Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test
11. Designing with Expansion Joints

- Types of Expansion Joints
- Pressure Thrust
- Installation of Expansion Joints
- Metal Bellows Expansion Joints

The Material in This Section is Addressed by B31.3 in:

Chapter II - Design
Appendix X - Metallic Bellows Expansion Joints
Types of Expansion Joints

Ball

Rubber Bellows

Metal Bellows

Pressure Thrust

Fig. B-5 Pressure Thrust

Expansion Joint Manufacturer’s Association (EJMA)
Pressure Thrust

For a bellows type expansion joint, the pressure thrust force is the effective thrust area recommended by the manufacturer times the pressure. In the absence of this information:

\[ F = P \times \frac{\pi \times d_p^2}{4} \]

Where

- \( F \) = pressure thrust force
- \( P \) = pressure
- \( d_p \) = mean diameter of bellows

Which types of expansion joints have this problem?
Pressure Thrust

Net force on nozzle = $P_{An}$
Net force on vessel = 0

Pressure Thrust

Net force on nozzle = $F - P_{An}$
Net force on vessel = $F$
Net force on anchor = $F$
Pressure Thrust Workshop

What is the apparent change in the weight of a vessel caused by increasing the pressure by 100 psi (700 kPa)?

See the supplement, page 52.

Installation of Expansion Joints

Anchors must be designed for full pressure thrust based on maximum operating pressure.

(EJMA)
Bellows Movement

**Axial (EJMA)**

**Rotation (EJMA)**

---

Bellows Movement

**Lateral (EJMA)**

Inefficient for bellows

Bellows are not intended to take torsional displacement.

**Efficient use of bellows for Lateral movement (EJMA)**
Universal Expansion Joint

Piping Technology & Products (PTP)

In-plane application (EJMA)

3-dimensional application (EJMA)
Hinged Expansion Joint

(EJMA) (Adasco) (Hae Jo Industrial)

Hinged Expansion Joint

(EJMA) (EJMA)
Gimbal Expansion Joint

(EJMA)  (Adsco)  (Hae Jo Industrial)
Pressure Balanced Expansion Joint

(EJMA) (Hae Jo Industrial)
Pressure Balanced Expansion Joint

Bellows Expansion Joint Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Type</th>
<th>Axial</th>
<th>Lateral</th>
<th>Rotation</th>
<th>Pressure Thrust</th>
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<td>Yes</td>
<td>Small</td>
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<td>Universal (tied)</td>
<td></td>
<td>Yes</td>
<td></td>
<td>Yes</td>
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<td>Hinged</td>
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<td></td>
<td></td>
<td>Yes</td>
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</tr>
<tr>
<td>Gimbal</td>
<td></td>
<td></td>
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<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Pressure Balanced</td>
<td></td>
<td>Yes</td>
<td>Small</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>
Metal Bellows Expansion Joints

- Bellows Shapes
- Failure Modes

Bellows Shapes (EJMA)

- Semi-toroidal
- U-shaped
- S-shaped
- Toroidal
- Flat
- Stepped
- Single Sweep
- Nested Ripple
Bellows Shapes (EJMA)

- Unreinforced U
- Reinforced U
- Toroidal

Metal Bellows Failure Modes

- In-plane squirm
- Column squirm
- Fatigue
  (Design Factor = 2.6 on cycles)
- Creep-fatigue
- Burst, collapse, over stretching
  (Design Factor = 3.0 on burst)
- Corrosion
Flixborough Disaster

- 1974 cyclohexane vapor cloud explosion (UK)
- Killed 28, injured 89, damaged 1821 homes
- Caused by plant personnel's failure to recognize expansion joint pressure thrust problem

Metal Bellows Fatigue

![Graph showing metal bellows fatigue with stress range vs. number of cycles for EJMA unreinforced, EJMA reinforced, B31.3 unreinforced, and B31.3 reinforced.]