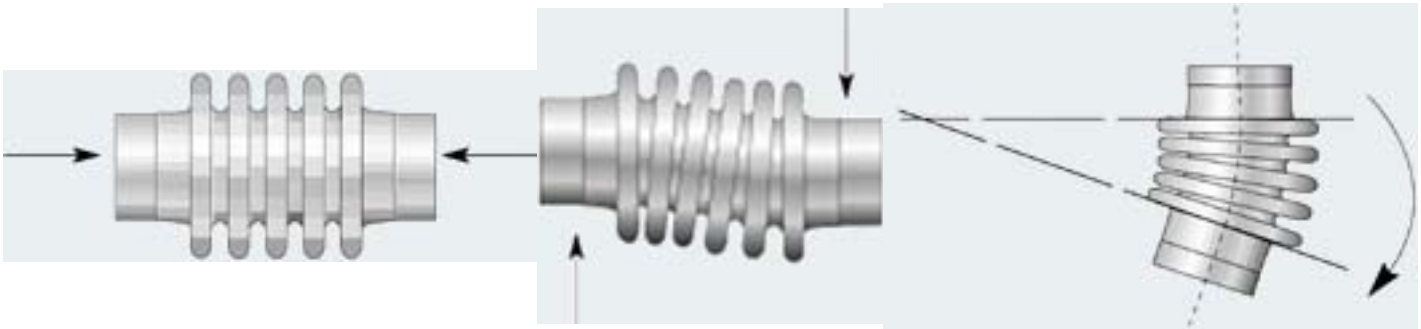
## How a Bellows Works

A bellows is a flexible seal. The convoluted portion of an expansion joint is designed to flex when thermal movements occur in the piping system. The number of convolutions depends upon the amount of movement the bellows must accommodate or the force that must be used to accomplish this deflection. The convoluted element must be strong enough circumferentially to withstand the internal pressure of the system, yet responsive enough to flex. The longitudinal load (pressure thrust) must then be absorbed by some other type of device. These devices include pipe anchors, tie rods, hinges, or gimbal structures. Pressure thrust can be calculated by multiplying the effective area shown in the catalog by the working pressure.



**Axial** **Lateral** **Angular**

## Pressure Thrust

For the purpose of understanding pressure thrust, a single bellows designed for pure axial motion can be modeled as hydraulic cylinder with a spring inside. Force on equipment or adjacent piping anchors:
"F" = (the effective area of the bellows) x (the working pressure) + (the spring rate of the bellows) x (the stroke of the bellows).

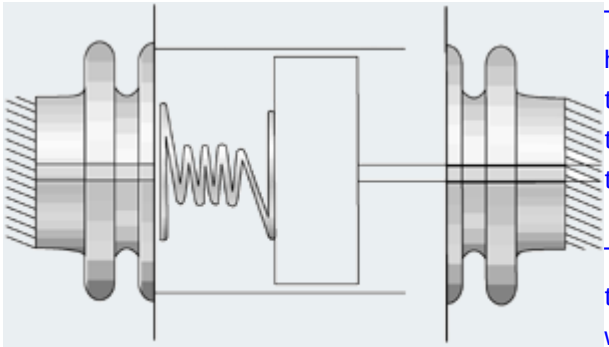


FIGURE 1. WORKING PRESSURE ACTING ON THE EFFECTIVE AREA OF THE BELLOWS.

The spring represents the axial spring rate of the bellows. The hydraulic piston represents the effect of the pressure thrust which the expansion joint can exert on the piping anchors or pressure thrust restraints (hinges, gimbals, tie rods) which may be part of the expansion joint assembly.

The area of the hydraulic cylinder would be the effective area of the bellows. For a 20", 150 psig catalog standard expansion joint with 20 convolutions, the spring force for 1" of axial stroke would be:
(the axial motion) x (the spring rate of the bellows) or 1 inch x 1521lbs. / inch = 1521 pounds.

The pressure thrust force would equal (the working pressure) x (the bellows effective area) or (150 lbs. / inch^2) x (359 inch^2) = 53,850 pounds. The pressure thrust force is typically much higher than the spring force. Expansion joints designed for lateral offset or angular motion are more complicated to model accurately. However, the effect of pressure thrust is the same.

## Pressure Stresses

The ability of a bellows to carry pressure is limited by hoop stress or S2 as defined in the standards of the Expansion Joint Manufacturers Association (EJMA). This is a stress that runs

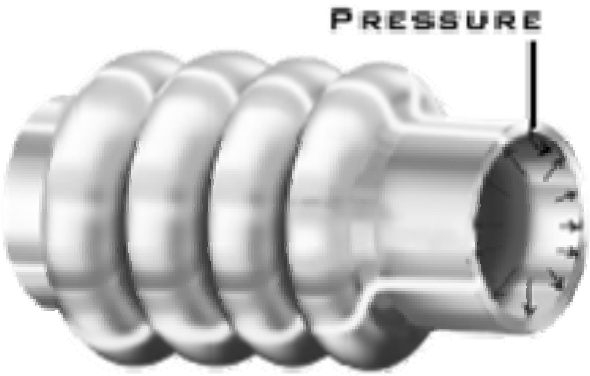
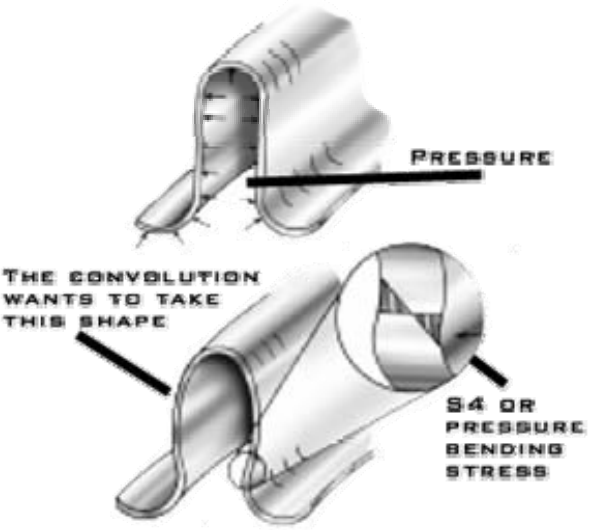



FIGURE 2. HOOP STRESS OR S2 RUNS IN THE CIRCUMFERENTIAL DIRECTION.




circumferentially around the bellows due to the pressure difference between the inside and the outside of the bellows.

Hoop stress is what holds a bellows together like the hoops on a barrel. This stress must be held to a code stress level. The customer should specify the code to be used.

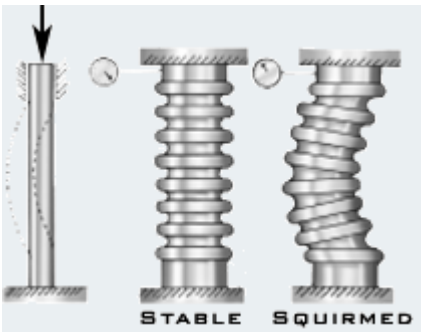
The bellow's ability to carry pressure is also limited by bulge stress or EJMA stress S4. This is a stress that runs longitudinal to the bellows centerline. More specifically, it is located in the bellows sidewall and it is a measure of the tendency of the convolutions to become less U-shaped and more spherical.

For bellows that are not annealed after forming, S4 is allowed by EJMA to exceed the initial yield strength of the bellows material by a large margin because it is cold worked. If a bellows is annealed after forming, S4 must be severely limited because the bellows sidewall material is no longer cold worked.

Accommodating a requirement for annealing will often result in the addition of reinforcing rings or a much heavier bellows material and more convolutions. Our standard policy is to provide bellows in the as-formed condition to take advantage of the added performance that is imparted to the bellows through cold work. Senior Flexonics Pathway will accommodate annealing requirements on request.

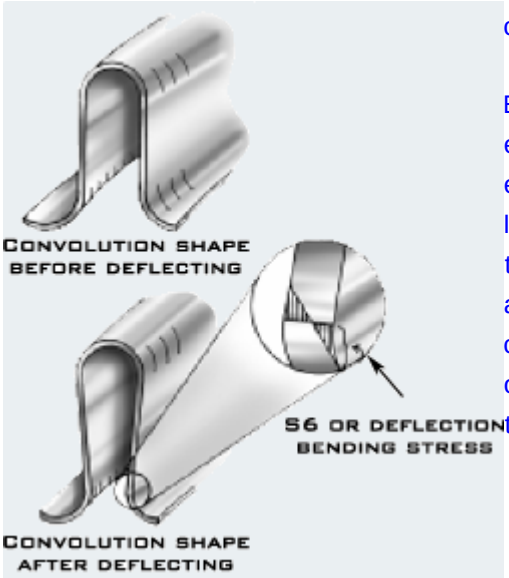
## Squirm

A bellows that is pressurized internally is similar in many ways to a column loaded in compression. At some loading, a long column will buckle. Similarly, an internally pressurized expansion joint will eventually buckle or squirm at some internal pressure loading. It is the responsibility of the expansion joint manufacturer to design the bellows to avoid squirm during operating conditions or pressure testing. Squirm can lead to catastrophic failure of a bellows. Our design equations treat squirm conservatively. A hydrostatic test of the completed expansion joint verifies stability. If hydrostatic testing is desired, it should be specified at the time of order placement.




## Cycle Life

When a bellows deflects, the motion is absorbed by bending of the sidewalls of each convolution. The associated stress caused by this motion is the deflection stress or EJMA stress S6. This stress runs longitudinal to the bellows centerline. The maximum value of S6 is located in the sidewall of each convolution near the crest or root.



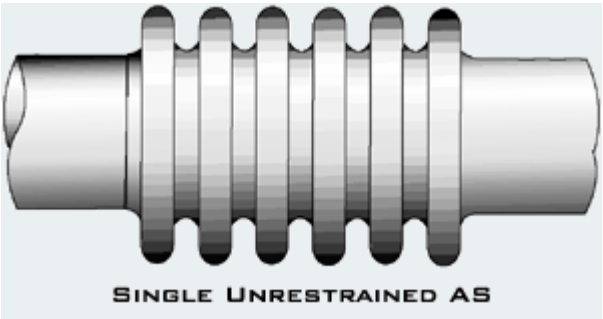

Expansion joints are designed to operate with a value for S6 that far exceeds the yield strength of the bellows material. This means that most expansion joints will take a permanent set at the rated axial, angular or lateral motion. Expansion joint bellows are rarely designed to operate in the elastic stress range. Therefore the bellows will eventually fatigue after a finite number of movement cycles. It is important to specify a realistic cycle life as a design consideration when ordering an expansion joint. An overly conservative cycle life requirement can result in a bellows design that is so long and soft that it is subject to squirm failure.

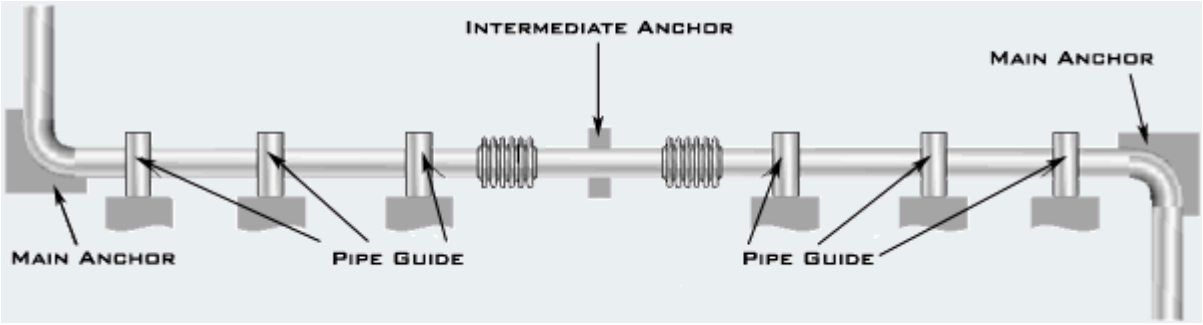
## Multiple Ply Construction

The necessary amount of metal to contain pressure can be achieved with a single ply of bellows material or multiple plies of material of reduced thickness. A bellows of multiple ply construction often has a lower spring rate than a single ply bellows for the same service. Thin material experiences less strain than a thick material for the same deflection. That means a multiple ply bellows may be shorter and it may have a higher cycle life than a single ply bellows for the same application.

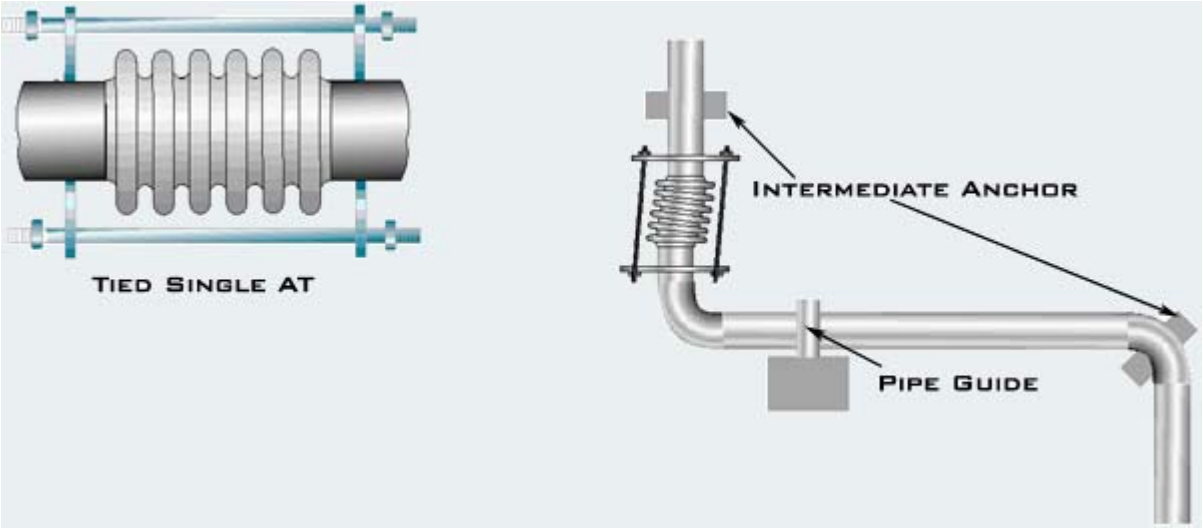
## Applications

**Single Expansion Joints AS** have one bellows. Axial compression and extension, lateral and angular movement can be accommodated. These expansion joints do not restrain the internal pressure thrust. The piping designer must provide the system with separate anchoring and guiding to resist the pressure thrust. Where small thermal movements are involved and proper anchoring and guiding is feasible, a single expansion joint is the most economical installation.

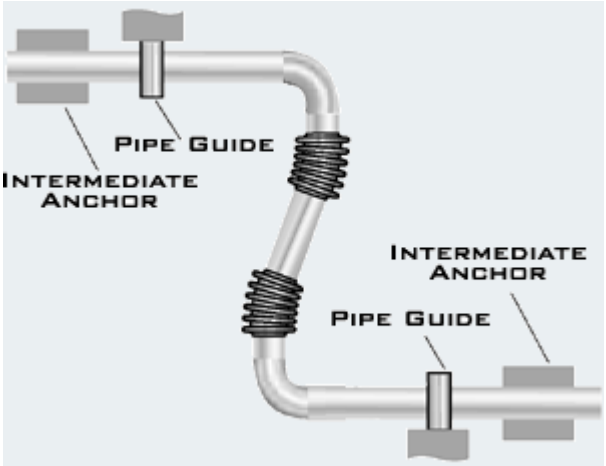



**Tied Single AT Expansion Joints** also have one bellows, except the overall length is restrained by tie rods designed to contain pressure thrust. A tied single is usually designed for lateral offset so that the tie rods can remain fully engaged and loaded with the pressure thrust force. A two tie rod design can accept angular deflection in a single plane.

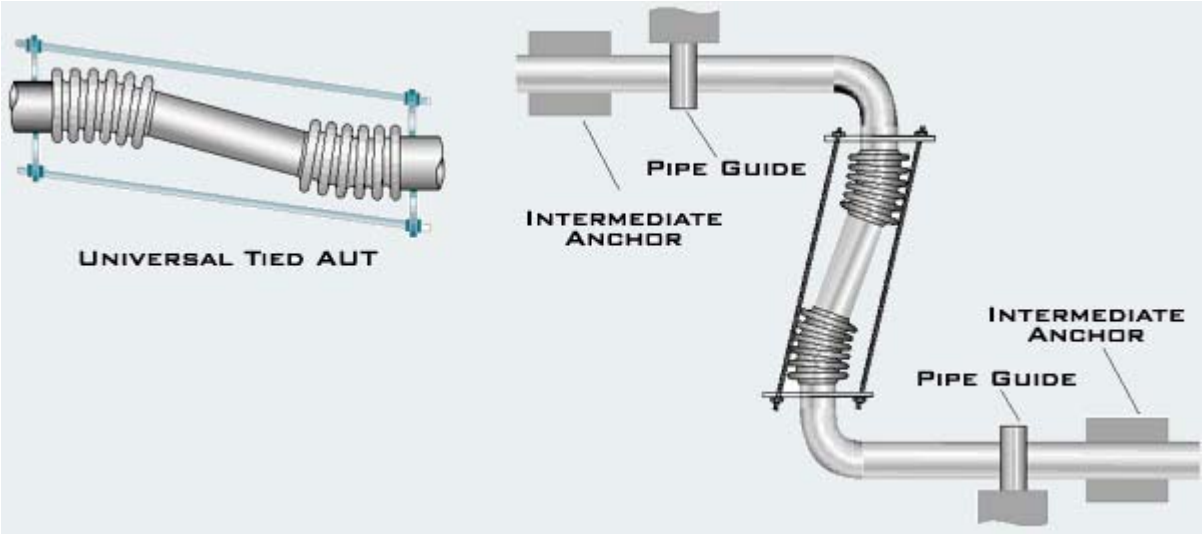


**Universal AU Expansion Joints** consist of two bellows separated by a pipe spool. This configuration accommodates large lateral movements, in addition to axial compression and extension and angular deflection. These expansion joints have no restraints to resist pressure thrust and like the singles, the piping designer must provide separate anchoring to handle pressure thrust.

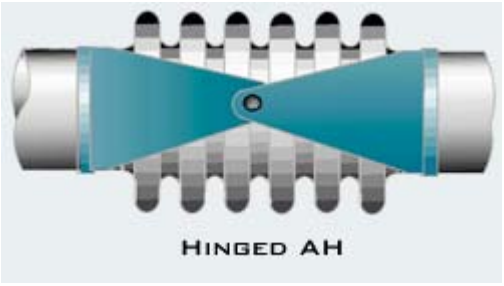




**Universal Tied, AUT Expansion Joints** contain two bellows separated by a pipe spool and tie rods designed to contain the pressure thrust force. These expansion joints are generally designed to accommodate lateral movement only. A universal expansion joint can be designed to have a very low lateral spring force to minimize forces on adjacent equipment. A two tie rod design can also accept angular deflection in a single plane.

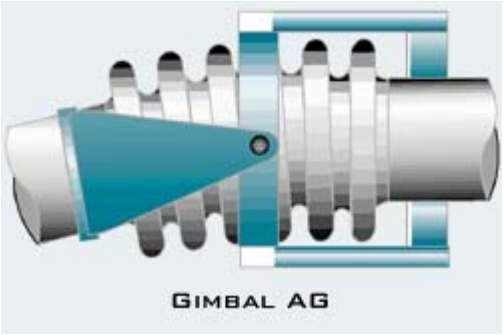
The tie rods are usually at or near ambient temperatures and, therefore, do not expand and contract as a function of the temperature of the media within the pipe. As a result, the thermal expansion of the length of pipe between the tie rod end plates is forced into the bellows as an axial movement. The bellows design must accommodate this axial thermal expansion as well as the specified lateral movement.




Sometimes a universal expansion joint has a very heavy center spool that can exert excessive weight on the bellows elements. To protect the bellows elements from excessive lateral loads, a support system such as a slotted hinge can be installed across the individual bellows elements to support the dead weight of the center spool.




**Hinged Expansion Joints AH** have a single bellows with overall length restrained by hinge hardware designed to accommodate pressure thrust. A hinged expansion joint allows angular movement in a single plane.




**Gimbal AG Expansion Joints** have a single bellows and gimbal hardware designed to resist pressure thrust. The gimbal expansion joint hardware operates like the universal joint on a drive shaft to accommodate angular movements in any plane.

## Applications

### Standard Liners (part number L)

Liners can be installed inside the expansion joint to protect the bellows from damage. Liners should be specified by adding the letter L to the part number when the following conditions exist:

- Smooth flow or low pressure drop is required.
- Velocities which may produce flow induced vibrations described below.
- For air, steam and other gases
    - Up to 6" Dia. flow greater than 4 ft/sec per inch of Dia. (Up to 150 mm Dia. flow greater than 0.05 M/sec per mm of Dia.)
    - Over 6" Dia. flow greater than 24 ft/sec (over 150-mm Dia. flow greater than 7.5 M/sec)
- For water and other liquids
    - Up to 6" Dia. flow greater than 1.67 ft/sec per inch of Dia. (up to 150 mm Dia. flow greater than 0.02 M/sec per mm of Dia.)
    - Over 6" Dia. flow greater than 10 ft/sec (over 150 mm Dia. flow greater than 3.0 M/sec)

### Covers (part number C)

Covers should be specified when:

- Protection from falling objects or protection from traffic is needed.
- Protection of personnel is needed.
- Insulation will be applied over the expansion joint.
- When high flow velocities may exist around the outside of the expansion joint, such as in the exhaust of a steam turbine.

Senior Flexonics Pathway always recommends a cover. The small cost for the cover is insurance against costly downtime due to damage. The standard cover is a removable design.

ANGULAR DEFLECTION: See DEFLECTION, ANGULAR.

ANGULAR ROTATION: The angular displacement of an expansion joint about the centerline of the bellows element. This type of movement is associated with an expansion joint with hinge or gimbal hardware. Units are typically Degrees.

ANGULAR SPRING RATE: The moment required per degree of angular displacement about the centerline of a single bellows element. Typical units would be (Inch-Pounds)/Degree. This is a critical performance indicator for hinged or gimbaled expansion joint. Angular spring rates listed in this web site are working spring rates. See SPRING RATE, WORKING for more explanation.

ANCHOR, MAIN: A structure used to restrain pipe from movement in any direction. It is designed to resist all forces imposed by the piping including pressure thrust from an expansion joint, guide friction, fluid inertia loads, wind load, seismic loads, and the dead weight load of the piping.

ANCHOR, DIRECTIONAL: An Anchor that resists movement in one or two axes only.

ANCHOR, INTERMEDIATE: An anchor that is located between expansion joints such that pressure thrust loads are canceled. An intermediate anchor is designed to resist guide friction, wind load, seismic loads, and the dead weight load of the piping.

ANCHOR BASE: An Anchor that is part of the expansion joint. The anchor base can be designed as a Main Anchor or Intermediate Anchor.

ANGULAR DEFLECTION: See DEFLECTION, ANGULAR

ASME CODE EXPANSION JOINT: An expansion joint manufactured to the ASME Section VIII Pressure Vessel Code or the ASME III Nuclear Code. Product requires certification and inspection by an independent agency. The most common code is Section VIII Division 1 that requires a "U" stamp.

AXIAL DEFLECTION: See DEFLECTION, AXIAL.

BANDS, NECK: A band of metal fused to the ID or OD of a bellows neck to increase the effective thickness of the neck portion of the bellows. A neck band may be used to facilitate welding of the bellows to the next component or it may be used to increase the thickness of the bellows neck for pressure containment.

BELLOWS: A corrugated metal cylinder, the corrugated portion of a metal expansion joint assembly.

BELLOWS NECK: The straight segment of bellows tube that extends outward from the outboard convolutions. A bellows element is generally attached to the next component at the end of the bellows neck. The neck portion must be long enough to isolate the bellows attachment weld from deflection stresses. Guidelines for neck length are defined in the Standards of the Expansion Joint Manufacturer’s Association.

CENTER SPOOL: Refers to the pipe spool that separates the two bellows elements in a double or dual expansion joint or universal expansion joint.

COLD SPRING: See PRESET

COLLAR: A band of metal used to reinforce the neck portion of a bellows to reduce the hoop stress on the bellows neck.

COMPENSATOR: Any device that compensates for movement of adjacent piping.

CONVOLUTION: A bellows element is made up of a series of annular bumps each of which is a convolution. A typical bellows convolution is “U” shaped with parallel side walls. A toroidal bellows convolution is has a spherical shape with curved side walls.

CONVOLUTION CREST: The curved portion of a convolution located at the outside diameter of the bellows element.

CONVOLUTED LENGTH: The length of the convoluted portion of a bellows element as measured from the root tangent of the first convolution to the root tangent of the last convolution.

CONVOLUTION ROOT: The curved portion of a convolution located at the inside diameter of the bellows element.

CORNER, CAMERA TYPE: A rectangular corner configuration in which the corrugation crests are attached to the corrugation roots of adjacent sides. The resulting corner shape has a 45 degree bevel at the corner, like the bellows on an old style box camera. Movements are somewhat reduced with this configuration. Fatigue life is magnitudes less than round corner design.

CORNER, MITERED: A rectangular corner configuration in which the adjacent corrugated rails are joined with a 45 degree miter like a picture frame such that the adjacent sides are attached crests to crest and root to root. This configuration has more movement capability than the camera corner. Fatigue life is magnitudes less than round corner design.

CORNER, ROUND: A rectangular corner configuration in which the adjacent corrugated rails are joined with a round corner. This configuration has more movement capability than the camera corner. Fatigue life of the round corner design is far superior to mitered corner or camera corner design.

COVER: A protective shroud that covers the outside surface of a bellows used to protect the bellows from external mechanical damage or high velocity flow. The cover may also be used as a mounting surface for insulation.

CYCLE LIFE: The number of combined displacement and pressure cycles that a bellows can withstand for a given design Code. Fatigue calculations vary depending on the Code that is applied. The Expansion Joint Manufacturer’s Association (EJMA) fatigue or cycle life calculation is an average number of cycles to failure. The ASME B31.3 or ASME Section VIII fatigue calculation predicts an assured number of cycles before failure. Cycle life predictions for Senior Flexonics Pathway products are based on EJMA criteria unless a Code is specified.

DEFLECTION, ANGULAR: Rotation about the center of a bellows element, the type of deflection that would occur if the expansion joint had hinge or gimbal type hardware. Angular deflection should not to be confused with torque which is rotation about the axial centerline of the expansion joint. See TORQUE. Units are in degrees or radians.

DEFLECTION, AXIAL: The compression or extension of an expansion joint along the axial centerline. Units are generally Inches or Millimeters.

DEFLECTION, LATERAL: The offset of an expansion joint in the direction perpendicular to the longitudinal centerline, shear type movement. Units are generally Inches or Millimeters.

DESIGN PRESSURE: See PRESSURE, DESIGN

DOUBLE EXPANSION JOINT: Two expansion joints separated by a center spool that contains an intermediate anchor. The Senior Flexonics Pathway “Double X-Press®” is a variation of the double expansion joint designed to accommodate movements from long pipe runs extending in both directions away from the anchored Double X-Press.

EFFECTIVE AREA: The area of the bellows defined by the Mean Diameter of the convolutions. Typical units are Inches^2. When effective area is multiplied by pressure the resultant is pressure thrust. See MEAN DIAMETER.

EJMA: See EXPANSION JOINT MANUFACTURER’S ASSOCIATION.

EXPANSION JOINT MANUFACTURERS ASSOCIATION®: Often referenced by the acronym EJMA, a trade association consisting of a grouping of the leading manufacturers of metal bellows expansion joints. EJMA publishes the Standards of the Expansion Joint Manufacturers Association, the most commonly specified reference for expansion joint design.

EXPANSION JOINT, METAL: A leak tight assembly of bellows elements and fittings designed to absorb imposed movements. Movements may include any combination axial, lateral and angular deflection.

EXTERNALLY PRESSURIZED EXPANSION JOINT: Refers to an expansion joint style that is designed to have the media pressure external to the bellows element. Externally pressurized expansion joints are generally designed to accommodate long axial strokes and relatively high pressure. Steam distribution and Liquified Natural Gas (LNG) service are typical applications. The long stroke capability requires a relatively long bellows element that may be subject to instability if it were pressurized internally. By designing the bellows to be externally pressurized instability concerns can be avoided.

FATIGUE LIFE: See CYCLE LIFE.

FLANGE, ANGLE: Flanged connection made from structural angle or as a fabricated section. Can be used with round or rectangular expansion joints. The flange can be drilled for field bolting or undrilled for welded installation.

FLANGE, FLOATING: A rotatable flange. See FLANGE, LAP JOINT or FLANGE, VANSTONED.

FLANGE, FORGED: Flange connection made from forged steel or forged alloy material faced and drilled to match specified flange standard.

FLANGE, LAP JOINT: Flange connection consisting of a fabricated pipe fitting (lap joint stub end) and rotatable backing flange (lap joint flange). The face of the stub end is machined to the raised face dimension of the specified flange standard. The fabricated fitting isolates the flange from potentially corrosive media such that the lap joint stub end can be made from less expensive material than the lap joint flange. Not to be confused with vanstoned flange. See FLANGE, VANSTONE.

FLANGE, PLATE: Flange connection made from plate material and drilled to match specified flange standard. The plate thickness matches the web thickness of the specified flange standard.

FLANGE, SLIP-ON: Generally refers to a forged flange with dimensions in accordance with ANSI B16.5 standards. A slip-on flange slips over the OD of the pipe to which it is attached and is seal welded on the flange ID and structurally welded to the raised hub on the back side of the flange.

FLANGE, WELD NECK: Generally refers to a forged flange with dimensions in accordance with ANSI B16.5 standards. A weld neck flange has a long tapered hub that allows for a butt weld attachment to the adjacent pipe. For B31.3 applications a weld neck flange is often preferred by customers because of the added strength that is imparted by the long tapered hub.

FLANGE, VANSTONED: Flange connection that is made by flaring the bellows material over the face of the flange. The flared bellows material forms a smooth raised face gasket surface with dimensions similar to a slip-on flange. This configuration is similar to a Lap Joint flange in that the flange is isolated from potentially corrosive media, thereby allowing the use of less expensive flange material. Like the Lap Joint configuration, the flange can rotate to facilitate field installation. The rotatable flange can be a plate flange or a slip-on type forged flange. See also FLANGE, LAP JOINT.

FLOW DIRECTION: The direction of flow of the fluid through and expansion joint. It is important to specify flow direction if a liner is used to isolate the bellows element from fluid flow.

GIMBAL EXPANSION JOINT: Gimbal expansion joints absorb angular movement in any plane. The construction is similar to the universal joint of an automobile. Two pairs of hinges attached to a central gimbal ring such that one hinge pair is rotated 90 degrees from the second hinge pair. The hinge / gimbal structure is designed to contain pressure thrust. A gimbal expansion joint does not absorb torsional movement. Generally gimbal expansion joints are used in pairs to accommodate lateral pipe movement angular deflection of each gimbal.

GUIDE, AXIAL: A pipe guide used to maintain axial alignment by resisting all non-axial movement of pipe.

GUIDE, INTERNAL: Refers to an expansion joint style that incorporates internal hardware that acts as an axial pipe guide. An externally pressurized expansion joint is internally guided by design. An internal guide can be incorporated into any internally pressurized expansion joint that is designed to accommodate axial movement only.

GUIDE, PIPE: Any type of guide that directs pipe to move in a specific direction. See GUIDE, AXIAL.

GUIDE, PLANAR: A pipe guide that allows movement in a single plane.

HINGED EXPANSION JOINT: Hinged expansion joints permit angular motion in one plane. The hinges are designed to contain the full pressure thrust load. When two or three hinged expansion joints are correctly installed in a pipe run they can absorb thermal movements in a single plane.

HVAC: An abbreviation for Heating Ventilation and Air Conditioning.

IN-LINE PRESSURE BALANCED EXPANSION JOINT: A special type of pressure balanced expansion joint that eliminates pressure thrust but does not require an elbow or change in flow direction to be an integral part of the design. Pressure balancing is achieved by mechanically linking balancing bellows that have a difference in area that is exactly equal to the area of the flow bellows.

INTERNAL SLEEVE: See LINER, SINGLE or LINER, TELESCOPING.

LATERAL DEFLECTION: See DEFLECTION, LATERAL.

LINER, SINGLE: High media velocity against the bellows can result in harmonic vibration of the bellows element which can result in catastrophic failure of the bellows due to high cycle fatigue. A single flow liner is an internal sleeve fixed to the fitting at the upstream end of the bellows and open at the downstream end. It is used to isolate the bellows element from fluid flow. All expansion joints with a flow liner must have the flow direction clearly labeled on the outside of the assembly.

LINER, TELESCOPIC: A telescopic flow liner consists of two overlapping internal sleeves used to isolate a bellows from media flow. The internal sleeve is fixed to the fitting at the upstream end of the bellows and the external sleeve is fixed to the fitting at the downstream end of the bellows element. A telescoping liner may be used to minimize the loss of flow area through a bellows. Telescoping liners are also used when it is necessary to minimize the operating temperature of the bellows in service. Flow direction must be clearly labeled on the outside of the expansion joint.

LIVE LENGTH: The corrugated length of a single bellows element as measured from the root to root of the outboard convolutions. For a universal expansion joint live length is the length of the entire universal as measured from the root of the outboard convolutions.

MEAN DIAMETER: The average diameter of the bellows element calculated by adding the bellows inside diameter plus outside diameter and dividing by two. Mean diameter is used to calculate the bellows effective area. See EFFECTIVE AREA, PRESSURE THRUST FORCE.

MOTION INDICATORS: An arrow and scale device that visually displays the movement of an expansion joint from the as-installed position.

MULTIPLE PLY BELLOWS: Bellows elements made from two or more tubes that have been telescoped together prior to forming of the convolutions. Each ply is designed to accommodate a portion of the design pressure (hoop stress) such that all plies are required for safe operation. For a given set of design conditions a multiple ply bellows element has a lower axial spring rate and a higher cycle life than a single ply bellows element. Friction between the plies also has a dampening effect making a multiple ply bellows more attractive for high frequency and high cycle vibration situations. Not to be confused with Ply Testable Bellows. See also PLY TESTABLE BELLOWS.

NDT: See NON-DESTRUCTIVE TESTING

NON-DESTRUCTIVE TESTING: In process manufacturing tests that might include dye penetrant examination of welds, radiography of butt welds, pressure testing, ultrasonic testing, helium leak testing, Positive Material Identification and others. The extent of testing is a requirement of the imposed Code or customer preference.

NOMINAL PIPE SIZE: Refers to the rounded dimension in Inches that is most closely associated with a given pipe size. For standard pipe sizes over 12” the dimension is the actual pipe OD in Inches. For pipe sizes 12” and under the dimension is approximately the same as the ID for a standard wall pipe. For actual dimensions refer to ANSI B36.10 for carbon steel pipe and ANSI 36.19 for stainless steel pipe. Nominal pipe sizes may be stated in millimeters as DNXXX where XXX is a rounded millimeter value based on ISO standards.

NPS: See NOMINAL PIPE SIZE

PACKED EXPANSION JOINT: An expansion joint that uses a packing material to seal against the media. Packed expansion joints are either ball type for rotational movement or axial type for longitudinal movement. Axial expansion joints with packing are also called slip joints.

PACKLESS EXPANSION JOINT: Metal bellows type expansion joint.

PANTOGRAPH LINKAGE: A double diamond shaped truss that is used with a universal expansion joint to equalize individual bellows movements while providing support to the center spool. The ends of the linkage are fixed to the outboard fittings on the universal expansion joint and the center of the pantograph is fixed to the center of the spool separating the bellows elements. Holding one end of the expansion joint fixed, the pantograph forces the center spool to move exactly half of the movement of the opposite end. The pantographic linkage does not resist pressure thrust.

PIPE GUIDE: See GUIDE, PIPE

PITCH: The length of a single convolution in a bellows element or (live length)/(number of convolutions)

PLY: Refers to one layer of material used to make up a metal bellows element. Most bellows are single ply construction. Bellows elements made of more than one ply are called multiple ply bellows. See MULTIPLE PLY BELLOWS and PLY TESTBLE BELLOWS

PLY TESTABLE BELLOWS: A special type of multiple ply bellows in which each ply is designed to accommodate 100% of the design pressure (hoop stress) such that only a single ply is required for safe operation. The ply testable bellows design provides 100% operational redundancy. The space between the plies is generally monitored to sense for any leakage of the ply that is against the media. This ply testable concept is very attractive for expansion joints that are used in critical service conditions.

PRESET: Lateral, axial or angular deflection applied to a finished expansion joint, also known as Cold Spring. The preset is maintained with shipping devices until the assembly is installed. Preset is used to increase the movement capability of an expansion joint or to provide the opportunity for the expansion joint to operate with a low spring force in service.

PRESSURE BALANCED ELBOW: See PRESSURE BALANCED EXPANSION JOINT

PRESSURE BALANCED EXPANSION JOINT: A specialized expansion joint assembly that incorporates a flow bellows element and a balancing bellows element of equal area to balance pressure thrust forces thereby eliminate pressure thrust on adjacent anchors. The most common pressure balanced expansion joint incorporates a pipe elbow with the balancing element located on the back side of the elbow. Tie rods connect the flow bellows and the balancing bellows elements. A pressure balanced expansion joint can accommodate axial, lateral and angular movements. See also IN-LINE PRESSURE BALANCED EXPANSION JOINT

PRESSURE, DESIGN: The customer specified pressure (must be combined with Design Temperature) that is used to design the bellows element and pressure thrust restraint hardware.

PRESSURE, EXTERNAL: If an expansion joint is applied in a situation wherein the assembly is exposed to external pressure, this condition must be clearly specified. Expansion joints that operate inside of pressure vessels are frequently designed for external pressure conditions as well as internal pressure conditions.

PRESSURE, INTERNAL: Most expansion joints are internally pressurized in service and it is assumed that the design pressure is internal to expansion joint unless another condition is specified. Any bellows that can accommodate 15 PSIG of internal pressure can also accommodate full vacuum conditions.

PRESSURE, OPERATING: The pressure at which an expansion joint is intended to operate in service. Generally, the design pressure is slightly higher than the operating pressure to accommodate unanticipated pressure surges. See PRESSURE, DESIGN.

PRESSURE, SQUIRM: All internally pressurized bellows will become unstable at some pressure, similar to a column under compressive loading. The EJMA design equations predict a theoretical pressure at which squirm is likely to occur. The Squirm or Stability Pressure that is shown on a Senior Flexonics Bellows Design Analysis is the theoretical value divided by a generous safety margin.

PRESSURE, STABILITY: See PRESSURE, SQUIRM

PRESSURE, TEST: For the purpose of this web site, the pressure at which an expansion joint is to be pressure tested prior to shipping. The test pressure can be customer specified or calculated based on the customer specified Code. Pressure testing is one of many optional Non-Destructive Tests that can be performed on an expansion joint.

PRESSURE THRUST FORCE: An expansion joint can be modeled as a hydraulic cylinder with a spring inside. The spring represents the mechanical resistance to movement. The area of the hydraulic cylinder is the mean area of the bellows, the area defined by the mean diameter of the convolutions. When pressurized internally, a bellows will elongate with a force equal to the applied pressure times the mean area of the bellows. The elongating force is called the pressure thrust force. See MEAN DIAMETER, EFFECTIVE AREA

PUMP CONNECTOR: A metal expansion joint with limit rods or hose assembly used to isolate pumps or compressors from rigid piping.

PURGE CONNECTIONS: A port or ports located between the upstream end of a bellows element and the liner attachment. Purge media is introduced through the purge ports to flush the bellows – liner cavity to avoid build up of contaminants or particulates.

REINFORCED BELLOWS: Refers to a bellows element that includes external reinforcing rings to increase the bellows strength for high operating pressure. See RINGS, REINFORCING.

RODS, CONTROL: Rods (usually threaded) fixed to plates or lugs on adjacent ends of an expansion joint and used to control the movements of an expansion joint bellows. Control rods are not designed to contain pressure thrust at design or test pressure.

RODS, LIMIT: Rods (usually threaded) fixed to plates or lugs on adjacent ends of an expansion joint and used to limit the axial extension or compression of an expansion joint bellows. Similar to control rods except that limit rods are designed to contain pressure thrust at design and test pressure.

RODS, TIE: Rods (usually threaded) fixed to plates or lugs on adjacent ends of an expansion joint and generally used to fix the length of an expansion joint bellows. Tie rods like limit rods are designed to contain pressure thrust at design and test pressure.

RINGS, EQUALIZING: A Tee shaped reinforcing ring that limits the axial compression of each convolution to the gap that exists between each reinforcing ring.

RINGS, REINFORCING: Rings that are installed between convolutions to reinforce the bellows element. The ring material is in intimate contact with the bellows element thereby reducing the hoop stress of an internally pressurized bellows while it is at pressure. The rings can be made from tubing, pipe, forgings, or machined plate or they can be fabricated from any combination of these materials.

SHIPPING RESTRAINTS: Also called shipping bars, shipping restraints are welded or bolted connections that fix the overall length of an expansion joint and restrain movement of any internal components that are supported by the bellows elements. The shipping restraints protect the expansion joint bellows elements from fatigue that could result from transportation movements and they facilitate handling of the expansion joint during installation. The restraints are to be left in place until installation is complete.

SHROUD: See COVER

SINGLE EXPANSION JOINT: An expansion joint with one bellows element.

SLOTTED HINGE EXPANSION JOINT: A single or universal expansion joint with slotted hinge hardware bridging the bellows element(s). The slotted hinge hardware accommodates axial and angular movement. Generally the slotted hinge concept is used to resist shear forces (lateral deflection forces) across the bellows element. In a universal expansion joint slotted hinges are often used to support a heavy center spool, thereby isolating the bellows element from the weight of the center spool. Generally the slotted hinge hardware is not designed to resist pressure thrust.

SWEAT END: Refers to an overlapping or telescoping end connection that is joined by soldering or brazing. Commonly used with copper tube.

SPRING RATE: General reference to the spring constant of a metal bellows or expansion joint assembly. See SPRING RATE, AXIAL, SPRING RATE, LATERAL, SPRING RATE, ANGULAR, SPRING RATE, WORKING, SPRING RATE, ELASTIC.

SPRING RATE, AXIAL: The force per unit of deflection required to compress or extend a bellows or expansion joint along its longitudinal centerline. Typical units are Pounds/Inch or Newtons/Millimeter. Spring rates listed in this web site are working spring rates. See SPRING RATE, WORKING for more explanation.

SPRING RATE, ANGULAR: The moment per unit of deflection required to rotate an expansion joint about the center of a bellows element. Angular spring rate should not to be confused with torsional stiffness or torsional stiffness about the bellows axial centerline. See TORQUE. Typical units are in Inch-Pounds/Degree or Newton-Meters/Degree. Spring rates listed in this web site are working spring rates. See SPRING RATE, WORKING for more explanation.

SPRING RATE, ELASTIC: The initial force per unit of measure required to deflect a bellows or expansion joint assembly. All bellows spring rates are derived from the axial spring rate. The elastic spring rate is generally described as the "Theoretical axial elastic spring rate" in the Standards of the Expansion Joint Manufacturer's Association Standards. Spring rates for expansion joints listed on this web site are working spring rates that take into account plastic deflection. See SPRING RATE, WORKING.

SPRING RATE, LATERAL: The force per unit of deflection required to offset of an expansion joint in the direction perpendicular to the longitudinal centerline. Typical units are Pounds/Inch or Newtons/Millimeter. Spring rates listed in this web site are working spring rates. See SPRING RATE, WORKING for more explanation.

SPRING RATE, TORSION: The moment per degree of rotation to deflect a bellows about the axial center line. Axial torsion causes a shear stress in the bellows membrane and should be avoided or minimized by design. However, it is recognized that torsion is generally present to some degree at most expansion joint locations. When evaluating an expansion joints using a pipe stress program it is important to input a reasonably accurate value for expansion joint torsional spring rate. Assuming a very high torsional spring for an expansion joint in a pipe stress input is not conservative. The Senior Flexonics Pathway bellows design output provides a torsional spring rate value for use in pipe stress programs. Typical units are (Inch-Pounds)/Degree or Newton-Meters/Degree. Torsional spring rate should not be confused with angular spring rate. See SPRING RATE, ANGULAR

SPRING RATE, WORKING: The average force per unit of measure required to deflect a bellows or expansion joint assembly. This is a spring rate that takes into account plastic deformation of the bellows and the resulting reduction in average spring rate that occurs during plastic deflection. Most industrial expansion joints are designed for deflections that result in plastic movement of the bellows. Spring rates for expansion joints listed on this web site are working spring rates that take into account plastic deflection.

TANGENT: See BELLOWS NECK

TIE RODS: See RODS, TIE

TOROIDAL BELLOWS: Refers to a reinforced bellows with circular convolutions in lieu of more typical “U” shaped convolutions. Toroidal bellows can accommodate very high pressures. The design parameters are described in the Standards of the Expansion Joint Manufacturer’s Association.

TORQUE: An axial moment applied to a bellows causing a shear stress in the bellows membrane. Torque should be avoided or minimized by design. However, it is recognized that torsion is generally present to some degree at most expansion joint locations. Hardware such as hinges, slotted hinges, and gimbals can be used to isolate the bellows elements from excessive torsional loading. Not to be confused with angular movement. See DEFLECTION, ANGULAR.

TORSION: See TORQUE

UNIVERSAL EXPANSION JOINT: A universal expansion joint consists of two bellows elements separated by a center spool. The bellows elements act like knuckles to accommodate lateral offset. An untied universal accepts axial and lateral movement and does not contain pressure thrust. A tied universal expansion joint accepts lateral movement only.

UNREINFORCED BELLOWS: Refers to a bellows that does not have any external reinforcement. Most bellows are of this design. See also RINGS, REINFORCING.

WELDED BELLOWS: Also known as disc welded bellows. Refers to a bellows made from profiled disks that are welded ID to ID, OD to OD, ID to ID to form convolutions of extremely short pitch. Disc welded bellows have extremely low spring rates and are preferred for many applications where spring rate and short length is critical. Disk welded bellows are generally not used for piping applications.

X-PRESS® EXPANSION JOINT: The brand name for an externally pressurized expansion joints manufactured by Senior Flexonics Pathway. The product is designed for use in long axial pipe runs such as steam distribution.