



# **Bellows Movements and Spring Rates**

# **Movement Capabilities**

There are four basic movements that can be applied to a bellows. These are Axial, Lateral, Angular and Torsional. Figures 1 through 5 illustrate these movements. Bellows be have like springs in a piping system. When they are compressed, the bellows resist the movement the same as a spring would. The spring rate of a bellows is entirely dependant on bellows geometry and material properties. Macoga is able to vary bellows geometry such as convolution height, pitch, thickness and number of plies to provide a bellows to satisfy any customer's needs.

# $\Box$ Axial Movement (+/ - mm)

Axial movement is the change in dimensional length of the bellows from its free length in a direction parallel to its longitudinal axis. Compression is always expressed as negative (-) and extension as positive (+). The units for axial spring rates displayed in N/mm.



# □ Angular Movement ( +/ - Degrees )

Angular movement is the rotational displacement of the longitudinal axis of the bellows toward a point of rotation. The convolutions at the inner most point are in compression (-) while those furthest away are in extension (+). The angular capability of a bellows is most often used with a second bellows. The units for angular carrier rates displayed in Nm (deg

The units for angular spring rates displayed in Nm/deg



# □ Lateral Movement (+/ - mm)

Lateral movement is the relative displacement of one end of the bellows to the other end in a direction perpendicular to its longitudinal axis (shear). Lateral movement can be imposed on a single bellows as depicted below but to a limited degree. A better solution is to incorporate two bellows in a universal arrangement as shown. This results in greater offset movements and much lower offset forces.

The units for lateral spring rates displayed in N/mm





# □ Torsional Movement (+/ - Degrees)

Torsional movement is the rotation about the axis through the center of a bellows (twisting). Macoga **DISCOURAGES ANY TORSIONAL ROTATION OF METAL BELLOWS EXPANSION JOINTS.** Torsion destabilizes an expansion joint reducing its ability to contain pressure and absorb movement. If torsion is present in a piping system, hinges, slotted hinges or gimbals are recommended to combat the torsion. Torsional spring rates are in Nm/deg and maximum torsional limits in degrees for computational modeling only. Piping software such as CAESAR II and COADE often require these spring rates for nodal input.



Pressure thrust is the force created by pressure acting on a bellows. This force is the system pressure times the effective area of the bellows. When a piping system without expansion joints is pressurized, the system will not move because the pipe is countering the force in tension. When an unrestrained expansion joint is introduced in the network, the force tends to pull the ends away from the expansion joint causing damage to itself and the pipe. This pressure thrust must be contained with either main anchors or restrained expansion joints designed to carry pressure thrust loads. The main anchors must be able to resist the pressure thrust force and a small amount of force due to the deflection of the bellows.





**Example:** Pipe size = 12" nominal P = System Pressure = 300 psig A = Effective Area of 12" part = 151 in<sub>2</sub>  $\Box$  = Pipe growth between anchors = 0.5 in compression SR = Axial Spring Rate of the 12" part = 6,255 Lbs/in **First find the force due to the pressure:** PRESSURE THRUST = P X A = 300 psig X 151 in<sub>2</sub> = 45,300 Lbs **Next find the force due to the bellows deflection:** BELLOWS SPRING FORCE =  $\Box$  X SR = 0.5 in X 6,255 Lbs/in = 3,128 Lbs **The main anchors must resist the sum of these two forces:** PRESSURE THRUST + BELLOWS SPRING FORCE = 45,300 Lbs + 3,128 Lbs = 48,428 Lbs

# **Basic Types of Expansion Joints**

# **Unrestrained Assemblies**

**Definition:** Assemblies not capable of restraining the pressure thrust of the system. The pressure thrust must be contained using main anchors or equipment.

# □ Single Bellows

The simplest type of expansion joint consists of a single Bellows element welded to end fittings, normally flange or pipe ends. The single bellows can absorb small amounts of axial, lateral and angular movement with ease, but adequate anchors and guides must be provided.



# □ Universal Expansion Joint

This expansion joint consists of two bellows connected by a center spool piece with flange or pipe ends. The universal arrangement allows greater axial, lateral and angular movements than a Single Bellows . Increasing the center spool length produces increased movement capability. Like the single, adequate anchors and guides must be provided.

# □ Externally Pressurized Expansion Joint

Line pressure acts externally on the bellows by means of a Pressure chamber. This allows a greater number of convolutions to be used for large axial movements, without fear of bellows instability. Externally Pressurized Expansion Joints have the added benefit of self-draining convolutions if standing media is a concern. Anchors and guides are an essential part of a good installation.





# **EXPANSION JOINT**



# **Restrained Assemblies**

**Definition**: Assemblies capable of restraining the pressure thrust of the system. Intermediate anchors are required to withstand

the spring force generated when the expansion joint is deflected. The need for main anchors is eliminated

# □ Tied Single Bellows

The addition of tie rods to a Single Bellows Assembly adds design flexibility to a piping system. The tie rods are attached to the pipe or flange with lugs that carry the pressure thrust of the system, eliminating the need for main anchors. With the assembly tied, the ability to absorb axial growth is lost. Only lateral and angular movement can be absorbed with the tied expansion joint. The addition of tie rods does not eliminate the need for a well-planned guide system for the adjacent piping.



# □ Tied Universal Expansion Joint

Similar in construction to a Universal Assembly except that tie rods absorb pressure thrust and limit movements to lateral offset and angulation. Large offset movements are possible in a Universal Assembly by increasing the distance between the two bellows.



Tied Universal Assembly

# □ Hinged Expansion Joint

When a Hinged Expansion Joint is used, movement is limited to Angulation in one plane. Hinged Assemblies are normally used in sets of two or three to absorb large amounts of expansion in high pressure piping systems. Only low spring forces are transmitted to the equipment. The hinge hardware is designed to carry the pressure thrust of the system, and often times, used to combat torsional movement in a piping system. Slotted Hinged Expansion Joints are a variant of the standard Hinged Expansion Joints that allow axial and angular movement. **Important note**: Once a Slotted Hinge is introduced, torsion in the piping system is still resisted but the hinge no longer carries pressure thrust.



Hinged Assembly

# □ Gimbal Expansion Joint

The gimbal restraint is designed to absorb system pressure thrust And torsional twist while allowing angulation in any plane. Gimbal Assemblies, when used in pairs or with a Single Hinged unit, have the advantage of absorbing movements in multi-planer piping systems. The gimbal works the same as an automobile's universal drive shaft.



# **EXPANSION JOINT**



# □ Pressure Balanced Elbow Expansion Joint:

These assemblies are used in applications where space limitations preclude the use of main anchors. Pressure thrust acting on the line bellows (bellows in the media flow) is equalized by the balancing bellows through a system of tie rods or linkages. The only forces transmitted to equipment are low spring forces created by the axial, lateral, or angular movements. An elbow must be present in the piping network to install this style of expansion joint.



Pressure Balanced Elbow Assembly

# □ In - Line Pressure Balanced Expansion Joint:

If an elbow is not present in a piping network and pressure thrust Must be absorbed by the expansion joint, an In-Line Pressure Balanced expansion joint is the solution. An equalizing bellows with twice the effective area as the line bellows is tied in the expansion joint through a series of tie rods. The opposing pressure forces cancel each other leaving only the low spring forces generated from the bellows deflection.

# Externally Pressurized Pressure Balanced Expansion Joint:

If large amounts of axial movement in a system are needed and the expansion joint must absorb pressure thrust, an Externally Pressurized Pressure Balanced expansion joint is the solution. The opposing force balancing theory is similar to the In-Line Pressure Balanced Assembly except the opposing forces are generated from pressure acting on the outside of the bellows.



In-line Pressure Balanced Assembly



Externally Pressurized Pressure Balanced Assembly

# **END CONNECTIONS & ACCESSORIES**

# □ Flanges

Any flange style can be added to a bellows for bolting into a system. Forged steel or plate flanges to match the pressure and temperature ratings of ANSI Class 150 or ANSI Class 300 are standard



# **EXPANSION JOINT**



# □ Vanstone Ends

Vanstone ends are modified flanged ends with the added flexibility for resolving bolt-hole misalignment or wetted surface corrosion.

# $\Box$ Weld Ends

Any pipe or duct can be attached to a bellows for welding into a system. Pipe in accordance with ASTM A53 Gr. B or A106 Gr. B is used for standard sizes 3 in. to 24 in. nominal diameter. Plate to ASTM A36 or A516 Gr. 70 rolled and welded is used for custom sizes 26 in. diameter. Stainless steel or other alloy pipe can also be provided.





### □ Liners (Internal Sleeves)

when any of the following conditions exist:

A. When pressure drop must be minimized and smooth flow is essential.

B. When turbulent flow is generated upstream of the expansion joint by changes in flow direction.

C. When it is necessary to protect the bellows from media carrying abrasive materials such as catalyst or slurry.

D. In high temperature applications to reduce the temperature of the bellows. The liner is a barrier between the media and the bellows.

E. For Air, Steam and other Gases

Up to 6 in. diameter - 4 ft/sec/in. of diameter

Over 6 in. diameter - 25 ft/sec.

For Water and other Liquids

Up to 6 in. diameter - 2 ft/sec/in. of diameter

Over 6 in. diameter - 10 ft/sec.

Flow liners can trap liquid if the expansion joint is installed with the flow vertical up. On this case the internal sleeve are provided with drain holes to prevent liquid buildup under the liner. For custom designs, flow direction should always be provided.



Flanged joint with Liner



Vanstone joint with liner



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# □ Protective Covers and Shrouds

Covers and shrouds can be provided either fixed or removable. Fixed types are used where high velocity external steam conditions exist such as in condenser heater connections. The removable type is the Macoga standard and permits periodic in service inspection. They are also used to prevent damage during installation and operation or when welding is going to be performed in the immediate vicinity. If the expansion joint is going to be externally insulated, a cover should be considered. Macoga always recommends covers for any expansion joint. The small cost increase is just economical insurance when compared to a complete joint replacement.

# $\Box$ Tie Rods

Ties rods are devices, usually in the form of bars or rods, attached to the expansion joint assembly and are designed to absorb pressure loads and other extraneous forces like dead weight. When used on a **Single** or **Universal Style Expansion Joint**, the ability to absorb axial movement is lost.

# □ Limit Rods

Limit rods are used to protect the bellows from movements in excess of design that occasionally occurs due to plant malfunction or the failure of an anchor. LIMIT RODS DO NOT CONTAIN THE PRESSURE THRUST DURING NORMAL OPERATION. Limit rods are designed to prevent bellows over-extension or over-compression while restraining the full pressure loading and dynamic forces generated by an anchor failure. During normal operation the rods have no function.

# □ Purge Connections

Purge connections are used in conjunction with internal liners to lower the skin temperature of the bellows in high temperature applications such as catalytic cracker bellows. The purge media can be air or steam which helps flush out particulate matter between bellows and the liner. This also prevents the build up of harmful solids in the convolutions that may stop the bellows from performing.



Weld end joint with cover













# **MATERIAL SELECTION GUIDELINES**

### **Bellows Material**

Selection of the bellows material is the single most important factor to be considered in the design of an expansion joint. Some of the factors, which influence the selection process, are as follows:

### **Factors Considerations**

□ Corrosion Properties Process media

Surrounding environment

Internal cleaning agents

□ Mechanical Properties High temperature service

Cryogenic service

**Operating stresses** 

□ Manufacturing properties Forming and cold working capabilities

# **BELLOWS MATERIAL**

### □ Stainless Steel - Type 300 austenitic series

### 304 (ASTM A240 - 304)

Services a wide range of applications. It resists organic chemicals, dye stuff, and a wide variety of inorganic chemicals. Type 304 resists nitric acid and sulfuric acids at moderate temperatures and concentrations. It is used extensively in piping systems conveying petroleum products, compressed air, steam, flue gas, and liquefied gases at cryogenic temperatures. The temperature range varies from -324 to 1200 degrees F.

### 304L (ASTM A - 240 - 304L)

Has a maximum carbon content of 0.03% versus 0.08% for type 304. This lower carbon content eliminates the problem of chromium carbide precipitation and makes it more resistant to intergranular corrosion. It is preferred over 304 for nitric acid service.

# 316 (ASTM A - 240 - 316)

This alloy contains more nickel than the 304 types. The addition of 2% to 3% molybdenum gives it improved corrosion resistance compared to 304 especially in chloride environments that tend to cause pitting. Some typical uses are flue gas ducts, crude oil systems high in sulfur, heat exchangers, and other critical applications in the chemical and petrochemical industries.

# 316L (ASTM A - 240 - 316L)

With its low carbon content of 0.03% maximum, it lends itself to highly corrosive applications where intergranular corrosion is a hazard.

# 321 (ASTM A240 - 321)

The addition of titanium to this stainless steel acts as a carbide stabilizing element that prevents carbide precipitation when the material is heated and cooled through the temperature range of 800 to 1650 degrees F. 321 finds uses in many of the same applications as Type 304, where the added safeguard from intergranular corrosion is desired. The standard catalog exhaust joints are made from this material because of the high operating temperatures they withstand.

# □ Nickel Alloys

# Nickel 200 (ASTM B162 - 200)

A commercially pure nickel (99.5% Ni), nickel 200 has good mechanical properties and excellent corrosion resistance to salt water attack and chloride cracking.

# Alloy 400 (ASTM B127 - 400)

This copper-nickel alloy (66.5% Ni, 31.5 Cu) is a higher strength material than Nickel 200 with excellent corrosion resistance over a wider range of temperatures and operating conditions.

### Alloy 600 (ASTM B168 - 600)

This nickel-chromium alloy (76% Ni, 15.5% Cr) has very desirable properties for the manufacture of expansion joints. It has a very high strength over a wide range of temperatures and a good resistance to a variety of corrosive environments. It finds wide use in steam and salt water services where it is virtually immune to chloride stress corrosion.





### Alloy 625 Gr.1 (ASTM B443 - 625)

This alloy contains a higher chromium content (21.5%) than alloy 600. With the addition of 9% molybdenum, it produces an alloy of superior strength and corrosion resistance over a wider range of temperatures and environments. It is used on many critical applications such as heat exchangers and catalytic cracker expansion joints. When exposed to temperatures above 1000 deg F for prolonged periods, it may become embrittled.

### Alloy 625 LCF (ASTM B443 - 625 LCF)

Similar to straight grade 625, this alloy has a slight change in material composition to enhance low-cyclic fatigue properties at elevated temperatures.

### Alloy 800 (ASTM B409 - 800)

This nickel-iron-chrome alloy is less expensive than alloy 600. It has good corrosion resistance properties and high temperature strength over a wide variety of difficult service conditions.

### Alloy 825 (ASTM B424 - 825)

This is a copper-chrome nickel alloy that exhibits excellent corrosion resistance to the most severe acids, in particular hot concentrated sulfuric acid and sulfur bearing environments.

### Alloy 20 or 20Cb - 3 (ASTM B463)

This nickel-iron-chrome alloy was specifically designed to resist hot sulfuric acid. It is able to resist intergranular corrosion in the aswelded condition and is practically immune to chloride stress corrosion cracking.

### **Other Materials**

In addition to the materials listed above, Macoga has successfully manufactured bellows from Hastelloy C22 and C276, Corten, AL6XN, duplex 2205, alloys 230, 253 MA, 330, 617, 718, 800H/HT, 3CR12, HR120 and others. Many grades of "SA" and "SB" materials are stocked for expansion joints requiring ASME partial data reports. Please consult Macoga for any material not listed or for ordering catalog parts with alternate materials Macoga manufactures bellows from mill-annealed material only and no annealing is performed after the forming process is complete. Macoga must know if the customer requires annealing of the material after forming. Occasionally, annealing will enhance material properties or corrosion resistance. Macoga discourages post-formed annealing because it hinders the bellow's ability to contain pressure and may also lower cycle life.

# **Shipping & Handling**

Every expansion joint that leaves the factory is provided with installation instructions. These instructions describe the simple, straightforward requirements that must be followed to insure a trouble-free installation.

**Shipping Bars** - These are temporary attachments that "hold" the expansion joint at its correct installed length during shipping and installation. Angle iron or channel section is used and is always painted bright yellow. Shipping bars must never be removed until after the unit has been correctly welded or bolted into the piping system. Caution: Tie rods or limit rods are sometimes mistaken for shipping bars. **NEVER TAMPER WITH THESE ATTACHMENTS.** 

NOTE: Great care must be taken when removing the shipping bars. If a welding or burning torch is used, ALWAYS protect the bellows element from burn splatter with a flame-retardant cloth or other shielding material.

**Liners** - When expansion joints are fitted with liners or internal sleeves, the unit is marked with an arrow indicating the direction of flow. The expansion joint must be installed in the system with flow in the correct direction.

**Flanged Assemblies** - These should be correctly aligned with their mating flanges (vanstone flanges permit some rotational misalignment). If a bellows is subjected to torsional forces due to hole misalignment, then reduced cycle life and/or bellows failure can occur.

Weld End Assemblies - The bellows elements should always be



Flanged expansion joint with shipping bars



Weld end expansion joint with shipping bars

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protected during the welding process with flame retardant cloth or other shielding material. Weld splatter, arc strikes, or cutting torch sparks can cause serious damage to the thin bellows element.

**Final System Check** - After installation has been completed and shipping bars removed, check all anchors, guides, and pipe supports. Slowly apply test pressure to the system, checking for any unusual movement of the bellows anchors or guides. If movement is observed, immediately lower the pressure and re-examine the system for damage.

NOTE: Unless otherwise specified, all expansion joints are designed for a test pressure of 1.5 times the design pressure.

# **UNRESTRAINED EXPANSION JOINTS: INSTALLATION GUIDELINES**

# Axial Movement

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**Single Bellows Assembly** axial unrestrained expansion joints are not provided with attachments such as tie rods or hinges to restrain pressure thrust. Therefore, they can be used only in a piping system that incorporates correctly designed anchors and pipe alignment guides. These components prevent the bellows from over extension and damage due to distortion under operating conditions.

# □ Types of Anchors

**MAIN ANCHORS** are the most important to consider from a design standpoint. They must resist the effects of all forces acting upon them. These are pressure thrust, bellows spring resistance, frictional resistance of pipe guides, and inertial forces at bends and elbows.

**INTERMEDIATE ANCHORS** are used to divide a long pipe run into shorter individual expanding sections, and should be structurally capable of withstanding bellows spring resistance and frictional forces only. Pressure thrust forces at this juncture are completely balanced and have no influence on the design of the anchor.

**DIRECTIONAL ANCHORS** permit movement in one direction only. The movement is often parallel to the direction of the lateral movement in installations where combinations of axial and lateral movements are encountered. 0

Pipe Alignment Guide Style 1



Pipe Alignment Guide Style 2



Pipe Alignment Guide Style 3

**PIPE ALIGNMENT GUIDES** are another essential part of a properly designed piping system. Thermal expansion in the system must be controlled so that the movement applied to the bellows assembly is axial only. Pipe alignment guides must be designed so they prevent bowing and buckling of the pipe. They should also keep frictional forces resulting from movement of pipe across the guide to a minimum.





# ENGINEERED EXPANSION JOINTS

# **EXPANSION JOINT**



# Application Engineering: Single Bellows Assembly

Figure 1 - This diagram shows the most basic application of a single bellows unrestrained type expansion joint. Installation sequence is as follows:

1. Install one expansion joint between main anchors (MA).

2. Locate main anchors at change in direction of piping. 3. Locate expansion joint immediately adjacent to a main anchor.

4. Space first pipe alignment guide (G1) within four pipe diameters of expansion joint.

5. The remaining guides (G) should be spaced in accordance with the pipe guide spacing chart as shown on page 64.





Figure 2 - When thermal expansion between the main anchors (MA) exceeds the capacity of a Single Bellows Assembly, then the pipe system must be divided into smaller sections. The use of an intermediate anchor (IA) located between two Single Bellows Assemblies or as an integral part of a Universal Bellows Assembly provides the best solution. Intermediate anchors, unlike main anchors, are designed to withstand spring resistance and frictional forces only. Pressure thrust at this juncture is canceled out because the effective areas of each of the bellows in the piping system are equal. Pipe alignment guides must be installed in accordance with the guidelines established above.

Figure 3 - If two expansion joints of different pipe diameters are used in the same section of pipe, such as a line containing a reducer, the pressure thrusts are no longer equal. In this case, the anchor dividing the expansion joints must be a main anchor designed to withstand the difference in pressure thrust generated by the different size expansion joints. Pipe alignment guides (G1) and (G2) and intermediate guides must be provided in the locations as shown in the diagram.







Figure 4 - A tee piece located in a pipeline makes a convenient location for dividing the pipe system into three separate expanding sections. The branch connection at this point is isolated from the effects of the thermal expansion present in the main pipe run. If an expansion joint is located in the branch line as depicted, then the fixed point at this location must be a main anchor. It is designed to absorb the pressure thrust of the branch line expansion joint. Pipe alignment guides must be provided in the locations as illustrated in the diagram.





# **Restrained Expansion Joints: Installation Guidelines**

### **Tied Expansion Joints**

Tied expansion joints can be of the Single or Universal Type provided with restraints such as tie rods, hinges or gimbals. Tie rods and gimbals allow the expansion joint to move in all planes. Hinges allow movement in a single plane only. These restraints are designed to absorb the pressure thrust and other external loads like pipe dead weight. For restraints to remain effective, the expansion joint can absorb only lateral offset or angulation in directional changes in the piping system, such as "Z" bends, "U" bends, or "S" bends. Tied units are used where the equipment or adjacent structures cannot accommodate pressure thrust. The only forces experienced are low offset forces resulting from the lateral spring rate of the expansion joint and friction forces of the pipe guides. Tied units are frequently used to protect the nozzles of pumps, turbines and condensers, and to absorb expansion of ducting in elevated locations. Large amounts of expansion can be accommodated with resultant low offset forces by providing a long center-tocenter distance between the two sets of bellows.

#### Installation Requirements

Although the initial cost of a Tied Expansion Joint is greater than a Single Bellows Type, considerable savings on anchors and guides can be achieved in certain applications.

#### Anchors

Anchors used are the intermediate type, because the pressure thrust is absorbed by the expansion joint structural restraint. The location of the intermediate anchor is not as critical as that of a main anchor. The forces acting on the intermediate anchors are usually low offset forces resulting from the lateral spring resistance of the bellows, plus friction in guides. For this reason, a much lighter structure can be utilized to support the anchor, such as pipe racks, roof trusses, or elevated structures found in refineries and petrochemical plants.

#### **Pipe Alignment Guides**

The weight of the pipe should be adequately supported along its length and, in particular, adjacent to the expansion joint. The pipe guides located nearest to the Tied Expansion Joint are planer pipe guides, which allow for the change in length of the offset leg as it swings through its movement arc. The diagram below shows the essential features in the correct use of Tied Expansion Joints.

KEY TO SYMBOLS

INTERMEDIATE







# Application Engineering: Tied Single Assembly Tied Universal Assembly

Figure 1 - Tied Single Assemblies are often used to protect rotating equipment from the effects of thermal expansion in a piping system as shown. The tie rod restraint is designed to absorb pressure thrust, which in turn, allows the use of intermediate anchors rather than main anchors. A planer pipe guide or spring support hanger is used in the system as shown, allowing the thermal growth present in the vertical pipe leg to be taken as natural flexibility in the long horizontal pipe run.





Figure 2 - There are many applications where thermal movement in the piping system is too great for a Tied Single Assembly. In these instances, a Tied Universal Assembly is the correct choice. The expansion joint assembly should be designed to fill the offset leg as shown so that axial movement within this pipe leg is absorbed by the bellows assembly. It is good practice to keep the maximum distance possible between the bellows. This results in low offset forces on adjacent equipment and structures. The center spool is usually supported by the tie rods or spring hangers when center spools are long and diameters large.

Figure 3 - A Tied Universal Assembly is often used to absorb thermal expansion in a multi-planer piping system as shown. This feature allows their use in a wide variety of different installations where main anchors and pipe alignment guides cannot be provided. The same design requirements as mentioned above also apply in this case. Tied Universal Assemblies are generally used to protect compressors, pumps, and turbines. They are also used to absorb thermal expansion in elevated piping systems found in oil refineries, power plants, and petrochemical installations.



# **EXPANSION JOINT**

### Application Engineering: Hinged Bellows Assembly Gimbal Bellows Assembly

Figure 1 - When two Hinged Bellows Assemblies are installed in a '2" offset, as shown, they can absorb large amounts of thermal movement in a piping system. The expansion joints should be cold sprung (pre-set in a deflected position) in order to maximize their movement capability. The thermal expansion in the offset leg is absorbed by the natural flexibility of the horizontal pipe runs. Pressure thrust is contained by the hinge restraint, allowing intermediate type anchors to be used. Planer pipe guides should permit the offset leg to swing through its movement arc as shown. It is good practice to make (L1) the maximum possible and (L2) a minimum.



Figure 1

Figure 2 - This system of Hinged Bellows Assemblies is designed to absorb thermal movement in both the horizontal leg and vertical offset leg. Location of the expansion joints should be as follows: Make distance (L1) and (L2) the maximum possible, (L3) minimum possible. The hinge restraint is designed to absorb pressure thrust and weight of the pipe between the two Hinge Units. Forces on anchors and equipment connections are reduced to friction and low offset forces.







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Figure 4

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Figure 4 - The Two-Hinged Bellows Assembly system shown is often used where a pipeline crosses a roadway or rail line that is supported by a pipe bridge or trellis. The hinge restraint is designed to support the center spool between the expansion joints in addition to the pressure thrust generated by the system pressure. The Hinged Assemblies can be cold sprung, which further increases the overall movement capability of the expansion joints. Offset forces are usually low, hence loads on the bridge structure are kept to a minimum.



Figure 5 - In a multi-planer piping system the use of two Gimbal Bellows Assemblies in a multi-plane "2" bend is the best solution. The gimbal restraint allows thermal expansion in two planes as shown, while still absorbing the pressure thrust. The thermal expansion in the offset leg is taken by the flexibility in the long horizontal pipe runs. The planer pipe guides shown control the direction of this vertical movement. Intermediate anchors are used to contain the resultant low offset forces.



Figure 6 - There are many applications in a multi-planer piping system where the horizontal pipe leg is insufficiently flexible to absorb the thermal expansion in the offset leg. To accommodate this movement, a Single Hinged Bellows Assembly is used in conjunction with the two Gimbal Bellows Assemblies in the locations shown. It is good practice to make (L1) and (L2) the maximum possible with (L3) a minimum. A regular pipe guide must be used on the lower pipe leg, while a planer pipe guide is used on the upper leg.



# Externally Pressurized Assembly

There are certain expansion joint applications that call for large axial movements. These are frequently encountered in steam distribution mains found in hospital, schools, or military installations. Internally pressurized assemblies become unstable even at low pressures when the number of convolutions reaches a certain limit; therefore, the problems created by these requirements cannot be solved using a Single Bellows Assembly. (If continually under pressure, an internally pressurized bellows will act as an unstable column under compression, and squirm.) In cases like these, an Externally Pressurized Assembly provides the most viable solution. When pressure is applied externally to the bellows, as shown in the diagram below, the bellows are placed under tension. In this condition squirm does not become a factor. A greater number of convolutions can be added to the bellows even at higher pressures, resulting in increased movement capability. This style joint has the added benefit of self-draining convolutions. All the trapped liquid media can be purged from the outer casing eliminating the possibility of liquid "flashing" to vapor.

An anchor foot can be added to the Single Externally Pressurized Style allowing it to act as an intermediate anchor. The anchor foot is designed to withstand any loads produced by the deflection of the bellows. Dual Style Externally Pressurized designs are equipped with an anchor foot as a standard. The internal and external rings on both styles act as a pipe guide so no first guide (G1) is necessary.

### **Design Features**

- \* Bellows protection
- \* Smooth flow oversize bellows
- \* Drain connection
- \* Purge connection
- \* Fail-safe design
- \* Self-Draining convolutions
- \* Joint acts as first guide





### Pressure Balanced Assembly

A Pressure Balanced Assembly is designed to absorb axial movement and/or lateral deflection, while absorbing pressure thrust. This is achieved by means of tie rod devices interconnecting a line bellows with an opposed balanced bellows also subjected to line pressure. This type of expansion joint can be used at a change in direction of the piping system or directly in the line as an In-Line Pressure Balanced Assembly.



#### Principle of Operation

Reference to the diagram below shows that during the movement cycle, internal pressure acting on the belows element (A), which is in the flow line, is balanced by the same pressure in the balancing belows element (B). The force exerted by the internal pressure against the line elbow is balanced by an equal and opposite force transmitted to the line through the tie rods (D) from the blank end (C) of the balancing section.

This type of expansion joint is usually seen at a turbine casing or other piece of rotating equipment where minimum forces and moments are required. It is also used in installations where the application of a main anchor would not be practical. The only loads seen by the turbine are the sum of the axial force required to compress or extend the line bellows and balancing bellows in the expansion joint.

Example: In a pipeline with unrestrained expansion joints, the maximum load on the anchors always occurs at the change of direction in the piping system. Such an anchor is always a main anchor. The load exerted at this point is composed of the internal pressure acting over the effective area of the bellows plus the force required to flex the expansion joint (see Pressure Thrust page 8). In a large expansion joint, or one operating under extremely high pressure, the resultant pressure thrust is considerable. To eliminate the thrust, a Pressure Balanced Assembly is the most practical solution.



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# In-Line Pressure Balanced Assembly

An In-Line Pressure Balanced Assembly is designed to absorb small amounts of axial and lateral movement while counteracting the pressure thrust in a system. This is achieved with a series of rods similar to the Pressure Balanced Elbow Assembly and a balancing bellows with twice the effective area as the line bellows. The elimination of the elbow is what makes this expansion joint unique.

#### **Principle of Operation**

Reference to the diagram below shows that the effective area of the balancing bellows (EB) is twice that of the line bellows (EA). These forces act across the tie rods that are attached to the tie plates. There is no change in pressure when the system is moved because the volume does not change. As the line bellows are compressed, the balancing bellows is extended causing no volume change.

This type of expansion joint is usually seen between two Pieces of load sensitive equipment where minimum forces And moments are required. It is also used in installations where the application of a main anchor would not be practical. The only loads seen by the equipment are the sum of the Axial force required to compress or extend the line bellows And balancing bellows in the expansion joint.

# **Externally Pressurized Pressure Balanced Assembly**

An Externally Pressurized Pressure Balanced Assembly is very similar to an In-Line Pressure Balanced assembly but it is capable of large amounts of axial movement. This is achieved by pressurizing the bellows externally eliminating the possibility of bellows squirm. This design has the added benefit of being self guided with self draining convolutions. Again, no elbow is need in this system.



EB = 2(EA)

n#n

EA - SMALL BELLOWS EFFECTIVE AREA EB - LARGE BELLOWS EFFECTIVE AREA

nn

Pressure

How an externally pressurized pressure balanced assembly works

#### **Principle of Operation**

Reference to the diagram bellows shows a series of opposing forces. The different color arrows act against each other to balance the system eliminating the need for main anchors. There is no change in pressure when the system is moved because the volume does not change. As the line bellows (A) are compressed, the balancing bellows (B), which has twice the effective area as (A), is extended causing no volume change.

This type of expansion joint is also seen between two pieces of load sensitive equipment where minimum forces and movements are required. It is also used in steam line installations where pipe main anchors are far apart. The only loads seen by the equipment are the sum of the axial force required to compress or extend the line bellows and balancing bellows in the expansion joint. Modified versions of this style are used in direct burial applications.



# **EXPANSION JOINT**

# Application Engineering Pressure Balanced Assembly

Figure 1 - This example shows a single Pressure Balanced Assembly used to protect rotating equipment from the effects of thermal expansion between two intermediate anchors (IA). In operation, the thermal growth in the system compresses the line bellows (A). Internal pressure acting through the tie rods instantaneously elongates the balancing bellows (B) an equal amount, providing a completely balanced system.

If no lateral movement is present, the number of convoluti in beliows (A) and (B) are equal. Pressure Balanced Assemblies are frequently used on gas and steam turbines pumps, and condenser installations.



Figure 3 - There are many installations where the lateral movement present in the system exceeds the capability of a single Pressure Balanced Bellows Assembly. This problem is best overcome by the use of a Universal Pressure Balanced Assembly as shown. The line bellows (A1) and (A2) are linked by a section of pipe that allows greater lateral movement in addition to the axial movement present. The balancing bellows (B) is designed to compensate for axial movement only. The rods link both sets of bellows and absorb the pressure thrust, resulting in low forces on adjacent equipment and structures. This design finds wide application on turbine/condenser crossovers, boiler feed water pumps, and other critical applications.



Figure 2 - A single Pressure Balanced Assembly can be used to absorb lateral and axial movement. In the example shown, bellows (A) has sufficient convolutions to absorb both the axial and lateral movement present in the piping system. The balancing bellows (B) requires only sufficient convolutions to compensate for the axial movement present in the horizontal line. Intermediate anchors (IA) and pipe alignment guides (G) should be installed in the locations shown.







# Application Engineering In-Line Pressure Balanced Assembly

Figure 1 - This example shows an In-Line Pressure Balanced unit in a typical installation. The two pieces of equipment are load sensitive requiring very low forces and moments at the flanged attachments. Both pieces of equipment are allowed to expand due to temperature while the In-Line Pressure Balanced Assembly absorbs all the axial growth. This style of expansion joint should be guided if the lengths of pipe between the equipment and the expansion joint exceed four times the diameter of the pipe.



### Externally Pressurized Pressure Balanced Assembly

Figure 2 - This example shows an Externally Pressurized Pressure Balanced Assembly in a typical installation. The two pieces of equipment are very load sensitive requiring low forces and moments at the flanged attachments. Both pieces of equipment are allowed to expand due to temperature while the Externally Pressurized Pressure Balanced Assembly absorbs all the axial growth. The first pipe guide is internal to the expansion joint so the next set of guides start at 14 times the diameter of the line pipe. This type of system can absorb much larger amounts of axial growth than the In-Line Pressure Balanced Assembly.







# **CRYOGENIC APPLICATIONS (LNG)**

The expansion Joints installed on cryogenic application could be of the same typologies showed before.

The first important think is the material utilized that must be full construction on Stainless Steel. The bellows could be also made on Inconel 625 LCF.

For this type of services, where possible it is preferable to utilize Expansion Joint external pressurized.



EXTERNALLY PRESSURIZED EXPANSION JOINTS



# **Externally Pressurized Expansion Joints**

Externally pressurized expansion joints are utilized to compensate for large axial expansion of long piping systems. Macoga externally pressurized expansion joints are designed such that fluid/steam pressure acts on the outside of the bellows in addition to the internal surface of the bellows. The stabilizing effect of this external pressure increases the bellows ability to absorb long axial movements without the existence of squirm. This feature makes the externally pressurized expansion joint the best solution for many situations involving extensive axial movement.

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This uninsulated bellows coupling at the base of an LNG tank was accumulating ice balls and impairing the movement of the stainless steel corrugations. The relative motion inherent to bellows necessitated the use of Proper insulation because it always remains flexible, even at cryogenic temperatures.

# Expansion Joint applied on heat exchanger

1 Bellows installed over Shell



2 Bellows installed on tube side





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# **Disassembly joints**

When considering the installation of valves, shut off gates and pumps etc. into a piping system it is particularly beneficial to include a Macoga disassembly joint along side each of these critical pieces of plant. During maintenance axial clearance is easily and quickly achieved in the pipe system to allow removal or replacement of your equipment by simply compressing the demounting joint with its threaded draw bars.

The following points are proven to be advantageous during long periods of operation:

- Plant efficiency is enhanced since the task of removing and replacing components is quicker, considerably reducing down time
  of intervention and loss of production.
- Macoga demounting joints are made entirely of steel. No rubber or plastic elements are used. Therefore there is no wear, aging or leakage.
- Macoga disassembly joints can be used up to 300 ℃ taking into account the pressure reducing factor.
- Observations made over long operating periods indicate water loss reductions in the order of 15%.
- The excellent elasticity of the bellow allows it to absorb slight installation tolerances without creating leakage problems.



#### General

During pipe installation, especially when components are to be replaced for servicing and maintenance, it is essential to leave an axial gap for easy installation of the units.

The Macoga dismantling piece is completely maintenance free, ageing resistant and makes mounting and demounting considerably easier. Using the spring rate of the bellows, a gap is automatically generated while loosing the connection screws. Components can easily and quickly be removed.

The other way round, a mounting gap previously set is closed by definitely restraining the bellows.

As the movable component consists of a one-piece bellows, the Macoga dismantling piece remains 100% tight after as much mountings and demountings as you like. In the component itself, no supplementary seals are necessary. Only the piping components have to be provided with appropriate gaskets.

Thanks to the extreme flexibility of the multi-ply bellows, a minor flange misalignment during pipe installation can be compensated without tightness problems. Possible radial divergences:

 $\delta$  DN 500 = ca. ± 10 mm > DN 500 = ca. ± 5 mm

During installation, the Macoga dismantling piece is at one side flanged to the pipe end and then, using the special tie rods, pulled to the components. In mounted position, the Macoga dismantling piece is restrained. While demounting the piece, only the connecting bolts must be released. The dismantling piece will spring back and generate automatically the gap, necessary for easy demounting and later reinstallation of the components.









### **Reaction force**

When using unrestrained dismantling pieces, the following remarks are to be considered:

The bellows put under pressure tends to return in its smooth tube shape. A reaction force "F" is resulting, which can be calculated with the help of the formulae in section EJMA code. This reaction force must be compensated by the pipe construction, or taken in account by the layout of the anchor points. If axial movements occur, the spring rate has also to be considered.

### **Underground installation**

Macoga dismantling pieces are suitable for underground installation when equipped with outside protection sleeves. Protection tube for underground installation



### Execution

• Without tie rods, not for/ for underground installation. With this solution the end thrust pressure must be taken by other pipe components.





### With tie rods, not for/ for underground installation With this solution the end thrust pressure is taken from the dismounting joint.







# Example of Special application : Bellows installed on Valve



