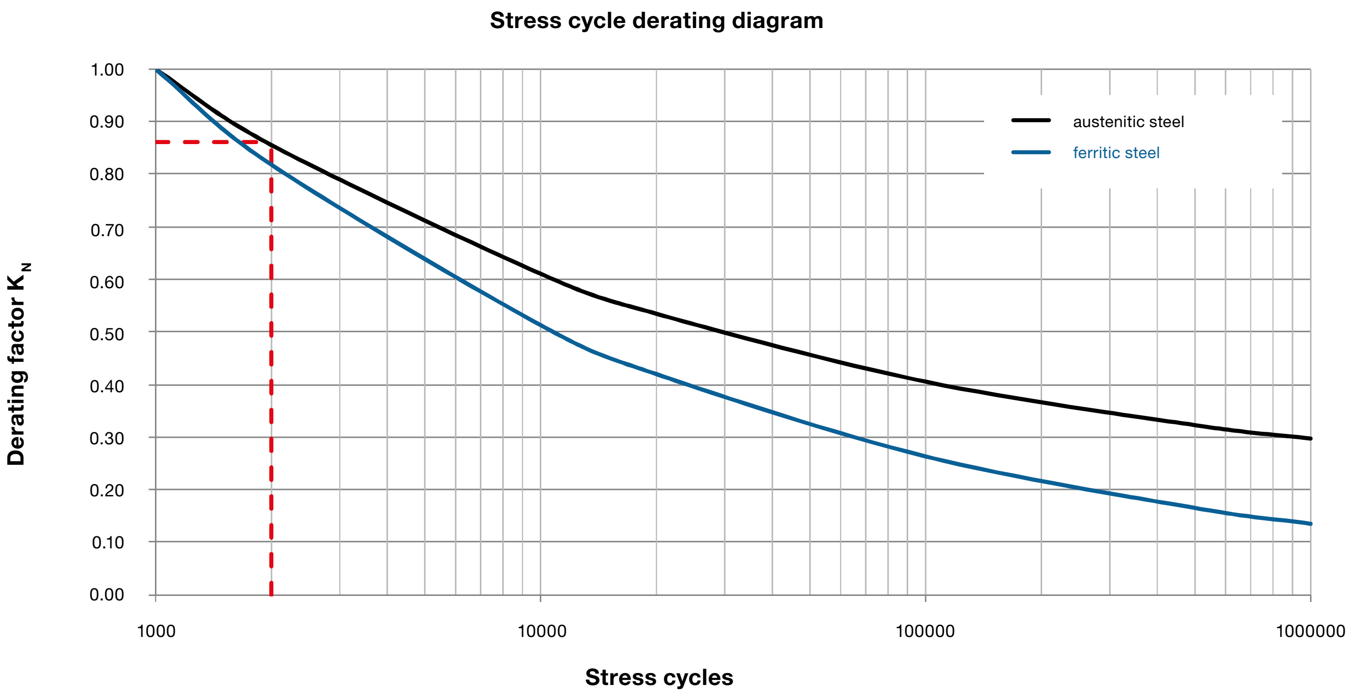
Axial

$$\Delta x(N) = \Delta x \times K_N$$

Angular

$$\Delta \alpha(N) = \Delta \alpha \times K_N$$

$\Delta x(N)$, $\Delta \alpha(N)$ = maximum permitted movement absorption at design conditions [mm]
Δx; $\Delta \alpha$ = nominal movement absorption from table values [mm]
K_N = temperature derating factor for movement at design number of stress cycles



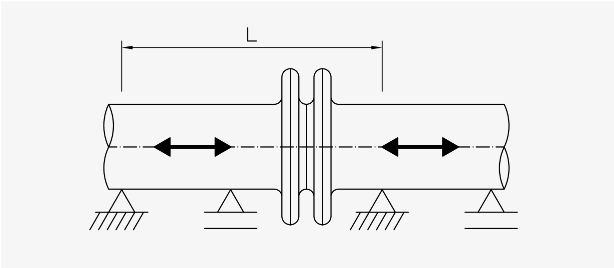
Stress cycle derating factor K_N								
number of stress cycles	1000	2000	5000	10000	20000	100000	500000	1000000
Austenitic steel	1.00	0.86	0.71	0.61	0.53	0.41	0.32	0.30
Ferritic steel	1.00	0.82	0.63	0.51	0.42	0.26	0.17	0.14

Example for selecting an expansion joint

The thermal expansion of a piping system during operation is to be absorbed by axial expansion joints. A pipe DN 350 is to be installed between two fixpoints with a centre distance of 12 m. The pipes are made of high-alloy austenitic steel (e.g. 1.4571). Water with an operating temperature of 150 °C and an operating pressure of 5 bar flows through the pipe. The piping is installed at an ambient temperature of at least 10 °C. The expansion joint is mounted into the pipe without any preset load. The entire system is subject to the Pressure Equipment Directive 97/23/EC). We are looking for a suitable lens expansion joint to be directly welded into the pipe and the associated horizontal reaction forces.

Operating data:

PS = 5 bar (operating pressure)
TS = 150 °C (operating temperature)
L = 12 m (length of pipe section)
T_0 = 10 °C (installation temperature)



Thermal expansion of the pipe section

$\Delta L(\Delta T) = L \times \alpha \times \Delta T$ — Length change due to temperature difference

ΔT = 150 °C – 10 °C = 140 K — Temperature difference
$\alpha = 17.5 \times 10^{-6}\ K^{-1}$ — Coefficient of thermal expansion for austenitic steel up to 200 °C
L = 12 m — Relevant calculation length between the fixpoints

$\Delta L(140\ K) = 12000\ mm \times 17{,}5 \times 10^{-6}\ K^{-1} \times 140\ K = 29.4\ mm$

Temperature-dependent pressure derating

$P(T) = PS_{20\,°C} \times K_T = 5$ bar — Permitted operating pressure due to operating temperature

$K_T = 0.76$ — Temperature derating factor
(intermediate values have to be interpolated linearly)

$PS_{20\,°C,\,req} = P(T) / K_T = 5\ bar / 0.76 = 6.58\ bar$ — Required operating pressure at 20 °C according to table

Example for selecting an expansion joint

Expansion joints which are subject to the Pressure Equipment Directive 97/23/ EC (PED) have to be dimensioned, manufactured and tested according to a set of rules (e.g. AD2000, EN14917, EN13445, EN13480). AD2000 data sheet B13 stipulates that a stress cycle safety of SL= 5 has to be taken into account for the permitted number of stress cycles. Approx. 1000 stress cycles result over a period of 20 years with weekly startup and shutdown of the system. The permitted movement absorption is derated due to the higher required number of stress cycles of 5000.

$\Delta x(N) = \Delta x \times K_N = 29.4$ mm — Permitted movement absorption due to number of stress cycles

$K_N = 0.71$ — Stress cycle dependent derating factor for 5000 stress cycles

$\Delta x_{req} = \Delta x(N) / K_N = 29.4\ mm / 0.71 = 41.4\ mm$ — Required operating pressure at 20 °C according to table

Selection according to catalogue

Lens expansion joint DN 350

$PS_{20\,°C,\,req}$ = 6.58 bar **Δx_{req} = 41.4 mm**

For higher expansion absorption levels, the lens expansion joint is manufactured from multiple convolutions. As a result, the required expansion can be a multiple of the value specified in the tables, but the maximum permitted operating pressure at 20 °C has to be greater than the required value. Without a preset load on the expansion joint, only compression and a 50 % utilization of the expansion absorption can be used (41.4 mm / (50 % × 22 mm) = 3.76 convolutions -> 4 convolutions).

In the example an L-MB 0350 / 4 / 1 × 3 / 400 / 1.4571 with the following data:

Lens expansion joint with Nominal diameter DN 350 with 4 convolutions, a wall thickness of 3 mm and 400 mm length, made of material 1.4571 for direct welding into the piping 355.6 × 3.0 mm.

N = 4 number of lens convolutions
$PS_{20\,°C}$ = 7.9 bar maximum operating pressure at 20 °C
Δx = 22 mm permitted axial movement absorption at 20 °C and 1000 stress cycles
$C_{\Delta x}$ = 4.06 kN/mm axial adjustment force rate per convolution
A_e = 1679 cm² effective bellows cross section

Determining the reaction forces

Reaction force resulting from the operating pressure:

$F_x(P) = A_e \times PS \times 10^{-2}$ axial reaction force due to operating pressure

$A_e = 1679\ cm^2$ efficient bellows diameter
$PS = 5$ bar operating pressure at operating temperature

$F_x(P) = 1679 \times 5 \times 10^{-2} = 83.95$ kN

To ensure best possible use of the movement absorption, expansion joints are usually installed with a preset load (pretensioned). The axial adjustment force results from the axial adjustment force rate (spring rate) and the movement. In this example, the pretensioning is omitted, therefore the axial movement is used in full forthe calculation (Δx/2 -> Δx).

$F_x(\Delta x) = \pm C_{\Delta x} \times \Delta x / N$

$C_{\Delta x} = 4.06$ kN/mm axial adjustment force rate per convolution
$\Delta x = 29.4$ mm existing axial movement
$N = 4$ number of lens convolutions

$F_x(\Delta x) = \pm 4.06 \times 29.4 / 4 = 29.84$ kN

No preset load is required for installation of the expansion joint.

$F_x = F_x(P) + F_x(\Delta x)$
$Fx = 83.95\ kN + 29.84\ kN = 113.79\ kN$

During operation, the expansion joint exerts an axial pressure force of approx. 114 kN on the anchor points. The dead weight of the pipes and additional parts as well as friction forces of plain bearings have to be taken into account for the dimensions of bearings. Loads have to be considered separately on the test bench.

HKS type designation for lens expansion joints

L- A F X 3000 / 003 / A070 / V / V - 1015 - 1045

Movement alignment

A – Axial movement
W – Angle movement
K – Cardan movement
L – Lateral movement
R – Radial movement

Version

N – Standard version
F – Inner sleeve/guide pipe
S – External protective sleeve
T – Telescopic sleeve
B – Inner sleeve and protective sleeve
D – Double shell
M – Double bellows version
P – Double bellows + inner sleeve
K – Corner relief

Special model (optional)

DN/NW

Nominal diameter in line with DIN 2402 in mm (always 4 digits)

PN

Pressure level in line with DIN 2401 (always 3 digits, rounded without decimals)

Total stroke (movement)

A – Axial (mm)
L – Lateral (mm)
W – Angle (degrees)
(always 3 digits per movement data)

1. Page / 2. Page

Connection parts

B – Swivel flange
F – Fixed flange
V – Welding neck flange
R – Weld end
S – Custom made flange
K – Customer part
D – Welding collar + swivel flange
Bs – Welded collar

Length in mm

Pretensioning (optional)

HKS type designation for rectangular lens expansion joints

L-RE T 0600 x 0400 / 001 / A120 / WF / WF - 775 - 835

Rectangular lens expansion joint

Version

N – Standard version
F – Inner sleeve/guide pipe
S – External protective sleeve
T – Telescopic sleeve
B – Inner sleeve and protective sleeve
D – Double shell
M – Double bellows version
P – Double bellows + inner sleeve

Connection dimensions in mm (always 2x4 digits)

PN

Pressure level in line with DIN 2401 (always 3 digits, rounded without decimals)

Total stroke (movement)

A – Axial (mm)
L – Lateral (mm)
W – Angle (degrees)
(always 3 digits per movement data)

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Connection parts

F – Fixed flange
R – Weld end
S – Custom made flange
K – Customer part
WF - angle flange

Length in mm

Pretensioning (optional)

HKS type designation for metal bellows (circular, rectangular, oval)

L- MB 1200 / 0,5 / 1 × 3 / 50 / 1.4404

Lenses

L – lenses (circular)
L-RE – lenses (rectangular)
L-OV – lenses (oval)

Metal bellows

DN / NW

Nominal diameter in line with DIN 2402 in mm (always 4 digits)

alternative:

0820 × 1370

connection dimensions in mm for rectangular or oval lens bellows (always 2 x 4 digits)

Number of convolutions

(0.5 in this case means: a half shell, only possible for lenses)

Number of layers x wall thickness

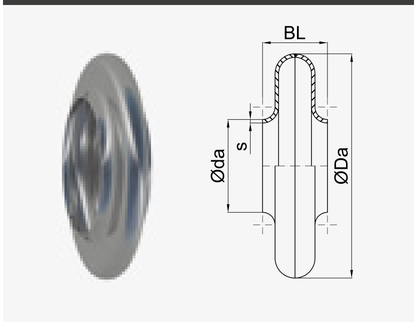
Length in mm

Material

LENS EXPANSION JOINT

Type L-MB

1 convolution



max. 7 convolutions

HKS lens expansion joints with round design up to Nominal diameter 500 consist of two moulded half shells forming one convolution, connected with a circumferential welding seam. The individual convolution create singleconvolution or multi-convolution lens expansion joints. The single-ply wall allows direct butt seam connections to standardised pipe sizes in line with EN 10216/10217 ff.

Materialcombination [1]	Bellows material	Permitted operating temperature TS [2]
Unalloyed steel	1.0425(P265GH)	-10 °C bis 400 °C
Low-alloy steel	1.5415(16Mo3)	bis 530 °C
Stainless steel	1.4541 (X6CrNiTi18-10) 1.4571 (X6CrNiMoTi17-12-2) 1.4404 (X2CrNiMo17-12-2)	-196 °C bis 550 °C
Heat resistant steel	1.4878 (X8CrNiTi18-10) 1.4828 (X15CrNiSi20-12)	bis 900 °C
Nickel-base alloy	2.4856 (NiCr22Mo9Nb - Alloy 625) 2.4858 (NiCr21Mo - Alloy 825)	-196 °C bis 450 °C

1. Chemical resistance depends on temperature and medium and has to be tested or requested.
2. The specified maximum permitted operating temperatures refer to the application in pressure vessels and can be < 0.5 bar higher in low pressure operation.

Individual versions

On request, expansion joints can be manufactured with individual dimensions far exceeding the standard specified in the tables. For example, a reduction of the convolution height reduces the movement absorption and increases the maximum permitted operating pressure. The lens expansion joint is individually tailored using these and other parameters. Our HKS specialists offer a suitable solution for any installation situation.

Tasks

› Absorption of axial and/or angular movements
› Reduction of tensions as well as forces andmoments in connections
› Compensation of installation inaccuracies
› Compensating for settling of buildings

Areas of application

› Plant engineering
› Apparatus engineering (heat exchanger)
› Power station construction
› Pipeline construction
› Mechanical engineering
› Steel, iron and smelting industry
› Cement industry
› Flue gas desulphurisation plants
› Chemical and pharmaceutical industry, acid production

Installation in heat exchangers

On customer request:

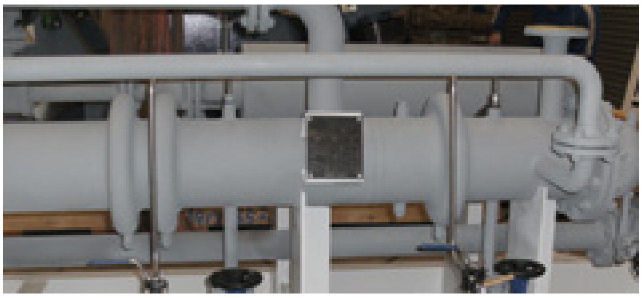
› With 30° groove or special dimensions
› Connection variants with swivel, fixed or welding neck flanges or welding ends
› As a universal expansion joint in double bellows version
› With tie rods as an angular or lateral expansion joint
› Heat treatment (normal or solution annealing)
› Temperature resistant special coatings
› Pickling of high-alloy, stainless steels
› Sandblasting of unalloyed or low-alloyed steels

Expansions:

› Inner sleeve, telescopic inner sleeve or conical inner sleeve
› Nozzle (threaded sleeve or nipple) for draining, venting or cleaning
› Heat resistant insulation of the convolution

Expansion joints with a nominal pressure ≤ 0.5 bar are not subject to the stipulations of the Pressure Equipment Directive (PED) 97/23/EC. Subject to deviations of the components from the ideal shape due to manufacturing (geometric imperfection). Observe manufacturer's information, installation information, load information and corrosive ambient influences.

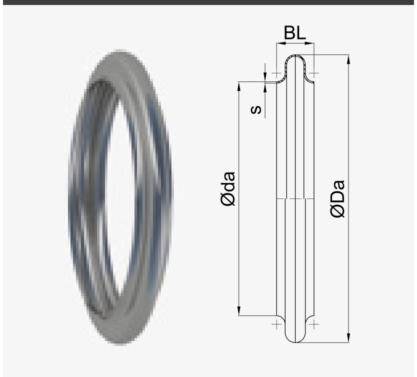
Nominal diameter	Outer connection diameter	Outer convolution diameter	Length	Wall thickness		Maximum operating pressure at 20°C	Nominal pressure absorption per convolution				Effective diameter	Adjustment forces (spring rate)	
							Unpressurised		At $PS_{20°C}$				
				nom.	min. - max.		Axial	Angular	Axial	Angular			
DN	da	Da	BL	s	s	$PS_{20°C}$	Δx	Δα	Δx	Δα	Ae	CΔx	CΔα
-	mm	mm	mm	mm	mm	bar	mm	Degrees	mm	Degrees	cm^2	kN/mm	kNm/Degrees
32	42.4	145	60	2	2 - 3	16	4	4.7	2.8	3	66.1	1.36	0.07
40	48.3	145	60	2	2 - 3	20	3.8	4.4	2.5	2.9	70.4	1.98	0.1
50	60.3	185	60	2	2 - 3	10	5	5.3	4	3.6	115	0.85	0.07
50	60.3	250	60	2	2 - 3	2.8	10	5.8	9	4	185	0.17	0.03
65	76.1	185	60	2	2 - 3	10	4	4.4	3	3.5	130	1.06	0.08
65	76.1	270	60	2	2 - 3	3	11	6.8	10	4.6	230	0.2	0.04
80	88.9	145	56	2	2 - 3	53	2.8	2.3	2.2	1.8	104	36.7	1.65
80	88.9	350	60	2	2 - 3	1.2	17	8	15	5.5	372	0.08	0.03
100	114.3	185	60	2	2 - 3	34	4.4	2.9	3.6	2.4	172	19.8	1.46
100	114.3	350	100	2	2 - 3	3.8	16	7.5	12	4.4	417	0.23	0.07
125	139.7	220	80	2	2 - 3	30	4.7	2.6	3.8	2.1	249	28	2.93
125	139.7	350	90	2	2 - 3	2.9	15	7.1	13	5.4	464	0.31	0.09
150	168.3	275	80	2	2 - 4	17.6	8.3	3.6	6.7	3	379	9.89	1.63
150	168.3	400	80	2	2 - 4	3.4	19	6.8	15	4.2	626	0.39	0.14
175	193.7	300	80	2	2 - 4	16.7	9.1	3.6	7.3	3	471	10.1	1.97
175	193.7	435	90	2	2 - 4	2.9	22	6.6	17	4.5	767	0.32	0.13
200	219.1	350	100	3	2 - 4	24	9.8	3.4	8	2.8	623	18.5	4.9
200	219.1	480	106	3	2 - 4	5.6	19	6	13	4	944	1.01	0.51
250	273	435	100	3	2 - 6	15.1	15	4.4	12	3.6	968	9.44	3.88
250	273	525	100	3	2 - 6	6	20	5.4	13	3.6	1232	1.26	0.76
300	323.9	525	100	3	2 - 6	9.5	24	5.6	19	4.6	1396	5.03	3.02
300	323.9	600	106	3	2 - 6	5.2	25	6.1	17	4.1	1655	1.12	0.89
350	355.6	575	100	3	2 - 6	7.9	29	6	22	4.6	1679	4.06	2.93
350	355.6	650	110	3	2 - 6	5	28	6.3	18	4	1962	1.01	0.94
400	406.4	600	120	3	2 - 6	10.7	23	4.6	18	3.8	1966	7.99	6.26
400	406.4	700	126	3	2 - 6	5	26	5.4	18	3.6	2378	1.33	1.44
450	457	650	120	3	2 - 6	10.3	23	4.3	19	3.4	2381	8.21	7.56
450	457	750	126	3	2 - 6	4.7	46	7.4	37	6	2833	2.48	3.05
500	508	700	126	3	2 - 8	10.2	23	3.9	18	3.1	2837	9.29	9.93
500	508	800	126	3	2 - 8	4.6	48	7.3	39	5.9	3329	2.59	3.62



Design: All table values were determined with at least 1000 nominal stress cycles with a safety of SL = 1 according to AD 2000 data sheet B13, EJMA or EN 14917 unpressurised and the maximum operating pressure at 20 °C. The calculation was carried out with a design temperature of 20 °C for the material 1.4571 with a permitted test pressure at 20 °C corresponding to 1.43 times the maximum operating pressure. A wall thickness tolerance was taken into account with +/- 0.1 mm. The indicated permitted expansion absorption values Δx or Δα are differences between the expanded and the compressed state or between two directions of rotation. That means Δx=40 mm or +/-20 mm; Δα=7.0° or +/-3.5°. Δx and Δα have to be reduced proportionately for simultaneous movement absorption. The sum of all parts must not exceed 100%.

LENS EXPANSION JOINT

1 convolution



max. 7 convolutions

HKS lens expansion joints with round design from Nominal diameter 550 consist of two flanged half shells forming one convolution, connected with a circumferential welding seam. The individual convolution create singleconvolution or multi-convolution lens expansion joints. The single-ply wall allows direct butt seam connections to standardised pipe sizes.

Materialcombination [1]	Bellows material	Permitted operating temperature TS [2]
Unalloyed steel	1.0425 (P265GH)	-10 °C bis 400 °C
Low-alloy steel	1.5415 (16Mo3)	bis 530 °C
Stainless steel	1.4541 (X6CrNiTi18-10) 1.4571 (X6CrNiMoTi17-12-2) 1.4404 (X2CrNiMo17-12-2)	-196 °C bis 550 °C
Heat resistant steel	1.4878 (X8CrNiTi18-10) 1.4828 (X15CrNiSi20-12)	bis 900 °C
Nickel-base alloy	2.4856 (NiCr22Mo9Nb - Alloy 625) 2.4858 (NiCr21Mo - Alloy 825)	-196 °C bis 450 °C

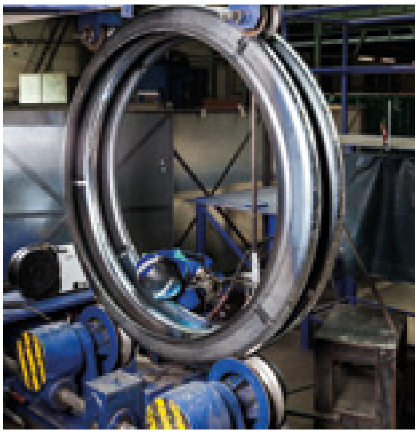
1. Chemical resistance depends on temperature and medium and has to be tested or requested.
2. The specified maximum permitted operating temperatures refer to the application in pressure vessels and can be < 0.5 bar higher in low pressure operation.

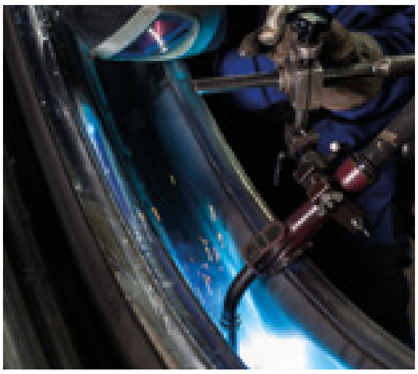
Tasks

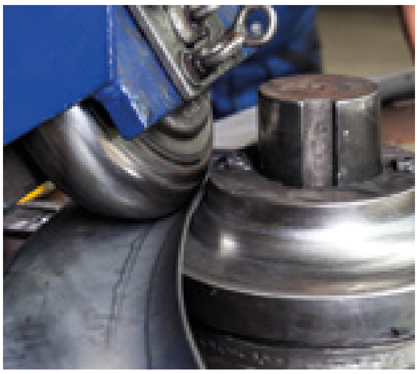
- Absorption of axial and/or angular movements
- Reduction of tensions as well as forces and moments in connections
- Compensation of installation inaccuracies
- Compensating for settling of buildings

Areas of application

- Plant engineering
- Apparatus engineering (heat exchanger)
- Power station construction
- Pipeline construction
- Mechanical engineering
- Steel, iron and smelting industry
- Cement industry
- Flue gas desulphurisation plants
- Chemical and pharmaceutical industry, acid production







Expansion joints with a nominal pressure ≤ 0.5 bar are not subject to the stipulations of the Pressure Equipment Directive (PED) 97/23/EC. Subject to deviations of the components from the ideal shape due to manufacturing (geometric imperfection). Observe manufacturer's information, installation information, load information and corrosive ambient influences.