EXPANSION JOINTS TECHNICAL CALCULATION

SELECTION OF THE EXPANSION JOINT

The main function of expansion joints is to compensate the movements and vibrations in piping systems, machinery and equipment. The movements that the expansion joint has to compensate are always movements from one part of the piping system relative to another. There are a wide variety of applications in which expansion joints can be used. To properly select the most suitable expansion joint for your application it is necessary to check all selection criteria.

1. Material of the bellow

The material of the expansion bellow depends on the medium that will go down the piping system, the working pressure of the system, the temperature and the kind of movement.

The most common expansion bellow materials are Stainless steel, a variety of rubber grades, PTFE and fabric. The standard stainless steel expansion joints are made out of AISI 316L (1.4404) material that covers a wide variety of media combined with a good pressure and temperature resistance. For the material resistance against the medium please check out our resistance chart.

2. Expansion joint type

An important parameter for the selection of the most suitable type of expansion joint is the combination of movements that the expansion joint will have to compensate. These will be vibrations, axial movements, lateral movements, angular movements or a combination.

Other important parameters are the nominal diameter, connections and built-in length of the expansion joint. Sometimes additional accessories will be required such as tie-rods, balancers or inner sleeves.

3. Piping system

The piping system influences the selection of the expansion joint. The length of the pipes and temperature differences define the magnitude of movements. Also the restriction into terms of installation possibilities, the piping accessories, anchors and guides will be taken into account when calculating an expansion joint. The system 's reliability is dependent on engineered anchors, guides and expansion joints. Unstable anchors can lead to dangerous situations.

4. Pressure and temperature resistance

When the piping system is working at elevated temperatures it is necessary to check if the bellow material resists these higher temperatures.

MATERIAL		MINIMUM [°C]	MAXIMUM [°C]
AISI 304	1.4301	-196	550
AISI 304L	1.4406	-270	550
AISI 321	1.4541	-270	550
AISI 316	1.4401	-196	550
AISI 316L	1.4404	-270	550
AISI 316Ti	1.4571	-270	550

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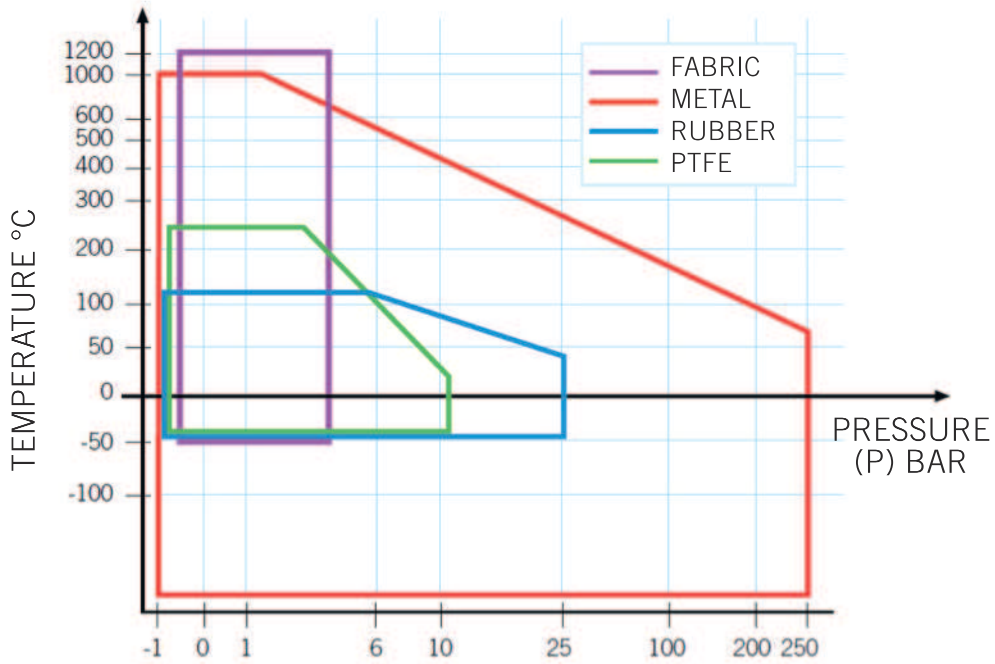
AISI 316L	1.4404	-270	550
AISI 316Ti	1.4571	-270	550
AISI 309	1.4828	-196	900
Alloy 825	2.4858	-270	540
EPDM		-40	100
NBR		-20	90
Hypalon		-15	90
PTFE		-50	230
Fabric		-50	1200

All pressures indicated in this catalogue are given at room temperature. For higher temperature it is necessary to take the derating of the material into account. When the temperature raises the materials will be less resistance to pressure forces. For stainless steel these derating factors are well-known:

	°C	20	50	100	150	200	250	300	350	400	450	500	550
EN	AISI												
1.4301	304	1	0.88	0.73	0.66	0.60	0.56	0.52	0.50	0.48	0.47	0.46	0.42
1.4541	321	1	0.92	0.83	0.78	0.74	0.71	0.67	0.64	0.62	0.61	0.60	0.59
1.4404	316L	1	0.88	0.74	0.67	0.62	0.58	0.54	0.52	0.50	0.48	0.47	0.47
1.4401	316	1	0.90	0.78	0.71	0.66	0.62	0.58	0.56	0.53	0.52	0.51	0.51
1.4571	316Ti	1	0.90	0.81	0.76	0.73	0.69	0.65	0.63	0.61	0.59	0.59	0.58

EXPANSION JOINTS TECHNICAL CALCULATION



CALCULATION PROCEDURE

1. Calculation of thermal expansion and contraction of the pipe
2. Determination of the kind of movements and their extent
3. Define built-in positions of the expansion joints, anchors and guide points
4. Consideration and / or calculation of the initial stress
5. Calculation of the sum of all forces on the fixed points

EXPANSION JOINTS TECHNICAL CALCULATION

1. Calculation of thermal expansion

Temperature changes cause a variation on the length of stainless steel and carbon steel pipes. An increase in temperature will cause elongation of the pipes, a decrease in temperature will cause the pipes to contract. The magnitude of this length variation is dependent of the length of the pipe, the difference in temperature and a material dependent factor (coefficient of thermal expansion).

MATERIAL	0° - 100°C	0°C - 200°C	0°C - 300°C	0°C - 400°C	0°C - 500°C
Carbon steel (<3%Cr)	$11{,}1 \cdot 10^{-6}$	$12{,}1 \cdot 10^{-6}$	$12{,}9 \cdot 10^{-6}$	$13{,}5 \cdot 10^{-6}$	$14{,}3 \cdot 10^{-6}$
Austenitic SS (18Cr-8Ni)	$16{,}4 \cdot 10^{-6}$	$17{,}1 \cdot 10^{-6}$	$17{,}6 \cdot 10^{-6}$	$18{,}0 \cdot 10^{-6}$	$18{,}3 \cdot 10^{-6}$
Alloy 825	$14{,}1 \cdot 10^{-6}$	$14{,}8 \cdot 10^{-6}$	$15{,}3 \cdot 10^{-6}$	$15{,}6 \cdot 10^{-6}$	$15{,}8 \cdot 10^{-6}$
Duplex	$13{,}0 \cdot 10^{-6}$	$13{,}5 \cdot 10^{-6}$	$14{,}0 \cdot 10^{-6}$	-	-

$$\Delta L = \alpha . L0 . \Delta T$$

ΔL = change of length [mm]

α = coefficient of thermal expansion [1/K]or [1/°C]

$L0$ = Initial length of the pipe [mm]

ΔT = temperature change [K] or [°C]

Example:

A DN300 pipe in St 35.8 (P235/265GH) is exposed to a temperature increase from 10°C to 400°C.

The pipe has a length of 10m

$\Delta L = 13{,}5 \,.\, 10^{-6} \,.10\,000\,.390$

$\Delta L = 52{,}65$ mm

EXPANSION JOINTS TECHNICAL CALCULATION

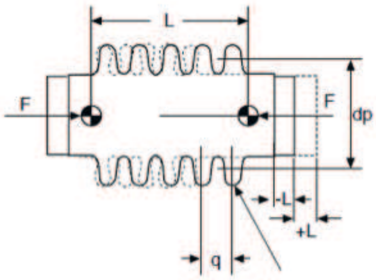
2. Movement definitions

Axial compression

Axial compression is the dimensional shortening of an expansion joint along its longitudinal axis. Axial compression has been referred to as axial movement, traverse or compression.

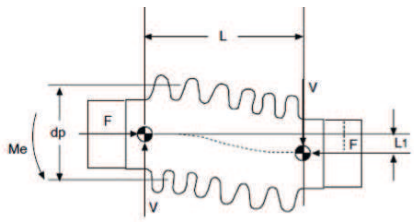
Axial extension

Axial extension is the dimensional lengthening of an expansion joint along its longitudinal axis. Axial compression has been referred to as axial movement, traverse, elongation or extension.



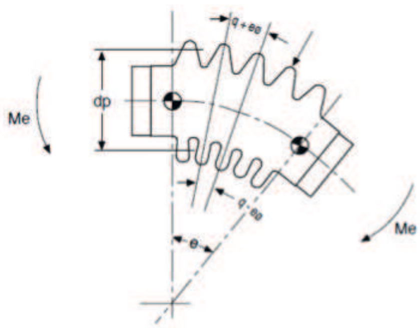
Lateral deflection

Lateral deflection is the relative displacement of the two ends of an expansion joint perpendicular to its longitudinal axis. This has been referred to as lateral offset, lateral movement, parallel misalignment, direct shear or transverse movement.



Angular rotation

Angular rotation is the displacement along the longitudinal axis of the expansion joint from its initial straight line position into a circular arc. Angular rotation is occasionally referred as rotational movement.



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Torstional rotation

The twisting of one end of the expansion joint with respect to the other end around the longitudinal axis. This twisting generally produces extremely high shear stresses in the bellows. For this reason it is extremely important that the special hardware is used to limit the amount of torsional shear stress in the bellows.

Rated movements

The maximum amount of movement (axial compression, axial extension, lateral deflection angular rotation of any combination thereof) that an expansion joint is capable of absorbing. This rating is different for each size, type and length of expansion joint.
The determination of compound movements can simply be calculated with the division in terms of percentage of the given movement values.

e.g. for expansion joint DN100 fixed EN Flanges.
For application with: Axial movement +18mm / Lateral movement +2mm

CODE	DN	Bellow	L	OD	Øk	Movements		
						± ax	± lat	± ang
KR8A100EVEV-K1	100	RBA8100K1-16	155	195	180	22	5	15
KR8A100EVEV-M1		RBA8100M1-16	210			35	5	15

KR8A100EVEV-K1
Use of ax.movement=18/22=81.8%
Lateral movement left=18.2%*5mm=0.91mm
→ Not suitable for combination of these movements (1000 cycles)

KR8A100EVEV-M1
Use of ax.movement=18/35=51.4%
Lateral movement left=48.6%*5mm=2.43mm
→ Suitable for the combination of these movements (1000 cycles)

Lifecycles at given movements

For Rubber, PTFE and fabric expansion joints the number of life cycles is depend on external factors. For metallic expansion joints this number of life cycles is easier to simulate by a calculation. All movements in the document are given for one thousand lifecycles. If more lifecycles are required, the allowable movements shall be lower.

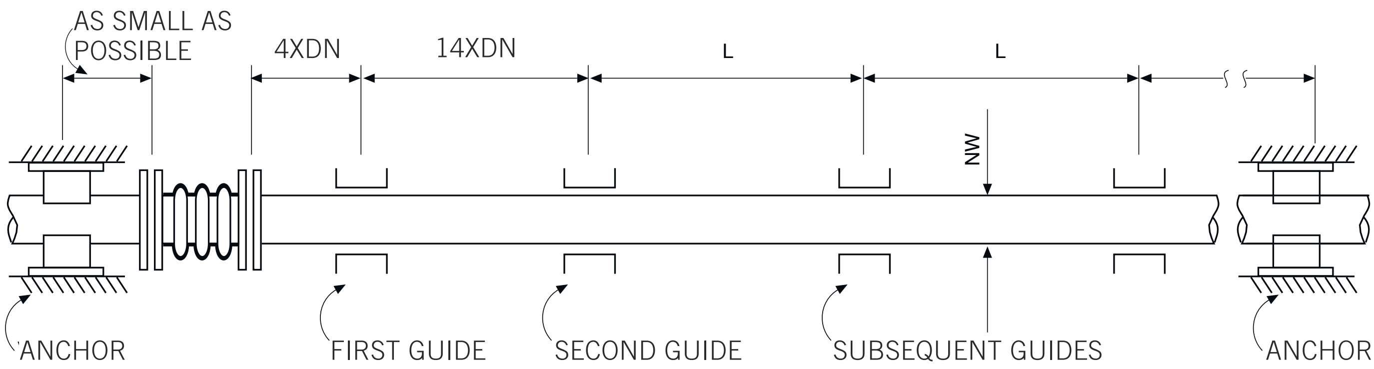
TOTAL LIFE CYCLES	PERCENTAGE OF MOVEMENT AVAILABLE
500	120
1000	100
2000	85
3000	77
5000	68
8000	61
10000	58
30000	44
50000	39

EXPANSION JOINTS TECHNICAL CALCULATION

3. Define built-in positions of the expansion joints, anchors and guiding points

The piping system in which bellows are fitted must be ended by fixed points. These fixed points must be firm enough to accommodate the reactive forces of the bellow and the frictional resistance of the guide points. The fixed points and guide points must be such that the bellow does not have to bear the weight of the piping.

Positions of the expansion joint guides



L is dependent of the pressure, temperature and diameter of the piping. It is recommended that dimension L is 75 – 100 times the Nominal Diameter.

Fixed points

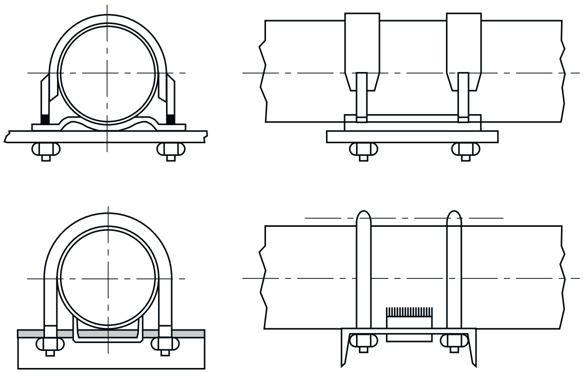
Fixed anchors are to be installed:

- At the beginning and ending of a pipe if the contraction / extension is to be absorbed by one or more expansion joints
- With a change of direction of the piping / flow
- Between two expansion joints with a different diameter
- With a branch in the main pipe
- At a closed end of a pipe
- As close as possible to the expansion joint

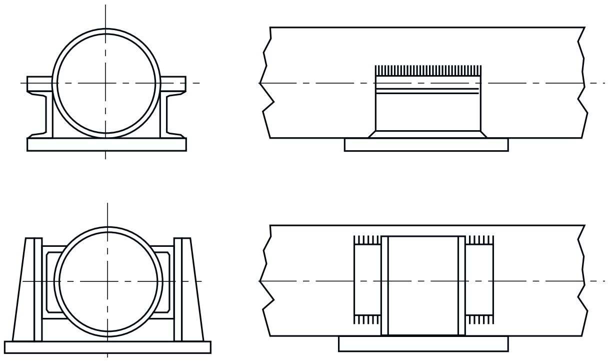
BM Europe can provide fixed points, please include the requirements in your inquiry.

EXPANSION JOINTS TECHNICAL CALCULATION

Examples



FOR SMALER DIAMETERS

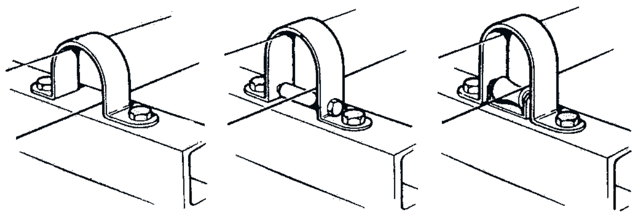


FOR LARGER DIAMETERS

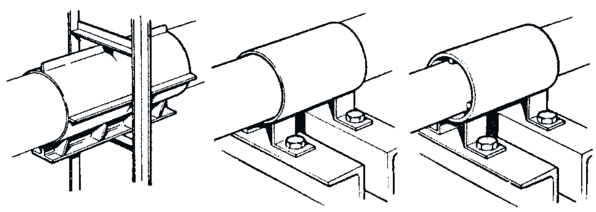
Guiding points

Guiding points are to be installed to maintain the alignment of the piping. Misalignment of the piping can cause premature failure.
BM Europe can provide guiding points, please include the requirements in your inquiry.

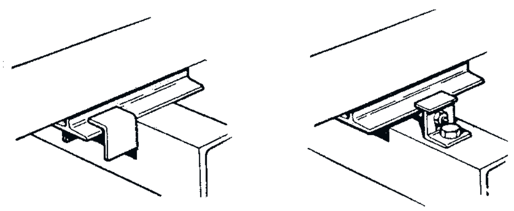
Examples



BAND GUIDE POINTS WITH OR WITHOUT ROLLERS



TUBULAR GUIDES



TEE-SLIDES

EXPANSION JOINTS TECHNICAL CALCULATION

4. Consideration and / or calculation of the pre-tensioning

In some applications it is recommended to pre-tension the expansion joint. This will positively influence the lifetime of the expansion joint, lower the reaction forces in the piping system and lower the risk of failure.
The principle of installing an expansion joint with pre-tensioning is that the expansion joints reache its neutral length at the average working temperature of the piping. It is important to calculate how much the pipe will expand when the temperature changes from the installation temperature (very often this is room temperature) to the mean working temperature. The pre-tensioning is established by stretching out the expansion joint with as much as the pipes will expand by warming up to the mean working temperature. When heated up to the mean working temperature the expansion joint will get back to its neutral length. For larger displacements during the pre-tensioning tie rods are required.
In some cases, when the working temperature is lower than the installation temperature, the pre-tensioning of the expansion joint requires compression of the expansion joint. To make sure the installation can be done easily tie-rods are required.
Please note that the maximum pre-tensioning is limited up to 50% of the total movement absorption capacity of the expansion joint.

5. Calculation of the total force on all fixed points

When an expansion joints is submitted to internal pressure it will cause a pressure thrust. This is a result of the corrugations. On the surface of each corrugation there is a pressure acting that causes a reaction force.
For axial expansion joints the total pressure acting on the fixed points are:
Pressure thrust (reactive force)

Fp=Working pressure*effective area

Fp=P*a

Forces as a result of the movement

Fm=Axial spring rate*axial movement

Fm=SRax*L

Friction Forces

Ff=Weight*Frictional coefficient

Ff=Mass*gravity constant*Frictional coefficient

Ff=m*g*μ

Lateral and angular expansion joints require further calculations. Please contact our sales department.