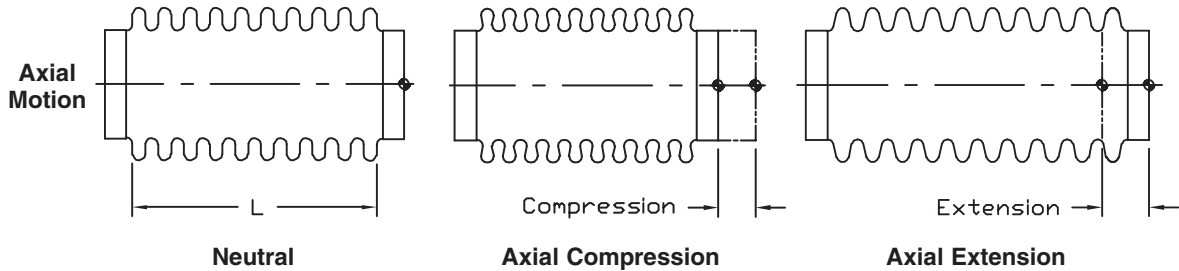
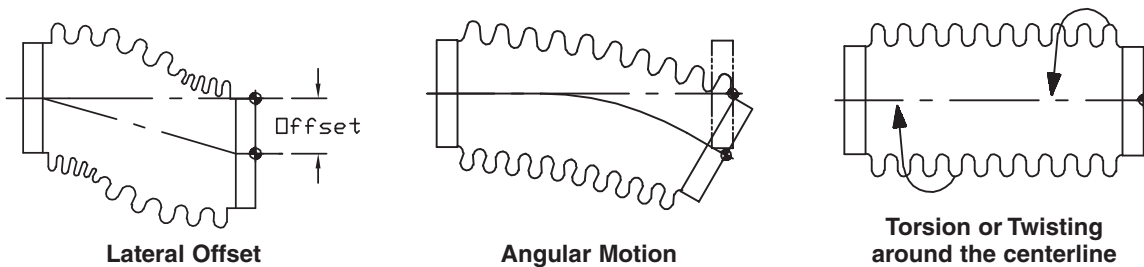


BELLOWS MOVEMENT

A metal bellows consists of individual convolutions have uniform inside and outside diameters, constant pitch or spacing, and the planes of each convolution are parallel. The flexibility of the convolutions gives the bellows the ability to absorb axial, angular and lateral displacements – individually or in combination.



Axial motion is extension or compression of the bellows along the longitudinal centerline (x-axis) with the ends remaining parallel. The motion is absorbed equally by all convolutions.



Lateral or offset motion is the displacement of the ends perpendicular to the longitudinal centerline with the end planes remaining parallel. The longitudinal centerline is shaped into a compound curve with the convolutions deforming in a similar manner.

Angular motion is the rotation or angulation of the end planes relative to each other, which results in the longitudinal centerline becoming an arc. The convolutions are extended along the outer radius of the arc, and compressed along the inside radius.

Torsion or twisting is rotation around the longitudinal centerline of the bellows and is sometimes confused with angular motion. A bellows does not absorb torsional displacement, and although a bellow can react torsional moments, they should be avoided if at all possible.

Bellows can absorb these movements as individual motions or in any combination and in multiple planes. Aside from the physical limitations of deflecting a bellows without damaging it, the design is normally based on specified cyclic movements for a given fatigue life at the operating pressure and temperature. The accepted method for equating axial, lateral and angular motions is outlined in the [Standards of the Expansion Joint Manufacturers Association, Inc.](#) The following equations are based on this method but are for complete bellows – not per convolution as described by the Standards.

x = Axial Extension (+) or Compression (-)

y = Lateral Offset (if offset is more than plane – resolve by vectorial analysis)

θ = Angular displacement (degrees)

d_m = Bellows Mean Diameter = $\frac{I.D. + O.D.}{2}$

L = Bellows Convolute Length

E_c = Rated Axial Compression = $E_\theta + E_y + E_x$

E_e = Rated Axial Extension = $E_\theta + E_y - E_x$

E_x = Axial Extension or Compression = x

E_y = Equivalent Lateral Offset = $\frac{3yd_m}{L \pm x}$

**E_θ = Equivalent Angular Travel = $0.00875\theta d_m$
(if angular travel and lateral offset are not in the same plane – resolve by vector analysis)**

A typical bellows design over a range of diameters has 12 inches convoluted (L) length and is rated for 3 inches compression (E_c) with zero lateral and angular movements. The following table is a tabulation of the equivalent lateral (E_y) with zero axial and angular, and the equivalent angular (E_θ) with zero axial and lateral.

Nominal Size	Mean Diameter, d_m (inches)	Lateral Offset, y (inches)	Angulation θ, (degree)
6 NPS	7.18	1.67	47.75
12 NPS	13.73	0.87	24.97
24.0" ID	25.25	0.48	13.58
48.0" ID	49.38	0.24	6.94
96.0" ID	98.00	0.12	3.50

The correct specification of bellows movement requirements is one of the most essential factors in the successful application of this product. The axial, lateral and angular movements must be realistically stated along with the corresponding cycle life. One of the most common mistakes made is to overstate these values in an attempt to obtain a conservative design. Over emphasis of any parameter can jeopardize other elements of the design as well as result in unnecessary costs. Several good rules to remember when specifying motions include:

- Separate the cyclic and noncyclic motions, such as installation displacements. Both should be included, but they obviously have different cycle requirements.
- Distinguish between normal operating movements and upset conditions.
- When comparisons are made to manufacturers rated motions, be sure to distinguish between concurrent and nonconcurrent values.
- Realistically state fatigue life requirements. Cycle life is not proportional to rated travel. Small changes of displacement can result in substantial cycle life changes, and visa versa.
- Avoid large lateral offset requirements for single bellows – particularly for large diameter bellows.