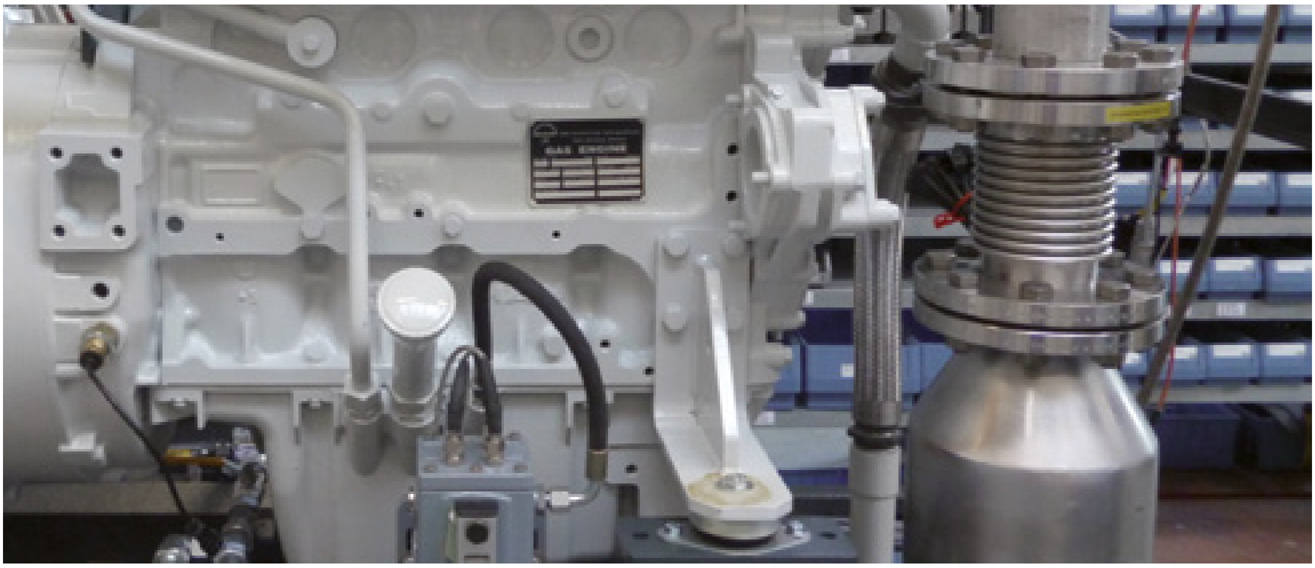
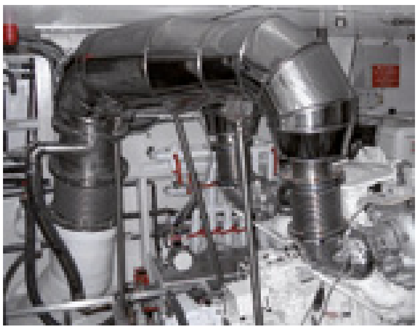


Corrugated expansion joints

HKS designs and manufactures corrugated expansion joints from the simplest standard expansion joints to highly complex expansion joints which are designed especially on the basis of individual customer requirements. Corrugated expansion joints are single or multi-layered stainless steel expansion joints with a high level of expansion absorption and a low spring rate. They are used as flexible pipe connections in mechanical engineering, power unit and pipeline construction, in district heating and exhaust pipes as well as in industrial and sprinkler systems.

Our expansion joints are under continuous further development to meet the current state of the art and the high requirements of the industry. HKS products comply with the highest quality requirements. This is proven by various certifications and approvals from classification bodies as well as by customer audits. For best possible dimensioning of the expansion joints, HKS uses the AD-2000 data sheets, EJMA, EN 14917, EN 13445, ASME Section VIII App. 26 and the finite elements method as the basis for calculations.



Areas of application

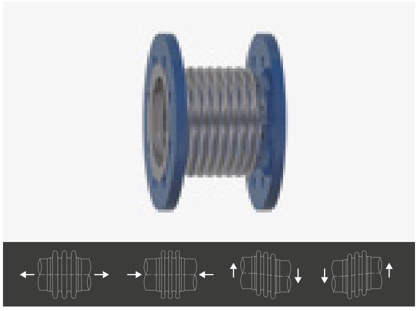
Application examples for HKS corrugated expansion joints are versatile and flexible. Options for movement with large expansions and at the same time a low adjustment force rate are suitable for many industries with different media and temperatures.

- Plant engineering
- Mechanical engineering
- Ship building
- Power station construction
- Engine building
- Pipeline construction
- Chemical industry
- Food processing industry

The main tasks are:

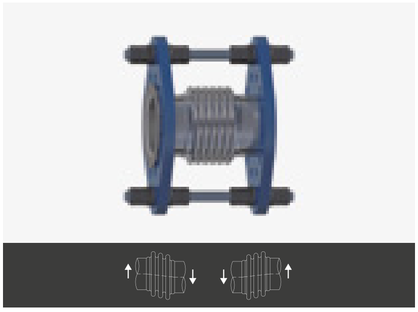
- Absorbing expansions
- Absorbing movement
- Damping oscillations and vibrations
- Compensation of installation inaccuracies
- Compensating for settling of buildings

Model variants



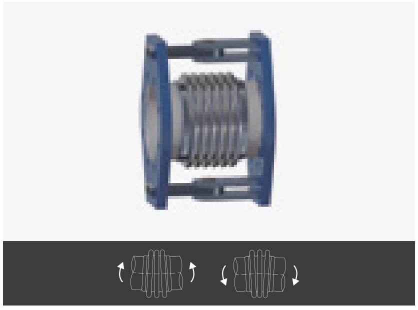
Axial expansion joint (example Type AN B-B)

- With swivel flanges, fixed flanges or welding ends
- Nominal diameters DN 20 – DN 2800 [1)]
- Pressure stages DN 1 – DN 40 [2)]
- Low adjustment force rates and high movement absorption



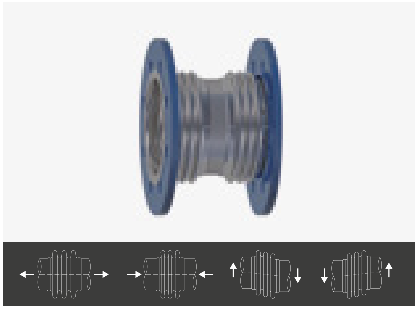
Lateral expansion joint (e.g. Type RN B-B)

- With swivel flanges, fixed flanges or welding ends
- Nominal diameters DN 20 – DN 2800 [1)]
- Pressure stages DN 1 – DN 40 [2)]
- With tie rod systems (tension rods or joints)
- With single joint movable on one side
- With tension rod or cardan joint moveable in all directions
- Tie rods absorb axial reaction forces



Angular expansion joint (example Type WN F-F)

- With swivel flanges, fixed flanges or welding ends
- Nominal diameters DN 20 – DN 2800 [1)]
- Pressure stages DN 1 – DN 40 [2)]
- With single joints movable on one side
- With cardan joints moveable in all directions
- Joints absorb axial reaction forces
- Large bending angles and compact lengths



Universal expansion joints (example Type AM B-B)

- With swivel flanges or welding ends
- Nominal diameters DN 20 – DN 2800 [1)]
- Pressure stages DN 1 – DN 40 [2)]
- With middle pipe
- High movement absorption and low adjustment force rates possible also in lateral direction

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

The bellows of an expansion joint

The metal bellows as a flexible basic elements has a high level of flexibility due to its continuous convolution. A high level of pressure resistance also has to be ensured. The bellows can be single or multi-layered. Wall thickness, number of layers, convolution geometry and number of convolutions are the adjustment parameters for designing an expansion joint (movement absorption, spring stiffness, convolution stability and column instability). The multiple walls divide the pressure load on the overall wall into several individual layers which offers the advantage of significantly increasing flexibility and lowering stiffness of the spring and therefore the adjustment forces.

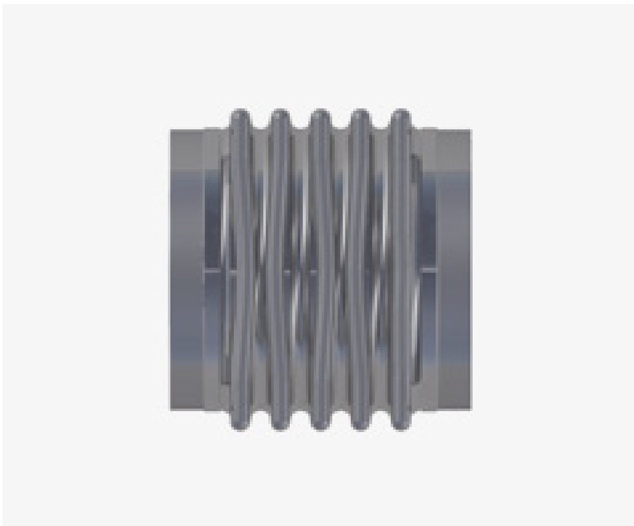
Single-ply

Double-ply

Multi-ply

Stability limits (crease and column instability) have to be taken into account when designing metal bellows. Column instability has to be taken into account for long expansion joints with small bellows diameters. The component tends to buckle. With larger bellows diameters, deformation of the individual convolution may occur. Stability of the convolution has to be taken into account here.

Column instability of a steel expansion joint



Inplane instability of a steel expansion joint

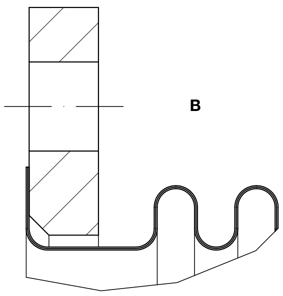
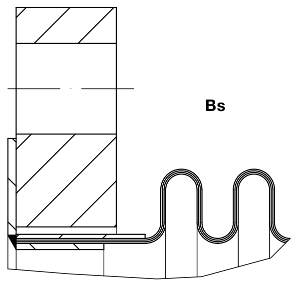
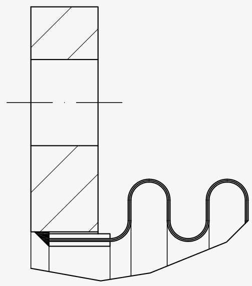
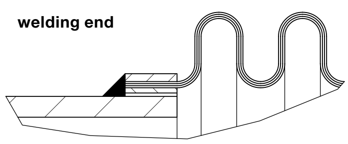
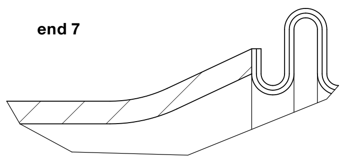
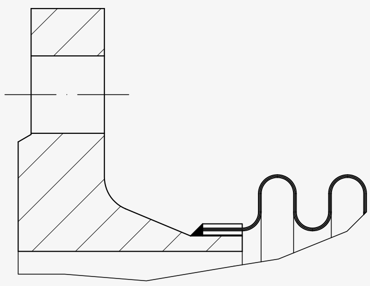
A temperature of 20 °C, the nominal pressure, the movement absorption and service life of 1000 stress cycles are normally used as a standardised basis for calculating the metal bellows of an expansion joint. A stress cycle is a complete, repeating oscillation of the bellows (zero position – max. positive deflection – zero position – max. negative deflection – zero position). Corrosion, high frequency vibrations, resonances, strong temperature changes and pressure surges are additional influencing factors.

Bellows materials:

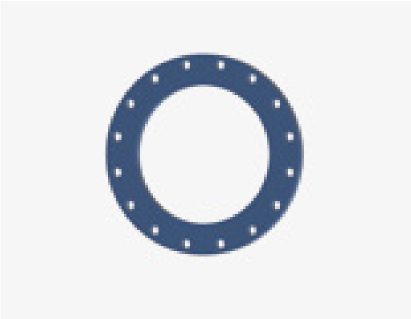
Material group	Material designation	Properties	Application options
Standard	X6CrNiTi18-10 1.4541	good resistance against aggressive media, high ductility, weld decay resistance from Ti content	paper and textile industry, petrochemical industry, film and photography chemicals, food processing industry, chemical apparatus engineering
Stainless steel	X6CrNiMoTi17-12-2 1.4571 X2CrNiMo17-12-2 1.4404	high ductility, high level of resistance to pitting from Mo content	water supply and processing, breweries, cellulose and dye industry, pharmaceutical industry, exhaust technology
Heat resistant steel	X15CrNiSi20-12 1.4828 X8CrNiTi18-10 1.4878	good to very good high temperature stability	steel and smelting industry, cement kilns, brick kilns, glass manufacturing, heat transmissions, exhaust technology
Nickel-base alloy	NiCr22Mo9Nb 2.4856 NiCr21Mo 2.4858	excellent oxidation resistance, very good resistance to atmospheres containing sulphur (acids), heat resistant	engine and turbine building, acid production, oil and gas production, flue gas desulphurisation plants, valve technology

Connection types

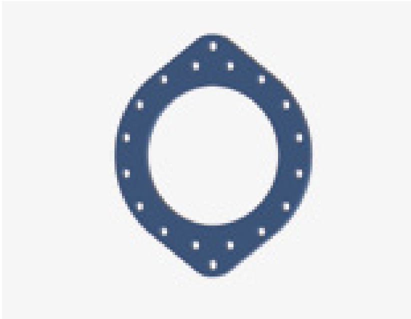
HKS expansion joints are equipped with flanges or welding ends for integration into pipe systems. All connections are manufactured to EN 1092-1 as a standard and comply with standardised dimensions. The following connections are used for axial and universal expansion joints.

Abbr. designation	Drawing	Description
B / Bs	 	› rotating swivel flange › B = press collar without welding seam › Bs = collar disc with welding seam and front ring
F		› welded-on fixed flange with reinforcing front rings
R	 	› welding end = welded-on weld end with reinforcing front rings › end 7 = welded-on conical weld end
V		› welded-on welding neck flange with reinforcing front rings

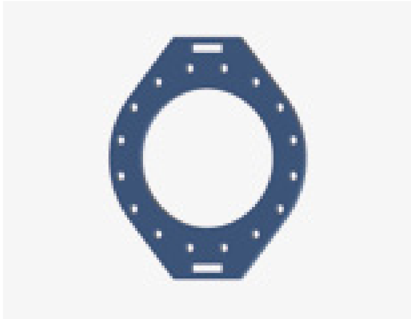
Flanges for lateral expansion joints are equipped with accommodations for tension rods. On angular expansion joints, the flanges are equipped with an accommodation for the joint tensioners. All connections are standardised and fit the standard commercial flanges (EN 1092-1) and pipes (EN 10216ff – 10217ff).



Standard flange



Flange with tabs for tension rods
(lateral expansion joint)



Flange with tabs for joint connection
(angular expansion joint)

Flanges made of unalloyed steel are treated with a corrosion protection coating. Components made of stainless steel are used where higher durability is required. Special shapes, other materials, galvanising or hotgalvanising, special paints and coatings are possible on request.

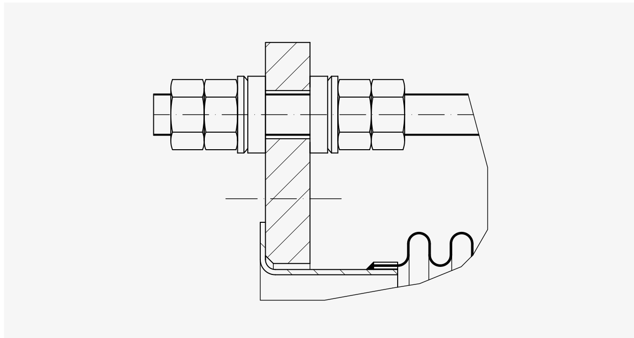
Flange and pipe materials:

Material group	Material designation	
	Flanges	Pipes
Standard	S235JR 1.0038	S235JR 1.0038
High-temperature steel	P265GH (HII) 1.0425 16Mo3 1.5415	P235GH-TC1 1.0305 (St 35.8I) 16Mo3 1.5415
Stainless steel	X6CrNiTi18-10 1.4541 X6CrNiMoTi17-12-2 1.4571	X6CrNiTi18-10 1.4541 X6CrNiMoTi17-12-2 1.4571
Heat resistant steel	X15CrNiSi20-12 1.4828 X8CrNiTi18-10 1.4878	X15CrNiSi20-12 1.4828 X8CrNiTi18-10 1.4878

Tie rods

For lateral and angular expansion joints, tie rod elements are used for absorbing the axial reaction forces. The fixed bearings of the pipe system only have to absorb adjustment forces and moments.

RN F-F



Tension rod connection (vacuum)

Tension rods

Lateral expansion joints are equipped with tension rods (generally threaded rods) for absorbing the reaction forces. These are supported by spherical and conical washers. The spherical and conical washers are fixed with two locknuts. Internal bearings are used in expansion joints with negative pressure (vacuum, outside pressure). This ensures that the expansion joint can only make vertical displacement movements. Tensioning elements made of unalloyed steel are usually electro-galvanised. Components made of stainless steel are used where higher durability is required. Other materials, hot galvanising, special paints and coatings are possible on request.

LM F-F

KN F-F

Hinged tensioners

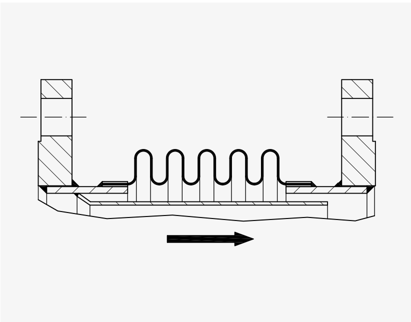
If the expansions to be absorbed in a pipe system are high to very high, expansion joints with joint tensioners are used. This can be lateral expansion joints and for very high expansions the mainly used angular expansion joints. Double bolt joint tensioners are used for lateral expansion joints which only absorb lateral movement in one plane. (see figure LM FF). When using ball-and-socket joints or cardan joints, all-around lateral movements on the circular plane are also possible. Compensation with two angular expansion joints instead of one lateral expansion joint offers the advantage that an intermediate pipe of practically any length can be used between the two angular expansion joints. This increases the permitted movement absorption proportionally to the length of the intermediate pipe. Angular expansion joints are also equipped with joint tensioners. Versions with a joint on one side are twoshear connections with tabs and bolts. The joint absorbs the axial reaction forces and only allows movements in one plane. Cardan joints are used for angular expansion joints with all-around movement. The joints are connected with a box (see figure KN F/F) or ring in this case. Joint connections made of unalloyed steel are treated with a corrosion protection coating. Components made of stainless steel are used where higher durability is required. Other materials, special paints and coatings are possible on request.

Materials for connecting parts

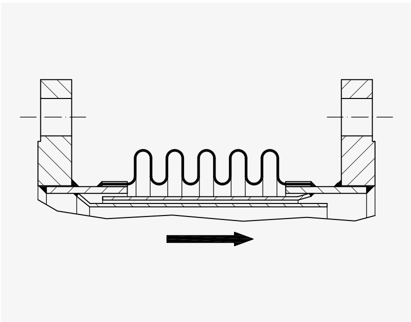
Material group	Material designation			
	Moulded parts/tabs	Spherical/conical washers	Tension rods/nuts	Joints
Standard (unalloyed steel))	S235JR 1.0038	C15 1.0401	5.6, 8.8 / 5, 8	S235JR 1.0038
High-temperature steel	16Mo3 1.5415	42 CrMo4 1.7225	42CrMo4 1.7225	16Mo3 1.5415
Stainless steel	X6CrNiTi18-10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

Inner sleeves

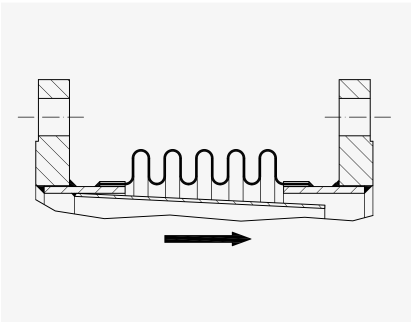
The high flow velocities can result in resonances of the bellows element or turbulences through redirection of flow. To minimise these effects and to transport the fluid with as little swirling as possible, inner sleeves are welded into the expansion joint. For media with a high risk of wear (abrasion), thebellows can be protected with an inner sleeve with an appropriate wall thickness. Depending on the application, inner sleeves are made of unalloyed (e.g. S235JR, P265GH), stainless (e.g. 1.4541, 1.4571) or wear resistant steel (e.g. HARDOX, XAR). Cylindrical inner sleeves are used for axial expansions. Telescopic inner sleeves are used to ensure function with high levels of movement absorption. Angular and lateral expansion joints are equipped with conical inner sleeves to still allow movement of the expansion joint.



Axial expansion joint with cylindrical inner sleeve



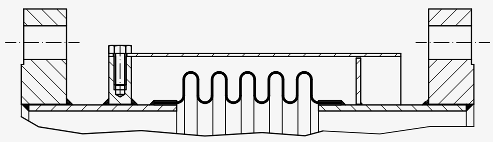
Axial expansion joint with telescopic inner sleeve



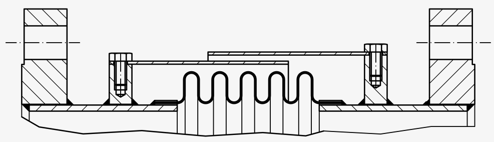
Lateral expansion joint with conical inner sleeve

Protective pipes

Protective pipes mounted on the outside protect the bellows against aggressive environmental media and mechanical damage. They can be screwed in or welded on. Applications are e.g. for district heating.



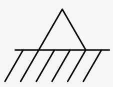
Expansion joints with removable protective pipe



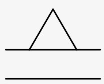
Expansion joint with telescopic protective pipe

Installation in pipe systems

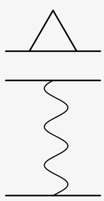
Expansion joints are used in piping systems to compensate for expansions. Combinations of several expansion joints for absorbing system specific movements have to be specially designed. This changes the stress on fixpoints and guides compared to an uncompensated system. On request, our HKS specialists 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.



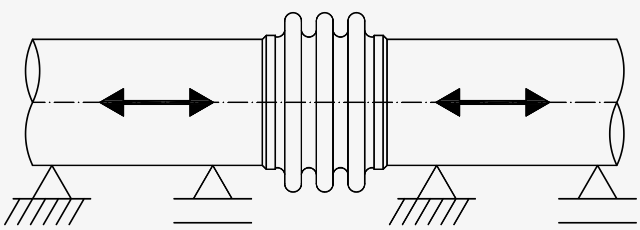
Fixed bearing



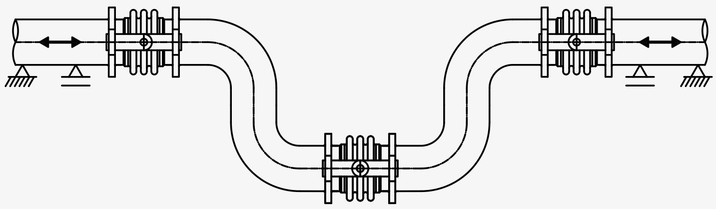
Floating bearing



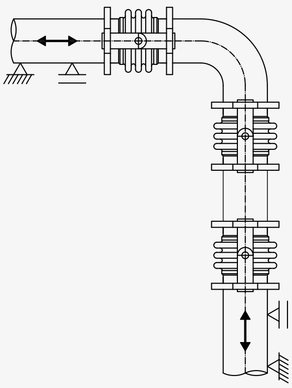
Spring bearing

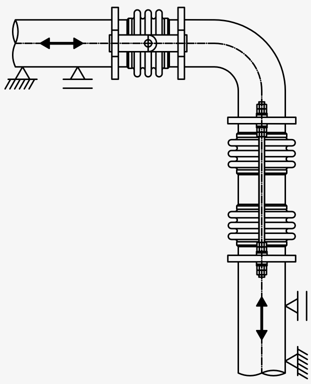


Absorption of axial expansion along the pipe axis using an axial expansion joint

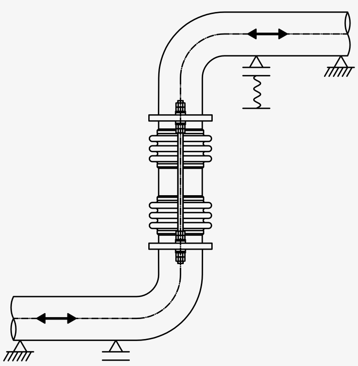


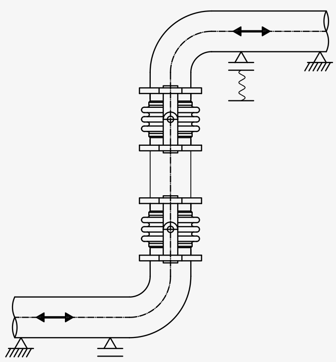
Axial expansions acting in a U-shaped arrangement are deflected in three angular movements (three hinges)**. This design is intended for absorbing large axial expansions in the pipe.**





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 corrugated 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). 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. On request, our HKS specialists can provide support for selecting the best possible expansion joint.

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.

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

$\Delta L(\Delta T)$ = 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	-	-	-	-

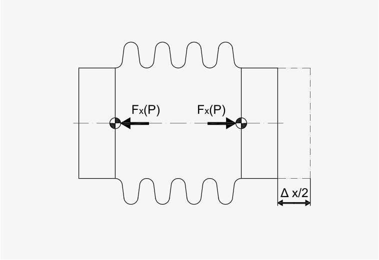
Forces and moments of expansion joints

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.

$$F_x(P) = A_e \times P \times 10$$

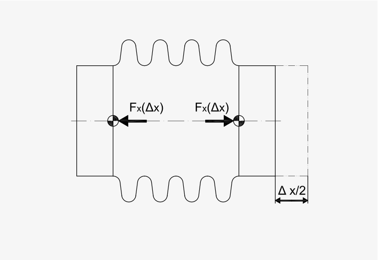
$F_x(P)$ = axial pressure force [N]
A_e = effective cross section [cm²]
P = operating pressure [bar]



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.

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

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



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

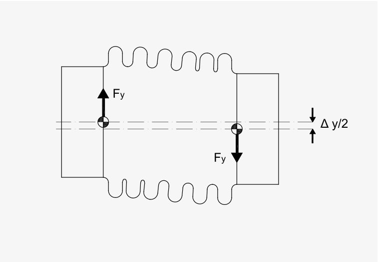
$$F_x = F_x(P) \pm F_x(\Delta x)$$

Lateral expansion joints:

The **lateral adjustment force** is the force required for lateral deflection from the rest position. It is calculated from the lateral adjustment force rate of the bellows and the lateral movement absorption.

$$F_y(\Delta y) = \pm C_{\Delta y} \times \frac{\Delta y}{2}$$

$F_y(\Delta y)$ = lateral adjustment force [N]
$C_{\Delta y}$ = lateral adjustment force rate [N/mm]
Δy = lateral movement absorption [mm]

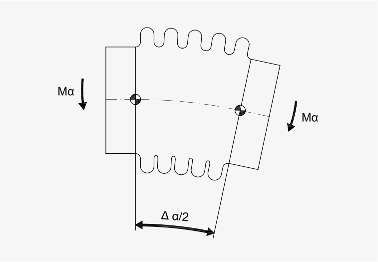


Angular expansion joints:

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.

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

$M_\alpha(\Delta\alpha)$ = angular adjustment moment [Nm]
$C_{\Delta\alpha}$ = angular adjustment force rate [Nm/Degrees]
$\Delta\alpha$ = angular movement absorption [Degrees]



Derating method

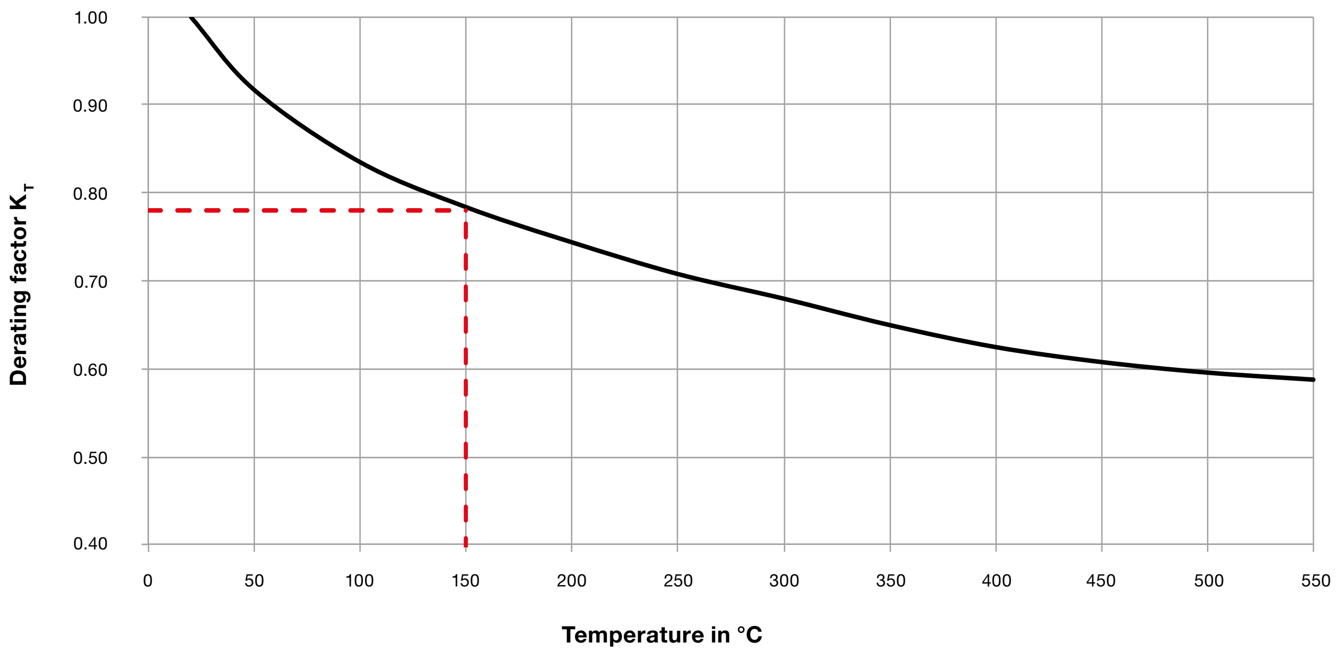
All table values were determined with 1000 nominal stress cycles with nominal operating load. The design was based on the respective nominal pressure PN and a design temperature of 20 °C for the standard bellows material 1.4541. Operating conditions usually differ from these standard conditions. The table values are simply adapted 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.

Temperature influence on the permitted nominal pressure

$P(T) = PN \times K_T$

P(T) = maximum permitted operating pressure at design temperature [bar]
PN = nominal pressure [bar]
K_T = temperature derating factor

Temperature derating diagram



Temperature derating factor K_T of the 1% expansion limit for 1.4541												
Temperature [°C]	20	50	100	150	200	250	300	350	400	450	500	550
K_T	1.00	0.91	0.83	0.78	0.74	0.71	0.67	0.64	0.62	0.61	0.60	0.59

Influence of the number of stress cycles on the movement absorption

Axial

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

Lateral

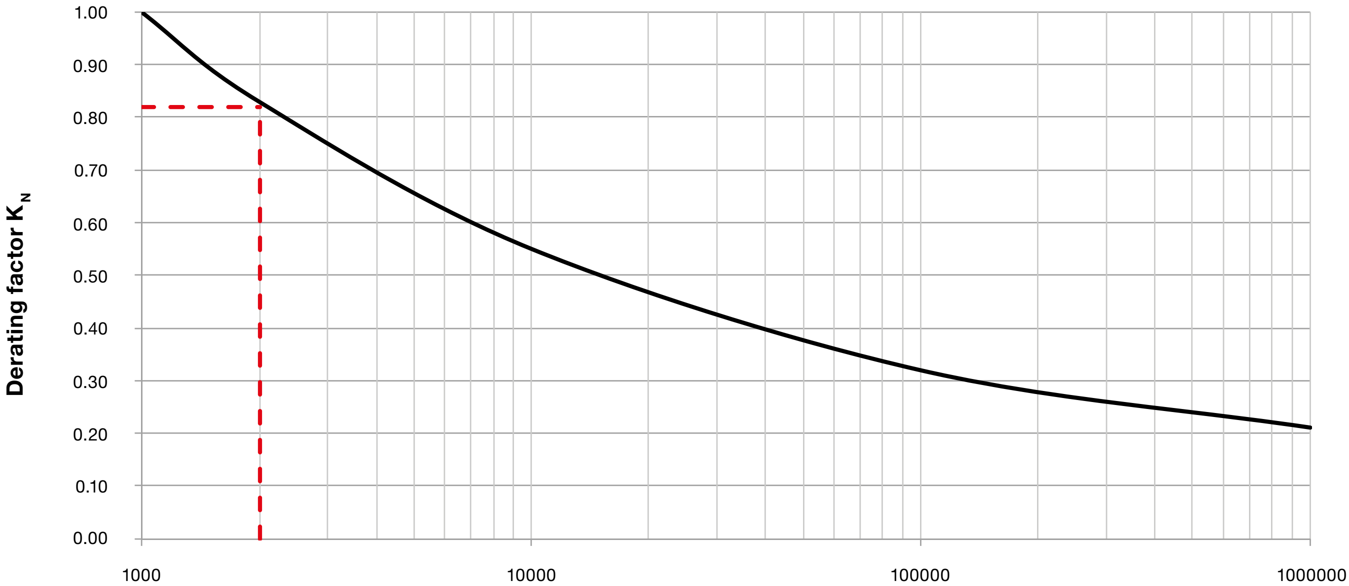
$$\Delta y(N) = \Delta y \times K_N$$

Angular

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

Δx(N); Δy(N), Δα(N) = maximum permitted movement absorption at design conditions [mm]
Δx; Δy; Δα = nominal movement absorption from table values [mm]
KN = temperature derating factor for movement at design number of stress cycles

Stress cycle derating diagram



Stress cycle derating factor K_N							
Number of stress cycles	1000	2000	10000	20000	100000	500000	1000000
K_N	1.00	0.83	0.55	0.46	0.32	0.23	0.2

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 300 is to be installed between two fixpoints with a centre distance of 20 m. The pipes are made of unalloyed ferritic steel (e.g. P235GH). Water with an operating temperature of 150 °C and an operating pressure of 5 bar flows through the pipe. The pipe is installed at an ambient temperature of at least 10 °C. For optimum use of the full movement absorption, the expansion joint is mounted with a preset load. The entire system is subject to the Pressure Equipment Directive (97/23/EC). We want to find a suitable expansion joint with swivel flanges and the associated horizontal pretensioning and reaction forces.

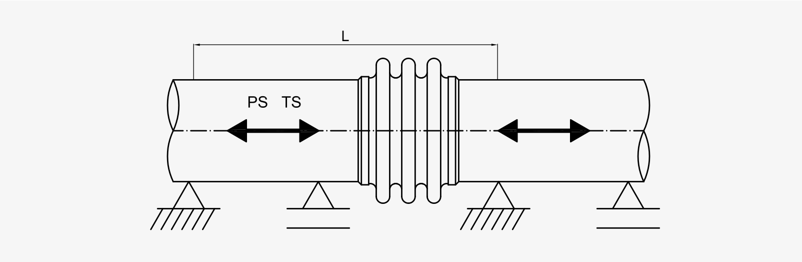
Operating data:

PS = 5 bar (operating pressure)

TS = 150 °C (operating temperature)

L = 20 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
$\alpha = 13 \times 10^{-6}\ K^{-1}$	Coefficient of thermal expansion for ferritic steel up to 200 °C
L = 20 m	relevant calculation length between the fixed points

$\Delta L(140\ K) = 20000\ mm \times 13 \times 10^{-6}\ K^{-1} \times 140\ K = 36.4\ mm$

Temperature-dependent pressure derating

$P(T) = PN \times K_T = 5$ bar	Permitted operating pressure due to operating temperature
K_T = 0.78	Temperature derating factor (intermediate values have to be interpolated linearly)
$PN_{req} = P(T) / K_T$ = 5 bar / 0.78 = 6.41 bar	Required nominal pressure at 20 °C according to table

Stress cycle dependent reduction of movement absorption

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=2 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 2000.

$\Delta x(N) = \Delta x \times K_N$ = 36.4 mm	Permitted movement absorption due to number of stress cycles
K_N = 0.83	Stress cycle dependent derating factor for 2000 stress cycles
$\Delta x_{req} = \Delta x(N) / K_N$ = 36.4 mm / 0.83 = 44 mm	Required movement absorption at 20 °C according to table

Selection according to catalogue

Axial expansion joint with swivel flange DN 300

PN_{req} = 6,41 bar **Δx_{req} = 44 mm**

Expansion joints from the next pressure stage or higher have to be selected. The movement absorption has to be at least 44 mm.

For example, an existing AN 0300 / 010 / A050 / B / B-250 with the following data: axial expansion joint (AN) with Nominal diameter DN 300 with swivel flanges (B / B) on both sides and a length of 250 mm.

PN10	Nominal pressure 10 bar at 20 °C
Δx = 50 mm	Permitted axial movement absorption at 20 °C and 1000 stress cycles
$C_{\Delta x}$ = 658 N/mm	Axial adjustment force rate
A_e = 954 cm^2	Efficient bellows diameter

Determining the reaction forces

Reaction force resulting from the operating pressure:

$F_x(P) = A_e \times PS \times 10$ Axial reaction force due to operating pressure

A_e = 954 cm^2	Efficient bellows diameter
PS = 5 bar	Operating pressure

$F_x(P) = 954 \times 5 \times 10 = 47700$ N = 47.7 kN

To make best possible use of the movement absorption, the expansion joint is installed with a preset load (pretensioned). The axial adjustment force results from the axial adjustment force rate (spring rate) and the movement.

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

$C_{\Delta x}$ = 658 N/mm	Axial adjustment force rate
Δx = 36.4 mm	Existing axial movement

$F_x(\Delta x) = \pm 658 \times 36.4/2 = 11976$ N = 12 kN

A preset load of approx. 12 kN has to be applied for installation of the expansion joint. After releasing the preset load, this force acts on the fixed bearings as a tensile force.

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

F_x = 47700 N + 11976 N = 59676 N = 59.7 kN

During operation, the expansion joint exerts an axial pressure force of approx. 59.7 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 designations for corrugated expansion joints

A N X 0200 / 006 / A020 / B / B - 220 - 235

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)

1st page / 2nd 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
Be - Milled collar
Vs - Screw fitting

Length
in mm

Pretensioning
(optional)

HKS type designation for metal bellows

MB 0300 / 12 / 4 × 0,5 / 278 / 1.4541

Metal bellows

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

Number of convolutions

Number of layers x wall thickness

Length
in mm

Material