**Application of Bellows Expansion Joints In Piping Systems**

It is very important to distinguish between the unrestrained expansion joint which is usually used for axial movement, and the restrained unit using bellows fitted with tie bars or hinges taking up offset and angular movement.

The two have completely different applications, act upon the pipe differently, and must be installed in a different way.

It is important at the design stage to find the pipe movements involved, the working and test conditions required, and the environment they are to work in. Any piping system, regardless of complexity, can be divided by anchors into a number of individual expanding or contracting sections, each with relatively simple configurations—straight run, ‘L’ shaped bends or Z bends. The number of and location of pipe anchors depends upon the piping configuration, the amount of movement which can be accommodated by a single joint, due to expansion, and the availability of convenient structural points suitable for anchors.

Expansion joint elements have limited capacity to transmit torque and absorb torsion rotation. Designers of piping systems should take care to prevent such loading on the expansion joint, and if it is impossible to eliminate turning action, our design section should be consulted.

**Unrestrained Expansion Joints - Or the Restrained Type?**

**A Guide to Choosing the Correct System**

**UNRESTRAINED UNITS**

Axial expansion joints are not pressure restrained - when pressurized they tend to open out lengthwise, in the same way as a piston in its cylinder. The thrust is equal to the effective area of the bellows multiplied by the internal pressure (including vacuum conditions). This force acts on pipes anchors, and when the pipe expands it must overcome the flexibility force of the bellows and the pressure force. The pressure force is nearly always very much larger than the elastic force.

*Note*: In vacuum conditions the bellows tends to contract and pull on the anchors - a phenomenon opposite to the expansion force.

The following rules governing installation of unrestrained units must be strictly observed to ensure a satisfactory installation.

1) **Anchor Points**

It is the function of an anchor to absorb the line loads and to control direction of the movement. To ensure a satisfactory installation the following should be observed.

a. Only one expansion joint should be used between two anchor points. This ensure that each unit works only within it’s design movements.

b. The pipe between anchors should be straight in plan and elevation. If the pipe is not straight the forces exerted by the expansion joint will tend to push the pipe sideways or bend any pipe offset unless the pipe is adequately guided. This can over extend the expansion joint and cause it to fail by instability.

c. Anchor points at the end of the pipe must be strong and rigid enough to resist all forces acting upon them.

The following influences should be considered when calculating anchor point loads:

1. Deflection load (bellows spring rate x maximum deflection)
2. Pressure thrust (effective area x design pressure)
3. Frictional resistance of pipe moving over its guides
4. Centrifugal thrust
5. Dead weight loads on vertical and sloping pipes
6. Shock loads, due to quick opening valves or bursting of safety discs
7. Wind loading
8. Additional thrust due to test pressure

Reference should be made to the data sheet for details of deflection forces and effective areas.

2) **Main Anchor**

A main anchor is installed in any of the following locations in a pipe system containing...
one or more bellows.

a. At a change in flow direction.

b. Between two bellows of different size installed in the same straight run. When small differences in pipe sizes occur, intermediate anchors should be adequate.

c. At the entrance of a side branch into the main line, but this only applies when the side branch is approximately equal to the dimension of the main pipe.

d. Where a shut-off or present reducing valve is situated in a pipe run between two bellows; a main anchor must be designed to take the pressure, deflection load, and other loads imposed in it.

3) Intermediate Anchor

Theoretically, intermediate anchors need only be of light construction since the pressure thrust force are absorbed by the main anchors. However, it is advisable in practice - except perhaps on high pressure and large diameter pipe - to design intermediate anchors as 'main anchors' and eliminate risk of failure if the line is later modified or tested incorrectly.

4) Pipe Alignment Guides

A pipe guide is a constraint allowing the true axial movement along its length, at the same time preventing lateral or angular movement.

Pipe alignment guide design should allow sufficient clearance between fixed and moving parts of the guide - ensuring positive guiding with out introducing less than one pipe diameter long and radial clearance between pipe and guide not more than 1.5mm on pipes up to 100mm outside diameter.

Guide efficiency can be reduced by incorrect installation (especially misalignment), and by the use of materials without the necessary strength, rigidity and wear resistance for long-term operation.

Guide Positions

The first guide for axial expansion joints should be positioned as close as possible to the expansion joints, and never more than four pipe diameters away. The distance between the first and second guide should not be more than fourteen pipe diameters.

Note: There should be sufficient clearance between the guide and bellows flange to allow for bolt access.

Cold Pulling Expansion Joints

Expansion joints can take compression and extension from the natural free position. Full advantage is taken of this facility by pre-setting the joints.

Assuming that installation is carried out with the pipe at it's minimum temperature then setting is done by extending or compressing the joint by half the total movement that it will ultimately be subjected to - and can be carried out in the final stages of installation.

Note: Axial expansion joints can be preset upon request. Setting consists of fitting temporary installation bars across the joint. These bars must be removed at the installation, and before system pressure testing begins.

Minimum load is obtained by allowing movement to be taken equally either side of the neutral position.

When pre-setting on site, allowance should be made for the difference between the temperature at installation time and the operating temperature range. The necessary length adjustment of the joint can be calculated using thermal expansion tables.

Restrained Expansion Joints

These joints operate on a completely different principle from the unrestrained tubes. In this case the expansion joints are able to bent and are restrained by spherical seated tie bars or hinges, or a braid preventing them from opening out lengthwise due to internal pressure.
The restrained expansion joint has the advantage of eliminating pressure thrust and providing flexibility with minimal forces.

Rules governing installation of restrained expansion joints are influenced by the free movement of the expanding pipe. Both anchors and guides can usually be quite light construction.

1) Anchor Points
These absorb the line-loads and control direction of movement. Again, it is important that the anchor points at the end of the pipes should be strong enough to resist all forces acting upon them.

When using restrained units, the unit itself carries the pressure load and thus there is no need for main anchors. The only types required are intermediate or directional restraint anchors.

2) Intermediate Anchors
An intermediate anchor must withstand transferred forces and movements of the pipe section in which it is attached. In a pipe with one or more expansion joints, these loads consist of the movements and forces required to deflect the expansion joint together with centrifugal thrust. The pressure load is absorbed by the tie rods, hinged restraints and gimbal restraints of the expansion joint.

3) Directional Restraint Anchor
The anchor prevents movement in one or more directions, and permits motion in another. It may be a main or intermediate anchor, depending upon its application; it may also function as a pipe guide. Designers minimize the friction load on these anchors by specifying low friction surfaces.

4) Pipe Alignment Guides
Where restrained units are used in expansion joints systems, unlike the unrestrained units, they exert minimal forces on anchors. These consist only of the deflection forces due to bellows spring rates, frictional resistance of the pipe moving over its guides or supports.

Because anchor loads are low, restrained expansion joint systems are frequently used with the pipe being supported on hangers, keeping alignment by its own weight.

When restrained units are displaced, there is a small overall length change which makes it necessary to install pipe guides on each side of the system, which allow for the change in length, in one plane only.

* These forces can be critical in certain conditions, and can be defined upon request.

Sliding supports may be used for horizontal pipes and spring supports for vertical systems on short runs in restricted space between vessels or machinery. This is important when large diameter pipes are in use. If it appears impossible to fix supports, we can design additional strength in the restraining parts before installation.

The longer the pipe run the greater is the force between pipe, supports and guides due to friction and inconsequent the greater the load of the anchors. When retrained bellows are used on long runs, roller supports or even low friction pads will keep friction to a minimum. Supports and guides located near a restrained expansion joint must be designed to accommodate the large movements that can occur, as there is a danger that under maximum movement conditions the pipe could fall off the guide or distort the support.

Guide Positions
Supports and guides should prevent bending and twisting of the expansion joints. If distortion occur, then the joint, or its restraint, may be incorrectly stressed.

Cold Pulling Expansion Joint
The theory of cold pull calculations in a restrained system is similar to the unrestrained system, except that the joint does not have to be extended or compressed. Pre-setting is applied by cutting the pipe run short by half the total movement to which the expansion joint will be subject.

Examples of cold pull

Cold Pulling Expansion Joint
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**Special Service Conditions**

If it is necessary to divert from some of the recommendations in the brochure, we will be pleased to advice on specific circumstances.

**Sleeves**

Internal sleeves should be used on all expansion joints in the following cases:

a) When it is necessary to hold media friction losses to a minimum and achieve smooth flow.

b) When velocities are high and could produce resonant vibration of the bellows. Sleeves are recommended when flow velocities exceed the following values:

   a. **Air, Steam, or other Gases**
      i. Up to 150mm diameter - 48mm/s/mm of diameter.
      ii. Over 150mm diameter - 20mm/s/mm of diameter.

   b. **Water and other liquids**
      i. Up to 150mm diameter - 20mm/s/mm of diameter.
      ii. Over 150mm diameter - 3m/s

c) Internal sleeves should be used when turbulent flow is generated upstream of the expansion joint by changes in flow direction, valves, tee or elbow section, and cyclonic devices. When the sleeves is long or large in diameter, and turbulence is high, heavy gauge sleeves may be required.

d) Use internal sleeves where there is the possibility of erosion. Example: in lines carrying catalyst of other abrasive media. RELATIVELY THIN BELLOWS MUST NEVER BE DIRECTLY EXPOSED TO EROSION.

e) Sleeves are used in high temperature applications to reduce the temperature of the bellows and enable the metal to retain its physical properties: (maximum effect will be obtained if the expansion joint is not externally insulated)

**More about sleeves**

Do Not use internal sleeves when high viscosity fluids, such as tars, are being transmitted. These fluids may cause ‘packing up’, ‘choking’ and ‘caking’, of the convolutions which in turn create premature expansion joint failure. When purging will prevent ‘packing up’, internal sleeves may be used in conjunction with purge connections.

In cases of rotation or lateral deflection, a sleeve must be small enough in diameter to give clearance between its external diameter and the internal diameter of the bellows. If the internal diameter of the sleeve cannot be reduced, then an oversize bellows, or an alternative expansion joint design must be used.

Sleeves should contain DRAIN HOLES when used on expansion joints for steam or liquid service when the flow direction is vertically upward.

**TYPICAL EXAMPLES OF SYSTEMS USING RESTRAINED EXPANSION BELLows**

![TYPICAL EXAMPLES OF SYSTEMS USING RESTRAINED EXPANSION BELLows](image)

- U-type pipe configuration
- Z-type pipe configuration system using 3 single hinged units
- System using hinged double unit
system using 2 single gimbal units or a universal tied unit

system using 1 single hinged unit and 2 single gimbal or tied unit

Choy Hong Private Limited
Block 3018, #02-05, Bedok North Street 5, Eastlink, Singapore 486132.
Tel: 64495341. Fax: 64487131. Email: sales@choyhong.com
Website: www.choyhong.com