INSTALLATION

The necessary steps for the installation of all expansion joints should be pre-planned. The installers shall be made aware of these steps. It is important that the joints are installed at the correct lengths and should not be extended or compressed to make-up deficiencies in pipe length, or offset to accommodate piping which has not been properly aligned. Any precompression or pre-extension of the joint should not be neglected if this has been specified.

The most critical phases of the installation are as follows:

a) Carried should be taken to prevent damage to the thin wall bellows section, such as dents, scores, arc strikes and weld spatter.

b) No movement of the joint due to pipe misalignment, for example, shall be imposed which has not been anticipated. If such movements are imposed, this can result in damage to the bellows or other components. Specifically the fatigue life can be substantially reduced, forces imposed on adjacent equipment may exceed their design limits, internal sleeve clearance may be adversely affected, and the pressure capacity and stability of the bellows may be reduced.

c) Anchors, guide and pipe supports shall be installed in strict accordance with the piping system drawings. Any field variations may affect proper functioning of the joint and must be brought to the attention of a competent design authority.

d) The joint, if provided with internal sleeves, shall be installed with the proper orientation with respect to flow direction.

e) Once the anchors or other fixed points are installed and the piping is properly supported and guided, shipping devices should normally be removed in order to allow the joint to compensate for changes in ambient temperature during the remainder of the construction phase.

POST INSTALLATION INSPECTION PRIOR TO SYSTEM PRESSURE TEST

Careful inspection of the entire system shall be made with particular emphasis on the following:

a) Are the anchors, guides and supports installed in accordance with the system drawing?

b) Is the proper joint installed in the proper location?

c) Are the joints flow direction and pre-positioning correct?

d) Have all shipping devices been removed?

e) If the system has been designed for gas, and it is to be tested with water, has provision been made for the support of the additional dead weight load? Some of the water may remain after test. If this is detrimental to the joint or the system, this should be removed before commissioning.

f) Are all guides and supports free to permit pipe movement?

g) Has any joint been damaged during handling or installation?

h) Is any joint misaligned?

i) Is the bellows and other moveable parts of the joint, free from foreign material?

INSPECTION DURING AND IMMEDIATELY AFTER SYSTEM PRESSURE TESTS.

WARNING: Extreme care must be taken while inspecting any pressurised system or components. A visual inspection of the system shall include checking the following:

a) Evidence of leakage or loss of pressure.

b) Distortion or yielding of anchors, joint hardware, bellows element and other piping components.

c) Any unanticipated movement of the system due to pressure.

d) Any evidence of instability (squirm) in the bellows.

e) The guides, joints and other moveable parts shall be inspected for binding.

f) Any evidence of abnormality or damage shall be reviewed and evaluated by a competent design authority.

PERIODIC SERVICE INSPECTIONS

a) Immediately after placing the system in operation, a visual inspection shall be carried out to ensure that the thermal expansion is being absorbed by the joints in the manner for which they were designed.

b) The bellows shall be inspected for evidence of unanticipated vibration.

c) A programme of periodic inspection shall be planned and conducted throughout the operating life of the system. These inspections shall include examination for evidence of external corrosion, loosening of threaded fastenings and deterioration of anchor guides and supports.

This inspection programme, without other information, cannot give evidence of fatigue, stress corrosion or general internal corrosion.

SYSTEMS OPERATION

A record should be maintained of change of system operating conditions (such as pressure, temperature, cycling, etc.) and piping modifications. Any such change shall be reviewed by a competent design authority to determine its effect on the performance of the joint, anchors, guides and pipework supports.
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<th>Cr-Mo (5-9%) mm/m</th>
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**Fig. 30. Axial expansion joint**

Disadvantages:
- strong anchor points, which may be technical or economical problem
- in long straight sections and for large movements it is necessary to have more than one axial bellows
- short sections which contain more elbows require a large number of anchors and each subsection has to be individually compensated
- stress-free connections in front of sensitive equipment is not guaranteed in the case of relatively higher pressures or larger diameters.

**SYSTEM DESIGN PROCEDURE**

When designing your axial bellows system a useful discipline is to observe the following procedure:
1. Establish the nominal pressure
2. Calculate thermal dilatation
3. Divide the pipeline installation into sub-sections and establish position of bellows
4. Establish position of anchor points and guides
5. Calculate "cold-pull" dimensions
6. Calculate forces acting on anchors

Once these six tasks have been completed you will have all the information you require to complete your design of an axial bellows system, and by referring to data sheets on axial bellows section you can select specific bellows to your requirements or can define your requirements in terms related to standard units.

1. **ESTABLISH THE NOMINAL PRESSURE**

For most applications, the pressure rating must be established as specified in DIN 2401.

In the table 1 on the page 2 you can find the data about temperature coefficient ($t_k$) for materials we commonly use.

**Example 1:**

Hot water, NO 150, $p = 11$ bar, $t = 130\, ^\circ C$

$$NP = \frac{P}{t_k}$$

$P$ - working pressure
$t_k$ - temperature coefficient

$$NP = \frac{11}{1} = 11$$ (round up to full nom. pressure)

NP = 16 bar

**AXIAL BELLOWS**

The first alternative for compensation of movement is with axial bellows. Axial bellows have low cost per unit, but strong anchor points and pipe guides are essential. Therefore it is necessary following the instructions, to calculate the anchor loads and consider if there were any limits (technical or economical) to make so strong anchor points. If there are, it is necessary to apply compensation with tied bellows for lateral or angular movement (See page 24.).

The most influential force which loads an anchor point is pressure thrust (working pressure x effective bellows cross-section), which means that axial bellows can be applied usually for relatively small diameters and low pressures. Axial bellows can also be installed in front of sensitive equipment (pumps, engines, compressors) to absorb all movements, vibrations or failures during montage.

**Advantages:**
- easily understood solution of the compensation problem
- no change in the direction of flow
- small lateral or angular movements are possible
- useful element for stress-free connections in front of sensitive equipment, if the operating pressures are low
- minimum installation space low cost per unit

**UNTIED BELLOWS**

Fig. 29. Possible movements of untied bellows
2. CALCULATE THERMAL DILATATION

The calculation of thermal dilatation (dilatation) is according to the following equation:

\[ \Delta_{\text{total}} = \alpha_t \cdot \Delta t \cdot L \]

- \( \Delta_{\text{total}} \) - total thermal expansion of the pipe (mm)
- \( \Delta t \) - difference between max. and min. temperature
- \( \alpha_t \) - coefficient of thermal expansion
- \( L \) - length between anchors (m)

Example 2:

\[ t_{\text{max}} = 130 \, ^\circ\text{C}, \quad t_{\text{min}} = -20 \, ^\circ\text{C}, \quad L = 35 \, \text{m} \]
\[ \Delta t = 130 - (-20) = 150 \, ^\circ\text{C} \]
\[ \Delta = 1,72 \, \text{mm/m} \]
\[ \Delta_{\text{total}} = \Delta \cdot L = 1,72 \cdot 35 = 60,2 \, \text{mm} \]

In the table 3 on page you can find already calculated thermal expansion of pipe for temperatures and materials we commonly use.

3. DIVIDE THE PIPELINE INSTALLATION INTO SUB SECTIONS AND ESTABLISH POSITION OF BELLOWS

Dividing the pipe work installation into sub-sections is only necessary when a single axial bellows is not enough to absorb the axial movement or if the pipework insulation has one or more elbows. A sub-section length is determined by permissible axial movement which an axial bellows can absorb.

Referring to data sheets on axial bellows section for each nominal diameter (ND) and nominal pressure (NP) you can select several movements.

In theory bellows can be positioned anywhere between two anchors, but in practice only two positions are used:

1. Near one anchor
2. At the centre between two anchors

In the first case, illustrated in Fig. 31 the axial bellows unit is positioned near an anchor point. In practice it is normally installed within roughly two pipe diameters (2 \( \cdot \) D) of the anchor point and the guide, or max. four pipe diameters (max. 4 \( \cdot \) D).

In the second case, illustrated in Fig. 32 the axial bellows unit is positioned at the centre of the pipe between two anchors. Therefore guides have to be positioned on both sides of the bellows unit (2 \( \cdot \) D, or max. 4 \( \cdot \) D) to prevent bowing. Usually we use this position of the axial bellows unit when we have a main pipework and several branch pipeworks. In this case bowing of branch pipeworks is reduced to a minimum.

NOTE:
It is allowed to install only one axial bellows unit between two anchors points

4. ESTABLISH POSITION OF ANCHOR POINTS AND GUIDES

Actually the position of the anchor points is established at the moment we have divided the pipework installation into subsections, which means that the sub-sections are separated by the anchor point.

Anchor points:
- Terminal anchor
- Deflection anchor
- Intermediate anchor
- Sliding anchor

The guiding of a pipe is most important if axial bellows units installed are to function correctly. Guides are necessary to ensure proper application of movement to the bellows and to prevent bowing or buckling of the pipework, Fig. 36. A good general rule regarding the location of guides related to expansion joints is that the first guide should be positioned within a distance of four pipe diameters (4 \( \cdot \) D) from the expansion joint.

Our recommendation is that this distance has to be roughly two pipe diameters (2 \( \cdot \) D). The distance between the first and the second guide must not be more than fourteen pipe diameters (max. 14 \( \cdot \) D). The distance among the rest of the guides has to be determined by the application engineer, because there are several ways how to calculate it, (Fig. 35).

Fig. 31. Bellows positioned near an anchor

Fig. 33. Bellows positioned in case of small distance between pipelines

Fig. 34. Anchors and guides positioned in case of different pipe diameters
Example 3:

Hot water:
NO 150, p = 11 bar
\( t_{\text{max}} = 130 \, ^{\circ}\text{C}, \ t_{\text{min}} = -20 \, ^{\circ}\text{C}, \ L = 35 \, \text{m} \)

\( L_{1\text{max}} = 4 \cdot \text{NO} = 4 \cdot 150 = 600 \, \text{mm} \)

\( L_{1\text{recomm}} = 2 \cdot \text{NO} + \frac{L_{\text{total}}}{2} = 2 \cdot 150 + \frac{600}{2} = 330.1 = 330 \, \text{mm} \)

\( L_{2\text{max}} = 14 \cdot \text{NO} = 14 \cdot 150 = 2100 \, \text{mm} \)

\( L_3 \) - is determined by the application engineer

5. CALCULATE "COLD-PULL" DIMENSIONS

Bellows movement is usually expressed as a ± figure based on a free length (L_b). This represents the equal movement in expansion and compression of which a bellows is capable. However, because it is more usual to find pipes carrying hot media than cold media (except of course in cryogenic applications), in practice bellows are usually selected for their capacity to compensate for pipe expansion. In order to make maximum use of the total movement available in any one bellows it is therefore necessary to do perform "cold-pull" (See Fig. 37).
During the installation of axial bellows it is necessary to leave a proper free space in pipework, and than axial bellows must be extended and change its free length \((L_{f0})\) into installation length \((L_{inst})\). The following formula is for calculation of "cold-pull":

\[ H_p = \frac{\Delta_{total}}{2} \left( \frac{L_{max} - L_{min}}{t_{max} - t_{min}} \right) \Delta_{total} \] (mm)

\[ L_{inst} = L_b + H_p \] (mm) - only for axial expansion joints

It is not possible to change installation length of the tied bellows. It is the most important to ensure that an axial bellows is never over-compressed at maximum operating temperature, or over-extended at minimum operating temperature.

### EXTENSION:

\[ t_{max} > t_{min} \]

\[ H_p = \Delta_{total} \left( \frac{0,5 - \frac{L_{max} - L_{min}}{t_{max} - t_{min}}}{L_{max} - L_{min}} \right) \Delta_{total} \] (mm)

### COMPRESSION:

\[ t_{min} > t_{max} \]

\[ H_p = \Delta_{total} \left( \frac{0,5 - \frac{L_{min} - L_{max}}{t_{min} - t_{max}}}{L_{min} - L_{max}} \right) \Delta_{total} \] (mm)

\[ \Delta_{total} - \text{total thermal expansion of pipe, (mm)} \]

\[ H_p - \text{cold pull, (mm)} \]

\[ t_{max} - \text{maximum temperature, (°C)} \]

\[ t_{min} - \text{minimum temperature, (°C)} \]

\[ L_{max} - \text{installation temperature, (°C)} \]

\[ L_{inst} - \text{installation length, (mm)} \]

\[ L_b - \text{free length of bellows, (mm)} \]

NOTE: A total thermal expansion of pipe must be less or equal to a total axial movement of an axial bellows unit.

\[ \Delta_{total} \leq (\pm) \Delta_b \]

### Example 4:

Pipeline, NO 300 mm, \( p = 14 \) bar

\( t_{max} = 60 \) °C, \( t_{min} = -20 \) °C, \( t_{inst} = 10 \) °C, \( L = 72 \) mm

\( \Delta_{total} = \Delta \cdot L = 0,89 \cdot 72 = 64,08 \approx 64 \ mm \)

Select the axial bellows: Data sheet, page 45

AR 16/300/70/N1

\[ L_b = 335 \ mm \]

\[ H_p = \Delta_{total} \left( \frac{0,5 - \frac{L_{max} - L_{min}}{t_{max} - t_{min}}}{L_{max} - L_{min}} \right) \Delta_{total} \]

\[ k = 0,5 - \frac{10}{(-20)} = 0,5 - \frac{30}{60} = 0,5 - \frac{375}{80} = 0,5 - 0,375 = 0,125 \]

This coefficient you can use only for temperatures in this example. If these temperatures \((t_{max}, t_{min}, t_{inst})\) are constant simply multiply total thermal expansion \(\Delta_{total}\) of each subsections with this coefficient \(k\). If the installation temperature \(t_{inst}\) is changeable it is necessary to calculate coefficient \(k\) again.

\[ H_p = \Delta_{total} \cdot k = 64 \cdot 0,125 = 8 \ mm \]

\[ L_{inst} = L_b + H_p = 335 + 8 = 343 \ mm \]

### 6. CALCULATE FORCES ACTING ON ANCHORS

To calculate the sum total of forces acting on any anchor in a pipe system incorporating axial bellows you must calculate the following:

1. Pressure thrust (Fp)
2. Deflection load (Fb)
3. Pipe friction (Ff)
4. Centrifugal force (Fc)

#### PRESSURE THRUST

Pressure thrust is the force due to internal pressure trying to extend the bellows into the pipe (See Fig. 38). This force is calculated using the following formula:

\[ F_p = p \cdot A \cdot 10^2 \] [N]

\[ p - \text{operating pressure (MPa)} \]

\[ A - \text{effective bellows cross section (cm}^2) \]

\[ A = \frac{d_s^2 \cdot \pi}{4} \]

\[ d_s - \text{mean bellows diameter} \]

**Fig. 38. Acting of pressure thrust**

As is shown in Fig. 39 the effective cross section of a bellows is the mean diameter of the bellows taking the tip and the root of the convolutions as the extremes. Values for effective area are given for each unit in the data sheets.

**Fig. 39. Effective bellows cross section**

#### DEFLECTION LOAD

Deflection load is due to the spring rate of the axial bellows. Values for spring rates are given for each unit in the data sheets. If you require a bellows which is not in the data sheets, all data you can find in our drawings.

This force is calculated using the following formula.

\[ F_b = OD \cdot \Delta_t \] [N]
OD  - spring rate (N/mm)
$A_k$  - movement (mm)

Movement is considered to be the maximum movement of which the bellows unit is capable within the design parameters of the installation, but it should be remembered that a stretched bellows (with a cold-pull allowance) is trying to pull anchors together.

**PIPE FRICTION**

The frictional resistance of a pipe moving over its guides can be calculated using the following formula:

$$ F_f = \mu \cdot m \cdot g \cdot L \cdot [N] $$

- $\mu$ - coefficient of friction (in the event of this not being available the value 0.3 can be taken for the majority of installations)
- $m$ - total mass of pipe (is the sum of pipe mass, media mass, insulation mass, and attached equipment mass) (kg/m)
- $L$ - distance between anchor and expansion joint (m)
- $g$ - gravity (9.81 m/s²)

**CENTRIFUGAL FORCE**

In the case of anchors situated at a pipe elbow the effect of centrifugal force due to flow of media within the pipe must be considered.

This force is calculated using the following formula:

$$ F_c = 2 \cdot A \cdot p \cdot \frac{v^2}{g} \cdot \sin \frac{\alpha}{2} \cdot 10^{-3} \ [N] $$

- $A$ - effective bellows cross section (cm²)
- $p$ - density of media (kg/m³)
- $v$ - velocity of flow (m/s)
- $\alpha$ - angle of pipe elbow

Each of these forces must be calculated for itself before summarising of the total force which act on anchor. Before you do that it is necessary to consider as follow:

a) In the case of anchor situated at a pipe elbow (See Fig. 40) the total force is calculated using the following formula:

If $\alpha = 90^\circ$

$$ R = \sqrt{F_1^2 + F_2^2} $$

If $\alpha \neq 90^\circ$

$$ R = \sqrt{F_1^2 + F_2^2 + 2 \cdot F_1 \cdot F_2 \cdot \cos \alpha} $$

b) If a long straight pipe changes its diameter the intermediate anchor situated between the axial bellows with different diameters is loaded with two different forces.

c) In the case of valve situated at a pipe one bellows under a pressure, and the other is not. Therefore the anchor between a valve and a bellows is the terminal anchor.

**FORCE ON INTERMEDIATE ANCHORS**

There is a limit to the amount of movement you can get out of a single axial bellows. When you are faced with an expansion problem in a straight run of a pipe which requires more movement then you can get out of one bellows, you must install additional bellows and with them additional intermediate anchor. If the pipe is the same diameter throughout its length the thrusts on intermediate anchors are balanced by the bellows on either side and in theory there is no force on the anchor once the full expansion has been taken up. It is recommended, however, that do not have the strength, rigidity and resistance to wear necessary for long term operation and therefore the force acting on intermediate anchor is a sum of deflection load and pipe friction.

**SPECIAL DESIGN CONDITIONS**

Except the forces acting on anchors at high above ground pipelines very important is a moment of force (See Fig 41).

One of the ways how to decrease load an anchors is to eliminate the pressure thrust. For this reason we have made a construction of "PB" expansion joint (pressure balanced). See Fig. 42. This expansion joint is not in our standard data sheet but is always designed in accordance with special requirements.
### Example 5

Pipeline

- NO = 400 mm - nominal diameter
- \( p = 1.3 \, \text{MPa} \) - working pressure
- \( T_{\max} = 165 \, ^\circ\text{C} \) - maximum temperature
- \( T_{\min} = -20 \, ^\circ\text{C} \) - minimum temperature
- \( v = 10 \, \text{m/s} \) - velocity of flow

Calculations

1. **ESTABLISH THE NOMINAL PRESSURE**

\[
N_p = \frac{p}{T_k}
\]

\[
p = 1.3 \, \text{MPa}, \ t_k = 1
\]

\[
N_p = \frac{1.3}{1} = 13
\]

\[
N_p = 16 \, \text{bar}
\]

2. **CALCULATE THERMAL DILATATION**

See Table 3, thermal expansion for difference between temperatures

\[
(t_{\max} - t_{\min}) = 165 - (-20) = 185 \, ^\circ\text{C}
\]

\[
\Delta = 2.20 \, \text{mm/m}
\]

A) \( \Delta_1 = 90 \cdot 2.20 = 198 \, \text{mm} \)

B, C) \( \Delta_2 = 30 \cdot 2.20 = 66 \, \text{mm} \)

3. **DIVIDE THE PIPELINE INSTALLATION INTO SUB-SECTIONS AND ESTABLISH POSITION OF BELLOWS**

Most of pipeline installations possible to divide into sub-sections in several ways. An application engineer can choose a way which is the most convenient (technical and economical).

In our example we offer you two solutions (A, B, C) The difference between solutions B and C is in different place of bellows. For required and calculated parameters it is possible to use three different movements of bellows (± 35, ± 62.5, ± 125) see page 45. The bellows are made with pipe ends:

- AR 16/400170/U/1, \( a=1520 \, \text{cm}^2 \), OD=607 N/mm
- AR 16/400/125/U/1, \( a=1520 \, \text{cm}^2 \), OD=495 N/mm
- AR 1614001250/U/1, \( a=1520 \, \text{cm}^2 \), OD=248 N/mm

A) \( \Delta_1 = 198 \, \text{mm}, \) choose movement (± 125) = 250 mm

\( \Delta_2 = 66 \, \text{mm}, \) choose movement (± 35) = 70 mm

B, C) \( \Delta_1 = 99 \, \text{mm}, \) choose movement (± 62.5) = 125 mm

\( \Delta_2 = 66 \, \text{mm}, \) choose movement (± 35) = 70 mm

4. **ESTABLISH POSITION OF ANCHORS POINTS AND GUIDES**

See Fig. 28. and the explanation on page 18

5. **CALCULATE COLD-PULL DIMENSIONS**

In case you want to have all the bellows the same, you must choose the bellows which is suitable for maximum expansion of pipe. In this case it is the unit type AR 16/400/250/U/1, and of course this is not optimum solution. As we have divided our pipeline installation into the sub-sections, it is possible to situate the bellows in several ways. In our example we offer three solutions (A, B, C).

6. **CALCULATE FORCES ACTING ON ANCHORS**

<table>
<thead>
<tr>
<th>SOLUTION</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchor Force (F&lt;sub&gt;p&lt;/sub&gt;)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F_p = \frac{p}{A} \cdot 100 )</td>
<td>197600</td>
<td>118839</td>
<td>197600</td>
</tr>
<tr>
<td>( p = 1.3 , \text{MPa} ), ( a=1520 , \text{cm}^2 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deflection load (F&lt;sub&gt;d&lt;/sub&gt;):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F_d = \frac{\Delta}{\Delta} )</td>
<td>24503</td>
<td>14023</td>
<td>20031</td>
</tr>
<tr>
<td>A) ( \Delta_1 = 198 , \text{mm}, ) OD=247.5 N/mm</td>
<td>24503</td>
<td>24503</td>
<td>14023</td>
</tr>
<tr>
<td>B, C) ( \Delta_2 = 66 , \text{mm}, ) OD=495 N/mm</td>
<td>20031</td>
<td>24503</td>
<td>14023</td>
</tr>
<tr>
<td>Pipe friction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F_t = \mu \cdot m \cdot L )</td>
<td>25092</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>( \mu = 0.3 ), ( m = 98 , \text{kg/m} )</td>
<td>-</td>
<td>8076</td>
<td>-</td>
</tr>
<tr>
<td>A) ( L_1 = 87 , \text{mm}, ) B, C) ( L_2 = 42.5 , \text{mm} )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centrifugal thrust (F&lt;sub&gt;c&lt;/sub&gt;):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( F_c = \frac{2 \cdot A \cdot \rho \cdot v^2}{\mu} \cdot \tan \alpha )</td>
<td>-</td>
<td>9141</td>
<td>-</td>
</tr>
<tr>
<td>( A=1520 , \text{cm}^2 ), ( \rho = 1000 , \text{kg/m}^3 ), ( v = 10 , \text{m/s} ), ( \alpha = 35^\circ )</td>
<td>-</td>
<td>-</td>
<td>9141</td>
</tr>
<tr>
<td>RESULTANT FORCES (kN)</td>
<td>247.2</td>
<td>142</td>
<td>225.7</td>
</tr>
<tr>
<td></td>
<td>222.1</td>
<td>36.8</td>
<td>142</td>
</tr>
<tr>
<td></td>
<td>225.7</td>
<td>234.4</td>
<td>25.4</td>
</tr>
<tr>
<td></td>
<td>154.3</td>
<td>225.7</td>
<td></td>
</tr>
</tbody>
</table>
COMPENSATORS FOR CENTRAL HEATING

DURO DAKOVIĆ - Kompenzatori d.o.o. Compensators represent a new stage in the development of bellows devices to absorb expansion in steam and hot water piping. They offer to a very high degree a combination of economy, simple installation and reliable service. By the use of high performance materials and exclusive manufacturing techniques, Đuro Daković - Kompenzatori d.o.o. have produced a range of compensators which are maintenance free and virtually as permanent as the piping system in which they are installed.

Fig. 43. Expansion joints for central heating

A number of features contribute to the reliability of these compensators. One is the uniformity of the stainless steel bellows, made under strict quality control supervision. Another is the full length inner sleeve which directs pipe movement squarely into the bellows, thus avoiding undue stresses. This inner sleeve also provides for a smooth flow and reduces pressure drop to a minimum. A third is the robust external casing which provides full length sleeve for minimum internal friction. A fourth is the installation pin which holds the compensator at its optimum length for installation and also protects the bellows from torsional damage installation.

SPECIFICATION

Bellows: Made from type ASME SA 240 type 321 (DIN 17441 W. Nr. 1.4541 x 10 CrNiTi 18 9, HRN C.4572) stainless steel. Conservatively rated for a working pressure of 1 MPa (10 bar) at 300 °C, and hydraulically tested to 1.5 MPa (15 bar).

Casing and other components of mild steel.

Inner sleeve: Attached at one end and guided at the other, thus preventing offset movement being transmitted to the bellows full length sleeve for minimum internal friction. Installation pin: Holds bellows at correct length for installation. Removed after fitting, and after guides and anchors have been installed.

End fittings: Welding ends, flanges or threaded unions.

Movement: Bellows expansion compensators allow axial movement of 30 mm.

INSTALLATION OF COMPENSATORS FOR CENTRAL HEATING

Anchors: The pressure thrust acting on the bellows must be absorbed by rigid anchors.

Note: Anchors must be designed to withstand test pressure being applied to the system. Main anchors should be located at branches and locations at which either the size or direction of the line changes. In addition, intermediate anchors should be used to break up straight runs to limit expansion in each section to 30 mm.

Guides: The compensator and attached piping must be guided axially to limit any lateral movement which would reduce the life of the bellows. Guides should be at least as long as two pipe diameters with the clearance between pipe and guide not more than 1.5 mm.

In locating guides it is recommended that the expansion compensator be located close to an anchor and that the first pipe quide be located within a distance of four pipe diameters from the compensator.

The distance between the first pipe guide and the second must be no more than fourteen pipe diameters. Spacing of subsequent guides may be determined from Fig. 44.

Fig. 44. Recommended distances between guides for standard steel pipelines
MAX-COMP EXPANSION JOINTS

RECOMMENDED PIPE ALIGNMENT GUIDE SPACING FOR STANDARD STEEL PIPES

USER ADVANTAGES

1. The unit is supplied with pipe ends prepared for welding.
2. A robust outer cover ensures that the convolutions are fully protected against damage in transit or on site.
3. The outer cover also acts as a guide tube in which a guide ring welded to one pipe end is free to slide. This in-built guide assembly prevents any lateral forces being imposed on the convolutions.
4. The guide pins are incorporated in the guide ring which move in linear slots machined in the outer guide cover. These pins act as stops and limit the travel of the expansion joint both in compression and extension. Thus it is impossible to disengage the telescopic sleeves due to over extension of the unit during installation.
5. Two Max-Comp expansion joints may be installed in a straight length of pipe between two anchors without an intermediate anchor between the units. The movement stops ensure even allocation of total pipe movement between the Max-Comp units.
6. The guide pins also prevent torsion being applied to the convolutions during installation on site.
7. The guide pins are designed to retain the pressure end load. In the event of an anchor failure the expansion joint will simply extend to its maximum permitted movement within the limit of the guide pin slots.

INSTALLATION

The unit is cold pulled to maximum length prior to dispatch by means of the pre-tensioning bolts. When the unit is installed by preinsulated pipe manufacturers these pre-tensioned bolts may be left in position and they are designed to break off when the pipe line is heated to operating temperature. There is no longer to personnel as the broken bolts are contained within the insulation.

The Bolt breaking load, must be considered in the anchor design when the pretensioning bolts are left in position. Full recommendations for anchor designs are given in our “Designers Guide”. Where the pipe line is open and the pre-tensioning bolts are not adequately covered, it is advisable to remove them prior to commissioning of the pipe line and after the anchors and guides have been installed.

If the installation temperature is higher then the minimum anticipated line temperature it will be necessary to adjust the installation length by means of the pre-tensioning bolts.

GUIDING

All axial compensators should be adequately guided in accordance with recommendations prior to pressure testing the pipe line. On each side of the Max-Comp the pipe should be provided with a guide at a max. distance from the Max-Comp equal to 18 times the pipe diameter. Where Max-Comp units are installed in pre-insulated pipe lines guides, other than those incorporated in the pipe system are not necessary. However it is essential to back-fill the pipe trench prior to pressure testing the pipe line.

USER ADVANTAGES

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>2.</td>
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</tr>
<tr>
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<tr>
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<td>The guide pins are designed to retain the pressure end load. In the event of an anchor failure the expansion joint will simply extend to its maximum permitted movement within the limit of the guide pin slots.</td>
</tr>
</tbody>
</table>

1. Max – comp with pipe ends  
2. PE – pipe A  
3. PE – pipe B  
4. PE – ring 1  
5. PE – ring 2  
6. PE – armour D  
7. PVC  
8. PUR – foam  
9. PE – pipe C  
10. PUR – foam  
11. Soft foam  
12. Rubber pipe  
13. Pipe clips  
14. Dekoradol band  
15. PE – armour E  
16. PE – ring 3  
17. LPE – ring 4  
18. Weld (PE – wire)
TIED BELLOWS

There are two groups of tied bellows:
- Bellows for lateral movement (TD, TM, HD, GD)
- Bellows for angular movement (HS, GS)

Advantages:
- anchor points question is of a secondary importance
- absorption of movements or expansions of any length is possible
- less intermediate anchors and pipe guides in comparison with absorption of movement with axial bellows
- absorption of movement in all three planes
- stress-free connection to sensitive pieces of equipment (pumps, engines, compressors) is guaranteed.

Disadvantages:
- deflection in the pipeline is necessary
- requires more installation space than an axial bellows

SYSTEM DESIGN PROCEDURE

When designing your tied bellows system a useful discipline is to observe the following procedure:

1. Establish the nominal pressure
2. Calculate thermal dilatation
3. Divide the pipeline installation into sub-sections and establish position of bellows
4. Establish position of anchor points and guides
5. Calculate “cold-pull” dimensions
6. Calculate forces acting on anchors

1. ESTABLISH THE NOMINAL PRESSURE

For establishing the nominal pressure the same formula as for the axial bellows is available, page 16

2. CALCULATE THERMAL DILATATION

See page 17

3. DIVIDE THE PIPELINE INSTALLATION INTO SUB-SECTIONS AND ESTABLISH POSITION OF BELLOWS

The tied bellows are installed in pipeline at the deflection place in contrast to the axial bellows. The most often applications:
- Z compensation
- L compensation
- compensation with a pipe loop

It is necessary to divide the pipeline installation into subsections:
- when the pipeline installation has many elbows and when movements occur in more than two planes.
- when an individual straight section is very long and the large movement occurring are therefore no longer absorbed by a single expansion joint
- when the anchor points of the piping is only possible at certain points.

The tied bellows are mostly situated near pipe elbows. However it is necessary to establish the distance between convolutions. In several practical examples is showed the way how to determinate the correct lateral bellows (TD, TM, HD, GD), angular bellows (HS, GS) and distance between convolutions.

It means that the tied bellows are not allowed to be installed like axial bellows for absorbing of axial movement. In that case, it is necessary to have changes in direction of flow (deflections) which allow converting of axial expansion into the lateral or angular movement of expansion joint. The tied bellows are named after tie elements (rods, bars) which take the pressure thrust ($F_p = p \cdot A$). As we know that the pressure thrust is the most influential force which loads anchors, therefore the main advantage of tied expansion joints, in contrast to the axial expansion joints, is that only very light anchors are necessary.

The areas between lateral and angular expansion joints are not rigidly defined, and a definite decision can only be made when the actual application is known. As a rule, three individual angular bellows are needed to absorb the movement properly. As long as the first guide support has been installed at a sufficiently long distance or that the required lateral deflections is limited so that as a result the circular are is minimal there will be no difficulties.
## AXIAL BELLOWS

**Design pressure:** 16 bar  
**Design temperature:** 300 °C  
**Test pressure:** 25 bar

<table>
<thead>
<tr>
<th>NOMINAL DIAMETER (mm)</th>
<th>MOVEMENT</th>
<th>FREE LENGTH</th>
<th>PIPE O/D (mm)</th>
<th>BELLOWS O/D (mm)</th>
<th>EFFECTIVE AREA (cm²)</th>
<th>SPRING RATE (N/mm)</th>
<th>MASS (kg)</th>
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</thead>
<tbody>
<tr>
<td>40</td>
<td>19, 30</td>
<td>38, 60</td>
<td>160, 230</td>
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Note: For unit sizes or operating conditions outside of the range specified above, please refer to manufacturer!