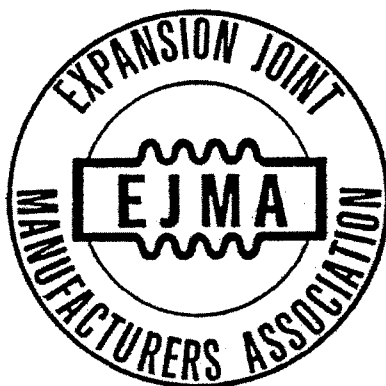


STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION, INC.

EIGHTH EDITION 2003



TM

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STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION, INC.

FOREWORD

Since 1958, when the Expansion Joint Manufacturer's Association (EJMA™) first published these Standards, continuing technological improvements in the application and design of Expansion Joints have been reported through the cooperative efforts of its association members by expanding the scope and content of this publication. Founded three years earlier in 1955, the Expansion Joint Manufacturer's Association began with a group of companies experienced in the application, design, and fabrication of Expansion Joints. The first EJMA™ Standard edition was, of necessity, somewhat brief and covered only applications involving axial movement. But as research and extensive testing results were catalogued, more detailed design data has been included in the EJMA™ Standard. The EJMA™ Standards are only intended for application to metallic bellows expansion joints.

The EJMA™ Technical Committee is dedicated to continuously improving the utility and technical content of the Standards. Suggestions and comments from industry users are welcomed and should be forwarded to the Secretary of this Association in writing.

It is important to note that the EJMA™ Standard is a trade association document containing recommendations for application of expansion joint products and in-depth technical information for use in designing expansion joint products. It is not a manufacturing standard or a quality assurance document. The type of non-destructive examination and the extent of quality assurance testing to be applied to given product should be addressed by other documents such as the ASME B31.3 Piping Code, the ASME Pressure Vessel Code or another user provided specification. The Standard does not limit or dictate the manufacturing process to be used for construction of expansion joints, nor does it establish specific engineering requirements deemed necessary for the safe application, design and manufacture of Expansion Joints. If there is a strong preference for a certain type of manufacturing process, the user should provide this information. Industry users are cautioned that these Standards should not be considered as a design handbook, and must not replace sound engineering judgment, education and experience.

As of this writing, the EJMA™ Standard thoroughly covers the design of expansion joint bellows elements. However, the Standard does not cover the design of hardware associated with restraint of pressure thrust. Pressure thrust restraint hardware is as important as the bellows element in the design and fabrication of an expansion joint assembly. Users are strongly advised to obtain documented design results for bellows elements and pressure thrust restraint hardware for any critical application.

NO WARRANTY EXPRESSED OR IMPLIED

The engineering Standards herein are recommended by the Expansion Joint Manufacturers Association, Inc. to assist users, engineers, architects and others who specify, design and install Expansion Joints in piping systems to obtain the most efficient service from Expansion Joint installations. These Standards are based upon sound engineering principles, research and field experience in the manufacture, design, installation and use of Expansion Joints. These Standards may be subject to revision as further investigation or experience may show is necessary or desirable. Utilization of these Standards remains entirely optional. Nothing herein shall constitute a warranty of any kind, expressed or implied. Accordingly, all warranties of whatever nature, expressed or implied, are herewith specifically disclaimed and disavowed.

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EXPANSION JOINT MANUFACTURERS ASSOCIATION, INC.

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Badger Industries, Inc. - Zelienople, PA
Expansion Joint Systems, Inc. - Santee, CA
Flexider S.r.l.- Torino, Italy
Hyspan Precision Products, Inc.- Chula Vista, CA
Senior Flexonics, Inc., Pathway Division – Oak Ridge, TN, New Braunfels, TX
U.S. Bellows, Inc. – Houston, TX
WahlcoMetroflex, Inc.- Lewiston, ME
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SECTION A - DEFINITIONS AND NOMENCLATURE

A-1. DEFINITION OF TERMS

The Expansion Joint Manufacturers Association, Inc. has adopted the following definitions of Expansion Joint components and related equipment.

A-1.1 EXPANSION JOINTS

Any device containing one or more bellows used to absorb dimensional changes, such as those caused by thermal expansion or contraction of a pipeline, duct or vessel.

A-1.1.1 DOUBLE EXPANSION JOINT

A double Expansion Joint consists of two bellows joined by a common connector which is anchored to some rigid part of the installation by means of an anchor base. The anchor base may be attached to the common connector either at installation or at time of manufacture. Each bellows acts as a single Expansion Joint and absorbs the movement of the pipe section in which it is installed independently of the other bellows. Double Expansion Joints should not be confused with universal Expansion Joints.

A-1.1.2 GIMBAL EXPANSION JOINT

A gimbal Expansion Joint is designed to permit angular rotation in any plane by the use of two pairs of hinges affixed to a common floating gimbal ring. The gimbal ring, hinges and pins must be designed to restrain the thrust of the Expansion Joint due to internal pressure and extraneous forces, where applicable.

A-1.1.3 HINGED EXPANSION JOINT

A hinged Expansion Joint contains one bellows and is designed to permit angular rotation in one plane only by the use of a pair of pins through hinge plates attached to the Expansion Joint ends. The hinges and hinge pins must be designed to restrain the thrust of the Expansion Joint due to internal pressure and extraneous forces, where applicable. Hinged Expansion Joints should be used in sets of two or three to function properly.

A-1.1.4 INTERNALLY GUIDED EXPANSION JOINT

An internally-guided Expansion Joint is designed to provide axial guiding within the Expansion Joint by incorporating a heavy internal guide sleeve, with or without the use of bearing rings. The use of such Expansion Joints will assure installation without initial lateral or angular misalignment and can be installed in pipelines where reverse flow will be encountered. The use of an internally-guided Expansion Joint does not eliminate the necessity of using adequate external pipe guides in accordance with the instructions given in Section B-2.4, nor will its use prevent bellows instability.

A-1.1.5 PRESSURE BALANCED EXPANSION JOINT

A pressure balanced Expansion Joint is designed to absorb axial movement and/or lateral deflection while restraining the pressure thrust by means of tie devices inter-connecting the flow bellows with an opposed bellows also subjected to line pressure.

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A-1.1.6 IN-LINE PRESSURE BALANCED EXPANSION JOINT

An in-line pressure balanced Expansion Joint is designed to absorb axial movement and/or lateral deflection while restraining the pressure thrust by means of tie devices interconnecting the line bellows with outboard compensating bellows also subjected to line pressure. Each bellows set is designed to absorb the axial movement and usually the line bellows will absorb the lateral deflection. This type of Expansion Joint is used in a straight run of piping.

A-1.1.7 SINGLE EXPANSION JOINT

The simplest form of Expansion Joint, of single bellows construction, for the purpose of absorbing any combination of the three basic movements of the pipe section in which it is installed.

A-1.1.8 SWING EXPANSION JOINT

A swing Expansion Joint is one containing two bellows joined by a common connector designed to absorb lateral deflection and/or angular rotation in one plane. Pressure thrust and extraneous forces are restrained by the use of a pair of swing bars, each of which is pinned to the Expansion Joint ends.

A-1.1.9 UNIVERSAL EXPANSION JOINT

A universal Expansion Joint is one containing two bellows joined by a common connector for the purpose of absorbing any combination of the three basic movements: axial movement, lateral deflection and angular rotation. Universal Expansion Joints are usually furnished with control rods to distribute the movement between the two bellows of the Expansion Joint and stabilize the common connector. This definition does not imply that only a universal Expansion Joint can absorb combined movement.

A-1.2 EXPANSION JOINT COMPONENTS AND RELATED EQUIPMENT

A-1.2.1 ANCHORS

A-1.2.1.1 MAIN ANCHOR

A main anchor is one which must withstand the full bellows thrust due to pressure, flow, spring forces, and all other piping loads. For additional information see Sections B-2.4.1 and B-2.4.1.2.

A main anchor base for connection to the anchor structure can be furnished as an integral part of a single or double Expansion Joint, if desired. The Expansion Joint manufacturer must be advised of the magnitude and direction of all forces and moments which will be imposed upon the anchor base, so that it can be adequately designed to suit the specific application.

A-1.2.1.2 INTERMEDIATE ANCHOR

An intermediate anchor is one which must withstand the bellows thrust due to flow, spring forces, and all other piping loads, but not the thrust due to pressure. For additional information, see Section B-2.4.1.1.

A-1.2.1.2 (continued)

An intermediate anchor base for connection to the anchor structure can be furnished as an integral part of a single or double Expansion Joint, if desired. The Expansion Joint manufacturer must be advised of the magnitude and direction of all forces and moments which will be imposed upon the anchor base, so that it can be adequately designed to suit the specific application.

A-1.2.1.3 DIRECTIONAL ANCHOR

A directional or sliding anchor is one which is designed to absorb loading in one direction while permitting motion in another. It may be either a main or intermediate anchor, depending upon the application involved. When designed for the purpose, a directional anchor may also function as a pipe alignment guide. In the design of a directional anchor, an effort should be made to minimize the friction between its moving or sliding parts, since this will reduce the loading on the piping and equipment and insure proper functioning of the anchor.

A-1.2.2 BELLOWS

The flexible element of an Expansion Joint consisting of one or more convolutions and the end tangents with $L_b / D_b \leq 3$.

A-1.2.3 CONTROL RODS

Devices, usually in the form of rods or bars, attached to the Expansion Joint assembly whose primary function is to distribute the movement between the two bellows of a universal Expansion Joint. Control rods are not designed to restrain bellows pressure thrust.

A-1.2.4 COVER

A device used to provide limited protection of the exterior surface of the bellows of an expansion joint from foreign objects or mechanical damage. A cover is sometimes referred to as a shroud.

A-1.2.5 CONVOLUTION

The smallest flexible unit of a bellows. The total movement capacity of a bellows is proportional to the number of convolutions.

A-1.2.6 EQUALIZING AND REINFORCING RINGS

Devices used on some expansion joints fitting snugly in the roots of the convolutions. The primary purpose of these devices is to reinforce the bellows against internal pressure. Equalizing rings are made of cast iron, steel, stainless steel or other suitable alloys and are approximately "T" shaped in cross section. Reinforcing or root rings are fabricated from tubing or solid round bars of carbon steel, stainless steel or other suitable alloys.

A-1.2.7 FLANGED ENDS

The ends of an expansion joint equipped with flanges for the purpose of bolting the expansion joint to the mating flanges of adjacent equipment or piping (See Section B-3).

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A-1.2.8 INTERNAL SLEEVE

A device which minimizes contact between the inner surface of the bellows of an expansion joint and the fluid flowing through it (See Section C-3 for application). These devices have also been referred to as liners or baffles.

A-1.2.9 LIMIT RODS

Devices, usually in the form of rods or bars, attached to the expansion joint assembly whose primary function is to restrict the bellows movement range (axial, lateral and angular) during normal operation. In the event of a main anchor failure, they are designed to prevent bellows over-extension or over-compression while restraining the full pressure loading and dynamic forces generated by the anchor failure.

A-1.2.10 MOTION INDICATORS

Devices attached to an Expansion Joint for the purpose of indicating the movement of the Expansion Joint. These devices are useful in determining if the piping system is behaving as planned and if the actual movements being imposed upon the bellows are within the limits of the original design criteria. An example of motion indicators used on hinge or gimbal hardware is an indicator attached to the hinge pin with an angular scale attached to the hinge arm. This allows one to quickly determine the extent of angular offset.

Another common example of motion indicators is found on slotted hinge assemblies. With the hinge pin used as an indicator, permanent marks are scribed upon the hinge hardware to record the original cold position. The relative distance between the pin and the cold position mark can then be used to determine the movements imposed upon the bellows.

A-1.2.11 PANTOGRAPH LINKAGES

A scissors-like device. A special form of control rod attached to the expansion joint assembly whose primary function is to positively distribute the movement equally between the two bellows of the universal joint throughout its full range of movement. Pantograph linkages, like control rods, are not designed to restrain pressure thrust.

A-1.2.12 PIPE ALIGNMENT GUIDE

A pipe alignment guide is a form of framework fastened to some rigid part of the installation which permits the pipe line to move freely in only one direction, along the axis of the pipe. For further information, see Section B-2.4.2 and the definition of planar pipe guide below.

A-1.2.13 PIPE SECTION

A pipe section is that portion of a pipe line between two anchors. All dimensional changes in a pipe section must be absorbed between these two anchors.

A-1.2.14 PLANAR PIPE GUIDE

A planar pipe guide is one which permits transverse movement and/or bending of the pipeline in one plane. It is commonly used in applications involving lateral deflection or angular rotation resulting from "L" or "Z" shaped piping configurations. For further information, see Section B-2.4.2.

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A-1.2.15 PURGE CONNECTIONS

Purge connections, where required, are usually installed at the sealed end of each internal sleeve of an expansion joint for the purpose of injecting a liquid or gas between the bellows and the internal sleeve to keep the area clear of erosive and corrosive media and/or solids that could pack the convolutions. Purging may be continuous, intermittent or just on start-up or shut down, as required. These are sometimes called aeration connections.

A-1.2.16 SHIPPING DEVICES

Rigid support devices installed on an expansion joint to maintain the overall length of the assembly for shipment. These devices may also be used to precompress, pre-extend or laterally offset the bellows. See Section E-1.2. They should not be used to resist pressure thrust during testing.

A-1.2.17 SLOTTED HINGES

Devices installed as diametrically opposed pairs on an Expansion Joint permitting axial and one plane angular movement. Slotted hinges can be designed to perform as control devices, distributing movements between two bellows of a universal Expansion Joint but do not restrain pressure thrust. They may also be designed as limiting devices, restricting the bellows movement range and can restrain the full pressure loading and dynamic forces generated by an anchor failure. These devices can be used to transmit extraneous loads and forces, such as system dead weight, wind and seismic loads transverse to the Expansion Joint axis, rather than across the flexible bellows element.

A-1.2.18 STABILIZER

A device, internally or externally attached to the Expansion Joint assembly, whose primary function is to increase the stability of a universal Expansion Joint assembly.

A-1.2.19 TANGENTS

The straight un-convoluted portions at the end of the bellows.

A-1.2.20 TANGENT REINFORCEMENT

A reinforcing member located around the circumference of the bellows tangent for the purpose of reducing excessive pressure stresses which could lead to circumferential yielding.

A-1.2.21 TIE RODS

Devices, usually in the form of rods, or bars, attached to the expansion joint assembly whose primary function is to continuously restrain the full bellows pressure thrust during normal operation while permitting only lateral deflection. Angular rotation can be accommodated only if two tie rods are used and located 90° opposed to the direction of rotation.

A-1.2.22 WELD ENDS

The ends of an expansion joint equipped with pipe suitably beveled for welding to adjacent equipment or piping.

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A-2 NOMENCLATURE

A_c = Cross sectional metal area of one bellows convolution (in. ²).

$$= (0.571q + 2w)t_p n \text{ (U shape)}$$

$$= \left[2\pi \left(r_i + \frac{t_p}{2} \right) + 2\sqrt{\left[\frac{q}{2} - 2 \left(r_i - \frac{t_p}{2} \right) \right]^2 + \left[w - 2 \left(r_i - \frac{t_p}{2} \right) \right]^2} \right] t_p n \text{ (V shape)}$$

A_e = Bellows effective area, corresponding to the mean diameter of the convolutions of the Expansion Joint (in. ²).

$$= \pi \frac{(D_m)^2}{4}$$

A_f = Cross sectional metal area of one reinforcement fastener (in. ²).

A_p = Internal area of pipe (in. ²).

A_r = Cross sectional metal area of one bellows reinforcing member (in. ²).

A_t = Cross sectional metal area of all bellows reinforcement collars (in. ²).

A_{tc} = Cross sectional metal area of one tangent collar (in. ²).

B_1 = Factor used in specific design calculations to relate toroidal bellows convolution segment behavior to a simple strip beam.

B_2 = Factor used in specific design calculations to relate toroidal bellows convolution segment behavior to a simple strip beam.

B_3 = Factor used in specific design calculations to relate toroidal bellows convolution segment behavior to a simple strip beam.

C_c = Factor used to account for curvature of tangent collar

$$= -0.2431 + 0.0168n_g + 0.3024n_g^2$$

C_d = Factor used in specific design calculations to relate U-shaped bellows convolution segment behavior to a simple strip beam.

C_f = Factor used in specific design calculations to relate U-shaped bellows convolution segment behavior to a simple strip beam.

C_m = Material strength factor at temperatures below the creep range.

= 1.5 for bellows in the annealed condition (without cold work).

= 3.0 for bellows in the as-formed condition (with cold work).

C_p = Factor used in specific design calculations to relate U-shaped bellows convolution segment behavior to a simple strip beam.

C_r = Convolution height factor.

$$= 0.3 - \left(\frac{100}{0.6P^{1.5} + 320} \right)^2$$

C_{sf} = Stress concentration factor derived from manufacturer's fatigue test results. It is a function of corner configuration and weld joint efficiency.

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A-2 (continued)

C_{sp} = Stress concentration factor derived from manufacturer's fatigue test results. It is a function of the effect of applied pressure.

C_w = Longitudinal weld joint efficiency factor from applicable code. Subscripts b , c , f , p and r denote the bellows, reinforcement collar, fastener, pipe, and reinforcing ring material, respectively.

C_z = Transition point factor

$$= \sqrt{\frac{4.72 f_{iu} q^2}{S_y D_b A_c}}$$

C_θ = Column instability pressure reduction factor based on initial angular rotation

$$= 1 - 1.822\gamma + 1.348\gamma^2 - 0.529\gamma^3$$

D_b = Inside diameter of cylindrical tangent and bellows convolutions (in.).

D_c = Mean diameter of bellows tangent reinforcing collar (in.)

$$= D_b + 2nt + t_c$$

D_I = Pipe inside diameter (in.).

D_m = Mean diameter of bellows convolutions (in.).

$$= D_b + w + nt \text{ for "U" profile}$$

D_r = Mean diameter of reinforcing ring (in.).

E = Modulus of Elasticity at design temperature, unless otherwise specified, for material (psi).

Subscripts b , c , f , p and r denote the bellows, reinforcement collar, fastener, pipe and reinforcing ring material, respectively.

F = Axial force required to move a single convolution axially the amount of e_x (lbs.).

F_g = Axial force per tangent collar gusset (lbs.).

$$= \frac{1}{n_g} \left[0.25\pi(D_m^2 - D_b^2)P + e_c f_w \right]$$

F_a = Axial force at the end of the convoluted length of an Expansion Joint resulting from axial deflection x (lbs.).

G = Modulus of Rigidity at design temperature for material (psi).

H = Resultant total internal pressure force acting on the bellows and reinforcement (lbs.).

$$= PD_m q$$

H_t = Hold time at temperature between cycles (hours).

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A-2 (continued)

I = Moment of inertia of rectangular bellows convoluted cross-section (in^4).

$$= N \left[\frac{nt(2w-q)^3}{48} + 0.4qnt(w-0.2q)^2 \right] \text{ for "U" and "V" profiles}$$

I_p = Moment of inertia of pipe cross section (in^4).

J_l = Rectangular bellows long side corner influence factor

$$= 12I \left(\frac{Nq}{t} \right)^3 \left(\frac{\beta}{(L_l)^4} \right) + 1.0$$

J_s = Rectangular bellows short side corner influence factor

$$= 12I \left(\frac{Nq}{t} \right)^3 \left(\frac{\beta}{(L_s)^4} \right) + 1.0$$

K_2 = Inplane instability factor.

$$= \frac{D_m}{2nt_p} \left[\frac{K_r}{0.571 + 2w/q} \right]$$

K_4 = Inplane instability factor.

$$= \frac{C_p}{2n} \left[\frac{w}{t_p} \right]^2$$

K_r = Circumferential stress factor

= The greater of the following but not less than 1.0

$$\frac{2(q+e_x)+e_\theta+e_y}{2q} \text{ where } e_x \text{ and } e_y \text{ are based on axial extension}$$

$$\frac{2(q-e_x)+e_\theta+e_y}{2q} \text{ where } e_x \text{ and } e_y \text{ are based on axial compression}$$

K_s = Shape factor for cross section (1.5 for rectangular) (see Table IV)

K_{sr} = Overall bellows spring rate (lb./in.).

$$= \frac{f_i}{N}$$

K_u = Factor establishing relationship between equivalent axial displacement per convolution due to lateral deflection and the ratio $L_u/(2L_b)$.

K_{um} = Factor for determining the moment reaction for a universal expansion joint with angular rotation about one end.

$$= \frac{0.0123 + 1.958R_u^{-1.1528}}{2.9359 + R_u^{-1.1528}}$$



STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION, INC.

A-2 (continued)

$K_{u\theta}$ = Factor for determining the moment and equivalent axial movement for a universal expansion joint with angular rotation about one end.

$$= \frac{-0.6042 + 2R_u^{1.1598}}{0.3914 + R_u^{1.1598}}$$

K_{uv} = Factor for determining the lateral force for a universal expansion joint with angular rotation about one end.

$$= 0.7713(1.2876)^{\frac{1}{R_u}} R_u^{-1.0641}$$

K_θ = Angular rotation internal pressure effect factor

$$= \frac{e_\theta C_\theta}{e_\theta C_\theta + 0.15q\phi}$$

L_b = Bellows convoluted length (in.).

$$= Nq$$

L_c = Bellows tangent collar length (in.).

L_d = Length from attachment weld to the center of the first convolution (in.).

L_f = Effective length of one reinforcing ring fastener (in.).

L_l = Mean length of long side of rectangular bellows (in.).
= long inside length + convolution height.

L_{ml} = Effective length of long side (in.).

$$= \frac{L_l}{3} \left(\frac{3L_s + L_l}{L_s + L_l} \right)$$

L_{ms} = Effective length of short side (in.).

$$= \frac{L_s}{3} \left(\frac{3L_l + L_s}{L_s + L_l} \right)$$

L_s = Mean length of short side of rectangular bellows (in.).
= short inside length + convolution height.

L_t = Bellows tangent length (in.).

L_u = Distance between outermost ends of the convolutions in a universal Expansion Joint (in.).

M_{Ll} = Moment at the ends of the convoluted length of an Expansion Joint resulting from lateral deflection y_l , parallel to the long side (in. lbs.).

M_{Ls} = Moment at the ends of the convoluted length of an Expansion Joint resulting from lateral deflection, y_s , parallel to the short side (in. lbs.).

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A-2 (continued)

M_l = Moment at the ends of the convoluted length of an Expansion Joint resulting from lateral deflection, y , (in. lbs.).

M_θ = Moment at the ends of the convoluted length of an Expansion Joint resulting from angular rotation, θ , (in. lbs.).

$M_{\theta l}$ = Moment at the ends of the convoluted length of an Expansion Joint resulting from angular rotation, θ_l , of the long side (in. lbs.).

$M_{\theta s}$ = Moment at the ends of the convoluted length of an Expansion Joint resulting from angular rotation, θ_s , of the short side (in. lbs.).

N = Number of convolutions in one bellows.

N_c = Fatigue life, number of cycles to failure (cycles).

P = Pressure (psig.).

P_d = Design pressure based on the most severe conditions, whether operational or test (psig.).

P_{sc} = Limiting internal design pressure based on column instability (psig.).

P_{si} = Limiting design pressure based on inplane instability and local plasticity (psig.).

P_t = Test pressure (psig.).

R = Ratio of the internal pressure force resisted by the bellows to the internal pressure force resisted by the reinforcement. Use R_1 or R_2 as designated in the equations.

= R_1 for integral reinforcing members.

$$= \frac{A_c E_b}{A_r E_r}$$

= R_2 for reinforcing members joined by fasteners.

$$= \frac{A_c E_b}{D_m} \left(\frac{L_f}{A_r E_f} + \frac{D_m}{A_r E_r} \right)$$

$$R_u = \frac{L_u}{2L_b}$$

S_a = Allowable material stress at design temperature, unless otherwise specified, from the applicable code (psi.). Subscripts b , c , f , p and r denotes bellows, reinforcement collar, fastener, pipe, reinforcing member material.

S_c = Allowable stress of pipe/vessel material at test temperature (psi.).

S_h = Allowable stress of pipe/vessel material at design temperature (psi.).

S_y = Yield strength at design temperature, unless otherwise determined, of the actual bellows material after completion of bellows forming and any applicable heat treatment (psi.).

$$= \frac{0.67 C_m S_{ym} S_{yh}}{S_{yc}}$$

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A-2 (continued)

S_{yc} = Yield strength at room temperature of the bellows material in the annealed condition from the applicable code or standard reference (psi).

S_{yh} = Yield strength at design temperature of the bellows material in the annealed condition from the applicable code or standard reference (psi).

S_{ym} = Yield strength at room temperature of the actual bellows material in the annealed condition from the certified test report (psi).

$T_{inst.}$ = Installation temperature (°F).

$T_{max.}$ = Maximum design temperature (°F).

$T_{min.}$ = Minimum design temperature (°F).

V_{Ll} = Lateral force at the ends of the convoluted length of the Expansion Joint resulting from lateral deflection, y_l , in a direction parallel to the long side (lbs.).

V_{Ls} = Lateral force at the ends of the convoluted length of the Expansion Joint resulting from lateral deflection, y_s , in a direction parallel to the short side (lbs.).

V_l = Lateral force at the ends of the convoluted length of the Expansion Joint resulting from lateral deflection, y (lbs.).

W_{cs} = Total dead weight of the center spool including pipe, refractory, insulation, attachments, and media (lbs.).

X, Y, Z = Lengths in coordinate directions.

Z_c = Section modulus of tangent collar about the neutral axis in the lateral direction (in.³).

e = Total equivalent axial movement per convolution (in.).

e_c = Equivalent axial compression per convolution (in.).

e_e = Equivalent axial extension per convolution (in.).

e_x = Axial movement per convolution resulting from imposed axial movement, x . This movement may be measured as compression or extension (in.).

e_y = Axial movement per convolution resulting from imposed lateral deflection, y (in.).

e_{yl} = Axial movement per convolution for a rectangular bellows resulting from imposed lateral deflection, y , in a direction parallel with the long side (in.).

e_{ys} = Axial movement per convolution for a rectangular bellows resulting from imposed lateral deflection, y , in a direction parallel with the short side (in.).

e_θ = Axial movement per convolution resulting from imposed angular rotation, θ (in.).

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A-2 (continued)

$e_{\theta l}$ = Axial movement per convolution for a rectangular bellows resulting from imposed angular rotation, θ , in a direction parallel with the long side (in.).

$e_{\theta s}$ = Axial movement per convolution for a rectangular bellows resulting from imposed angular rotation, θ , in a direction parallel with the short side (in.).

f_i = Bellows theoretical initial axial elastic spring rate per convolution (lb./in. of movement per convolution). Subscripts u, r, t denote unreinforced, reinforced and toroidal bellows respectively.

f_w = Bellows working spring rate (lb./in. of movement per convolution).

g = Acceleration due to gravity (32.2 ft. / sec.²).

k = A factor which considers the stiffening effect of the attachment weld and the end convolution on the pressure capacity of the bellows tangent.

$$= \frac{L_t}{1.5\sqrt{D_b t}} \quad \text{If } k \geq 1, \text{ use } k = 1$$

n = Number of bellows material plies of thickness, t .

n_g = Number of equally spaced gussets per tangent collar.

q = Convolution pitch, the distance between corresponding points of any two adjacent convolutions in a bellows (in.).

r = Mean radius of toroidal bellows convolution (in.).

r_i = Inside radius of rectangular bellows convolution (in.).

t = Bellows nominal material thickness of one ply (in.).

t_c = Bellows tangent reinforcing collar material thickness (in.).

t_p = Bellows material thickness for one ply, corrected for thinning during forming (in.).

$$= t \sqrt{\frac{D_b}{D_m}}$$

v = Velocity of media flow (ft./sec.).

w = Convolution height (see Figure C21 and C38) (in.).

x = Applied axial movement in compression or extension (in.).

y = Applied lateral deflection (in.).

y_{bml} = Bellows beam mode deflection due to pressure at the center of long span and mid-point of bellows live length (in.).

y_{bms} = Bellows beam mode deflection due to pressure at the center of short span and mid-point of bellows live length (in.).

y_l = Applied lateral deflection in a direction parallel with the long side (in.).

y_s = Applied lateral deflection in a direction parallel with the short side (in.).

α = Inplane instability stress interaction factor.

$$= 1 + 2\delta^2 + (1 - 2\delta^2 + 4\delta^4)^{0.5}$$

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A-2 (continued)

β = Rectangular bellows rigidity factor

$$= \frac{2r_i}{q} [w/r_i + 1.15] \text{ for "U" profile}$$

$$= \frac{2\pi r_i + 2\sqrt{q^2/4 + w^2 - r_i(2q + 4w)}}{q} \text{ for "V" profile}$$

δ = Inplane instability stress ratio.

$$= \frac{K_4}{3K_2}$$

θ = Applied angular rotation per individual bellows (radians).

θ_c = Angle of rotation for an unrestrained center spool (radians)

θ_l = Applied angular rotation per individual bellows in a plane parallel with the long side (radians).

θ_m = Maximum angular rotation from straight position (radians).

θ_s = Applied angular rotation per individual bellows in a plane parallel with the short side (radians).

θ_u = Angle of the universal expansion joint centerline with respect to horizontal (radians).

γ = Ratio of angular rotation before pressurization to angular rotation after pressurization.

$$= \frac{\theta_m D_m}{\theta_m D_m + 0.3L_b}$$

ϕ = Ratio of design pressure to critical pressure

$$= \frac{PN^2q}{0.764\pi f_{iu}} \text{ for unreinforced bellows}$$

$$= \frac{PN^2q}{0.675\pi f_{ir}} \text{ for reinforced bellows}$$

$$= \frac{PN^2r}{0.338\pi f_{iu}} \text{ for toroidal bellows}$$

ν = Poisson's Ratio

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SECTION B - SAFETY RECOMMENDATIONS AND APPLICATIONS

B-1 SAFETY RECOMMENDATIONS FOR PIPING SYSTEMS CONTAINING BELLOWS EXPANSION JOINTS

Bellows Expansion Joints are employed in piping systems to absorb differential thermal expansion while containing the system pressure. They are being successfully utilized in refineries, chemical plants, fossil and nuclear power systems, heating and cooling systems, and cryogenic plants. Typical service conditions have pressures ranging from full vacuum to 1000 psig and temperatures from -420 °F to 1800 °F. Such Expansion Joints fall into the category of a highly engineered product. The system operating characteristics, the Expansion Joint design and manufacturing quality, and the installation, test and operating procedures must all be considered for all Expansion Joint installations.

Unlike most commonly used piping components, a bellows is constructed of relatively thin gage material in order to provide the flexibility needed to absorb mechanical and thermal movements expected in service. This requires design, manufacturing quality, handling, installation and inspection procedures which recognize the unique nature of the product.

In general, the most reliable and safe bellows Expansion Joint installations have always involved a high degree of understanding between the user and manufacturer. With this basic concept in mind, this section was prepared in order to better inform the user of those factors which many years of experience have shown to be essential for the successful installation and performance of piping systems containing bellows Expansion Joints. Additional detailed information can be found in other sections of these Standards.

B-1.1 DESIGN SPECIFICATION

B-1.1.1 A design specification shall be prepared for each Expansion Joint application.

B-1.1.2 In preparing the Expansion Joint design specification it is imperative that the system designer completely review the piping system layout, flowing medium, pressure, temperature, and movements. The standard Expansion Joint Specification Sheet published in Appendix A can be used as a guide. Particular attention shall be given to the following items:

B-1.1.2.1 The piping system shall be reviewed to determine the location and type of Expansion Joint most suitable for the application. The EJMA Standards provide numerous examples to assist the user in this effort. The availability of supporting structures for anchoring and guiding of the line, and the direction and magnitude of thermal movements to be absorbed will have a definite bearing on the type and location of the Expansion Joint.

TORSIONAL ROTATION OF THE BELLOWS SHOULD BE AVOIDED.
Where torsional rotation cannot be avoided, refer to Section C-4.2.4.

B-1.1.2.2 The bellows material shall be specified and must be compatible with the flowing medium, the external environment and the operating temperature. Particular consideration shall be given to possible corrosion including stress corrosion. The 300 series stainless steels may be subject to chloride ion stress corrosion. High nickel alloys are subject to caustic induced stress corrosion. The presence of sulfur may also be detrimental to such nickel alloys.

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B-1.1.2.2 (continued)

The material chosen shall also be compatible with any water treatment or pipeline cleaning chemicals. In some cases, leachates from insulating materials can be a source of corrosion.

B-1.1.2.3 Internal sleeves shall be specified in all applications involving flow velocities which could induce resonant vibration in the bellows or cause erosion of the convolutions resulting in substantially reduced bellows life. See Section C-3.

B-1.1.2.4 The system design pressure and test pressure shall be specified realistically without adding arbitrary safety factors. Excess bellows material thickness required for overstated pressures may produce an adverse effect on the bellows fatigue life. In the case of extreme high temperature operating conditions, it may not be practical to test the Expansion Joint to a pressure of more than 1.5 times the design pressure, see Section D-3.2.1. This is due to the various materials employed in the Expansion Joint, temperature gradient utilized in design, pressure stability criteria, anchor strength and other considerations. The manufacturer must be consulted.

B-1.1.2.5 The maximum, minimum and installation temperatures shall be accurately stated. Where the ambient temperature can vary significantly during pipe line construction, pre-positioning of the Expansion Joint at installation may be required. See Sections B-2.1.2 and B-2.1.3.

B-1.1.2.6 The Expansion Joint manufacturer shall be advised if the Expansion Joint will be insulated and the manner by which the Expansion Joint will be insulated in order to properly design the component parts.

B-1.1.2.7 The movements to be absorbed by the Expansion Joint shall include not only piping elongation or contraction, but also movement of attached vessels, anchors, and the possibility of misalignment during installation. Unless included in the design requirements, misalignment of the Expansion Joint must be avoided. Where movements are cyclic, the number of cycles expected shall be specified. As in the case of pressure, the movement specified must be realistic. An excessive safety factor can result in an Expansion Joint which is highly flexible and could have reduced stability under pressure.

B-1.1.2.8 If the flowing medium can pack or solidify, provisions shall be made to prevent entrapment or solidification of the material in the convolutions which could result in damage to the Expansion Joint or pipeline.

B-1.1.2.9 Internal sleeves are usually installed in the direction of flow. If the stagnant flow medium trapped behind the sleeve is undesirable, drain holes in the sleeve or purge connections shall be specified. Where back flow will be encountered, an extra heavy sleeve shall be specified to prevent buckling of the sleeve and possible damage to the bellows.

B-1.1.2.10 The predicted amplitude and frequency of external mechanical vibrations to be imposed on the bellows, such as caused by reciprocating or pulsating machinery, shall be specified. The Expansion Joint must be designed to avoid the resonant vibration of the bellows to preclude the possibility of sudden fatigue failure. Field modifications to the Expansion Joint or other system components may be necessary.

B-1.1.3 The piping system drawings shall specify the location of all anchors, guides, supports and fixed points. Considerable information to assist the system designer in this regard is provided in these Standards. See Section B-2.4. Both the anchors and guides must be suitable for the highest pressures to be applied to the system. (NOTE: IN MOST CASES THE TEST PRESSURE WILL BE SIGNIFICANTLY HIGHER THAN THE SYSTEM OPERATING PRESSURE.)

B-1.1.4 The system designer shall specify those special features which best accomplish personnel protection in his particular system. Piping systems containing high pressure and/or hazardous materials which are located in close proximity to personnel shall be provided with additional safety features which will protect such personnel in the event of a failure in the system. Expansion Joints can be furnished with special features including, but not limited to, the following:

B-1.1.4.1 Extra heavy covers which would serve to impede the effect of a jet flow produced by a failure; however, such covers will not prevent the escaping medium from expanding and filling the surroundings in which it is located.

B-1.1.4.2 Limit rods designed for dynamic loading can be employed to restrain the longitudinal pressure thrust in the event of an anchor failure. Such rods would normally remain completely passive until the anchor restraint is removed.

B-1.1.4.3 A two ply or two concentric bellows design may be employed with each ply or bellows designed to contain the full line pressure. The annular space between the plies or concentric bellows can be monitored continuously for leakage by means of suitable instrumentation. A change in pressure in the annulus could be used to detect bellows leakage. (See Section B-2.5).

B-1.1.5 The system designer shall provide for the accessibility of components such as anchors and Expansion Joints in the piping system for periodic inspection after initial start up.

B-1.2 EXPANSION JOINT DESIGN

B-1.2.1 The Expansion Joint design shall conform to the requirements of these Standards, the ASME/ANSI Piping Codes and the ASME Boiler and Pressure Vessel Codes as applicable. The design of structural attachments shall be in accordance with accepted methods, based on elastic theory. Circular bellows design shall be based on the equations contained in Section C-4.2 with substantiating test data as stated in Section C-4. Rectangular bellows design can be evaluated based on the equations contained in Section C-7.

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B-1.3 EXPANSION JOINT MANUFACTURING QUALITY

B-1.3.1 The Expansion Joint manufacturer shall comply with the requirements of Section D-2. Each manufacturer shall be required to furnish, on request, a copy of his Quality Assurance Manual.

B-1.4 INSTALLATION

B-1.4.1 The necessary steps for installing all Expansion Joints shall be preplanned. The installers shall be made aware of these steps as well as the special instructions furnished by the manufacturer. Section E-1.3, as well as the individual instructions tags furnished by the manufacturer with the Expansion Joint, provides information necessary to the proper handling and installation of Expansion Joints.

B-1.4.2 The most critical phases of the Expansion Joint installation are as follows:

B-1.4.2.1 Care shall be exercised to prevent any damage to the thin bellows section, such as dents, scores, arc strikes and weld splatter.

B-1.4.2.2 No movement of the Expansion Joint (compression, extension, lateral offset, rotation) due to piping misalignment, for example, shall be imposed which has not been anticipated and designed into the movement capability of the Expansion Joint. If such movements are imposed, this can result in system malfunction, damage to the bellows or other components in the system. Specifically, cyclic life can be substantially reduced, forces imposed on adjacent equipment may exceed their design limits, internal sleeve clearances may be adversely affected, and the pressure capacity and stability of the bellows may be reduced.

B-1.4.2.3 Any field pre-positioning shall be performed in accordance with specific instructions which include both the direction and magnitude of movement.

B-1.4.2.4 Anchors, guides and pipe supports shall be installed in strict accordance with the piping system drawings. Any field variances from planned installation may affect proper functioning of the Expansion Joint and must be brought to the attention of competent design authority for resolution.

B-1.4.2.5 The Expansion Joint, if provided with internal sleeves, shall be installed with the proper orientation with respect to flow direction.

B-1.4.2.6 Once the pipeline anchors or other fixed points are in place, the piping is properly supported and guided and the Expansion Joint installed, the shipping devices should be removed in order to allow the Expansion Joint to compensate for changes in ambient temperature during the remainder of the construction phase.

B-1.5 POST INSTALLATION INSPECTION PRIOR TO SYSTEM PRESSURE TEST

B-1.5.1 A careful inspection of the entire piping system shall be made with particular emphasis on the following:

B-1.5.1.1 Are anchors, guides and supports installed in accordance with the system drawings?

B-1.5.1.2 Is the proper Expansion Joint in the proper location?

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B-1.5.1.3 Are the Expansion Joint flow direction and pre-positioning correct?

B-1.5.1.4 Have all of the Expansion Joint shipping devices been removed?

B-1.5.1.5 If the system has been designed for a gas, and is to be tested with water, has provision been made for proper support of the additional dead weight load on the piping and Expansion Joint? Some water may remain in the bellows convolutions after the test. If this is detrimental to the bellows or system operation, means shall be provided to remove such water.

B-1.5.1.6 Are all guides, pipe supports and the Expansion Joints free to permit pipe movement?

B-1.5.1.7 Has any Expansion Joint been damaged during handling and installation?

B-1.5.1.8 Is any Expansion Joint misaligned? This can be determined by measuring the joint overall length, inspection of the convolution geometry, and checking clearances at critical points on the Expansion Joint and at other points in the system.

B-1.5.1.9 Are the bellows and other movable portions of the Expansion Joint free of foreign material?

B-1.6 INSPECTION DURING AND IMMEDIATELY AFTER SYSTEM PRESSURE TESTS

WARNING: Extreme care must be exercised while inspecting any pressurized system or component.

B-1.6.1 A visual inspection of the system shall include checking for the following:

B-1.6.1.1 Evidence of leakage or loss of pressure.

B-1.6.1.2 Distortion or yielding of anchors, Expansion Joint hardware, the bellows and other piping components.

B-1.6.1.3 Any unanticipated movement of the piping due to pressure.

B-1.6.1.4 Evidence of instability (squirm) in the bellows.

B-1.6.1.5 The guides, Expansion Joints and other movable parts of the system shall be inspected for evidence of binding.

B-1.6.1.6 Any evidence of abnormality or damage shall be reviewed and evaluated by competent design authority.

B-1.7 PERIODIC IN-SERVICE INSPECTION

WARNING: Extreme care must be exercised while inspecting any pressurized system or component.

B-1.7.1 Immediately after placing the system in operation, a visual inspection shall be conducted to insure that the thermal expansion is being absorbed by the Expansion Joints in the manner for which they were designed.

B-1.7.2 The bellows shall be inspected for evidence of unanticipated vibration.

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B-1.7.3 A program of periodic inspection shall be planned by the system designer and conducted throughout the operating life of the system. The frequency of these inspections will be determined by the service and environmental conditions involved. These inspections shall include the items in sections B-1.7.1 and B-1.7.2 as well as an examination for signs of external corrosion, loosening of threaded fasteners and deterioration of anchors, guides and other hardware. IT MUST BE UNDERSTOOD THAT THIS INSPECTION PROGRAM, WITHOUT ANY OTHER BACKUP INFORMATION, CANNOT GIVE EVIDENCE OF DAMAGE DUE TO FATIGUE, STRESS CORROSION OR GENERAL INTERNAL CORROSION. THESE CAN BE THE CAUSE OF SUDDEN FAILURES AND GENERALLY OCCUR WITHOUT ANY VISIBLE OR AUDIBLE WARNING. Where the critical nature of the system warrants, it may be necessary to devise means for minimizing the probability of this type failure, including periodic preventive replacement of critical system components.

B-1.7.4 When any inspection reveals evidence of malfunction, damage or deterioration, this shall be reviewed by competent design authority for resolution.

B-1.8 SYSTEM OPERATION

B-1.8.1 A record shall be maintained of any changes in system operating conditions (such as pressure, temperature, thermal cycling, water treatment) and piping modifications. Any such change shall be reviewed by competent design authority to determine its effect on the performance of the anchors, guides and Expansion Joints.

B-1.9 TYPICAL CAUSES OF EXPANSION JOINT FAILURE

Bellows expansion joints will give many years of satisfactory service when they are properly designed and manufactured for specified piping system conditions. Failures can occur for many reasons, but experience has shown that certain causes of failure fall into fairly distinct categories. The following are some typical causes:

B-1.9.1 Shipping and handling damage.

Examples: Denting or gouging of bellows from being struck by hard objects (tools, chain falls, forklifts, adjacent structures, etc.)

Improper stacking for shipping or storage.

Insufficient protection from weather or other adverse environmental conditions.

B-1.9.2 Improper installation and insufficient protection during and after installation.

Examples: Joints with internal liners installed in reverse direction with respect to flow.

Installing a joint in a location other than as prescribed by the installation drawings.

Premature removal of shipping devices.

Springing of bellows to make up for piping misalignment.

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B-1.9.2 (continued)

Insufficient protection from mechanical damage due to work in the surrounding area.

Insufficient protection of bellows during nearby welding operations.

Failure to remove shipping devices before system operation.

B-1.9.3 Improper anchoring, guiding, supporting of the piping system.

B-1.9.4 Anchor failure in service.

B-1.9.5 Bellows corrosion.

Examples: Improper selection of bellows material for the flowing medium and/or adverse external environment. Specifically, chlorides leaching from insulation, have been frequently the cause of stainless steel bellows corrosion. Stress corrosion cracking (consult material manufacturer for proper selection).

B-1.9.6 System over-pressurization (in-service or hydrotest).

B-1.9.7 Bellows vibration (mechanical or flow-induced) resulting in fatigue failure.

B-1.9.8 Excessive bellows movement (axial, lateral, and angular movement greater than design values).

B-1.9.9 Bellows erosion.

Example: Bellows without internal liner installed in a system having a very high velocity and/or erosive flowing medium.

B-1.9.10 Packing of particulate matter in bellows convolutions which inhibits proper movement of the bellows.

B-2 EXPANSION JOINT APPLICATIONS

B-2.1 SELECTION OF EXPANSION JOINTS AND CALCULATION OF THERMAL EXPANSION

B-2.1.1 The first step in the selection of Expansion Joints is to choose tentative locations for the pipe anchors. Any piping system, regardless of its complexity, can be divided into a number of individual expanding pipe sections having relatively simple configurations (ie: straight runs, "L" shaped bends, "Z" shaped bends and other means), by means of anchors. The number of pipe anchors selected, as well as their locations, will depend upon the piping configuration, the amount of expansion which can be accommodated by a single Expansion Joint, the availability of structural members suitable for use as anchors, the location of various pipe fittings, the location of connected equipment, the location of branch connections and other considerations.

The major pieces of connected equipment such as turbines, pumps, compressors, heat exchangers, reactors, and similar devices can be considered as anchors in most applications. It is usually necessary to supplement these equipment anchor points by locating additional anchors at valves, at changes in the direction of the pipe, at blind ends of pipe and at major branch connections. It is generally advisable to start out with the assumption that the use of single and double Expansion Joints in straight axial movement will provide the simplest and most economical layout, unless there are obvious advantages to be gained from another approach.

After the anchor points have been tentatively located, the resulting pipe configurations should be reviewed to determine whether they conform to the standard pipe sections shown in Sections B-2.2 and B-2.4. At this point, consideration should be given to the relative merits of systems utilizing single and double Expansion Joints for axial movement only, as opposed to those utilizing universal, pressure balanced, hinged and gimbal Expansion Joints. A final decision on anchor locations and the types of Expansion Joints to be used can only be made after a comparison of various alternative solutions. Cost, the ability to comply with cyclic life and force requirements, space restrictions and similar items should be considered.

The next step is to calculate the actual change in length of each leg of each individual pipe section due to temperature changes. The minimum and installation temperatures are assumed to be 70° F unless otherwise specified. An allowance, added by the system designer, should then be included in the actual calculated movements to account for the following possibilities:

- (a) The minimum and/or installation temperatures used in the design calculations may have been based on the erroneous assumption that the metal temperature of the pipe is the same as the ambient temperature.

B-2.1.1 (continued)

- (b) During erection of the piping, it may be necessary to relocate some of the anchor points because of construction problems encountered at the job site.
- (c) During operation the system may be subject to a different temperature range than the designer anticipated, particularly during start-up.

**SAMPLE CALCULATION FOR A STRAIGHT RUN OF PIPE
CONTAINING AN AXIAL EXPANSION JOINT (See Table I)**

Given a 150 foot length of carbon steel pipe operating between 25° F. and 375° F.

Expansion at 375° F = 2.48 in./100 ft.

Expansion at 25° F = -0.32 in./100 ft.

The difference = 2.80 in./100 ft.

The change in length for 150 feet would be (2.80) (150/100) = 4.20 in.

Although bellows Expansion Joints can be designed to absorb both axial compression and axial extension, for purposes of a sample calculation, it is assumed that the Expansion Joint can absorb only axial compression.

B-2.1.2 The above sample calculation would be complete if the Expansion Joint were being installed at 25° F. Frequently, an Expansion Joint is installed at a temperature higher than the minimum design temperature of the piping system. The piping will contract in such a case and the Expansion Joint will be extended beyond its installed length. It is obvious in the sample calculation above that if the Expansion Joint was installed at 70° F, the pipeline would contract a total of 0.32 x 150/100 inches or 0.48 inches and would expand 2.48 x 150/100 inches or 3.72 inches from this installation temperature. Since the Expansion Joint selected is rated for axial compression only, it must be pre-compressed prior to installation in order to provide for extension when the pipeline contracts from 70° F to the minimum design temperature of 25° F.

The amount of pre-compression equals:

$$\frac{(\text{Rated Movement}) \times (\text{Coefficient at } T_{\text{inst.}} - \text{Coefficient at } T_{\text{min.}})}{\text{Coefficient at } T_{\text{max.}} - \text{Coefficient at } T_{\text{min.}}} \quad (\text{B-1})$$

Assuming the selected Expansion Joint is rated for 5 inches axial compression, and substituting numerical values from the above example in this formula, we have:

$$\frac{(5) \times [0 - (-0.32)]}{[2.48 - (-0.32)]} = 0.57 \text{ inches of pre-compression}$$

STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION, INC.

TABLE 1
Thermal Expansion of Pipe in Inches per 100 Feet

Temp. Degrees F.	Carbon C-Mo. 3Cr-Mo Steels	5CR-Mo through 9Cr-Mo Steels	Austenitic Stainless Steels 18Cr-8Ni	310 SS 25 Cr- 20Ni	Alloy 400	Cu-30Ni	Copper	Nickel 200	Alloy 800, 825	Alloy 600, 625,691	Aluminum	Temp Degrees F.
-325	-2.37	-2.22	-3.85	...	-2.62	-3.15	...	...	...	...	-4.68	-325
-300	-2.24	-2.10	-3.63	...	-2.50	-2.87	...	-2.44	...	...	-4.46	-300
-275	-2.11	-1.98	-3.41	...	-2.38	-2.70	...	-2.35	...	...	-4.21	-275
-250	-1.98	-1.86	-3.19	...	-2.26	-2.53	...	-2.25	...	-2.30	-3.97	-250
-225	-1.85	-1.74	-2.96	...	-2.14	-2.36	...	-2.13	...	-2.17	-3.71	-225
-200	-1.71	-1.62	-2.73	...	-2.02	-2.19	...	-2.01	...	-2.04	-3.44	-200
-175	-1.58	-1.50	-2.50	...	-1.90	-2.12	...	-1.83	...	-1.87	-3.16	-175
-150	-1.45	-1.37	-2.27	...	-1.79	-1.95	...	-1.65	...	-1.70	-2.88	-150
-125	-1.30	-1.23	-2.01	...	-1.59	-1.74	...	-1.47	...	-1.54	-2.57	-125
-100	-1.15	-1.08	-1.75	...	-1.38	-1.53	-1.83	-1.29	...	-1.37	-2.27	-100
-75	-1.00	-0.94	-1.50	...	-1.18	-1.33	-1.57	-1.11	...	-1.17	-1.97	-75
-50	-0.84	-0.79	-1.24	...	-0.98	-1.13	-1.31	-0.93	...	-0.97	-1.67	-50
-25	-0.68	-0.63	-0.98	...	-0.77	-0.89	-1.05	-0.75	...	-0.76	-1.32	-25
0	-0.49	-0.46	-0.72	...	-0.57	-0.66	-0.79	-0.56	...	-0.56	-0.97	0
25	0.32	-0.30	-0.46	...	-0.37	-0.42	-0.51	-0.36	...	-0.36	-0.63	25
50	-0.14	-0.13	-0.21	...	-0.20	-0.19	-0.22	-0.16	...	-0.16	-0.28	50
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	70
100	0.23	0.22	0.34	0.32	0.28	0.31	0.34	0.25	0.28	0.26	0.46	100
125	0.42	0.40	0.62	0.58	0.52	0.56	0.62	0.47	0.52	0.48	0.85	125
150	0.61	0.58	0.90	0.84	0.75	0.82	0.90	0.69	0.76	0.70	1.23	150
175	0.80	0.76	1.18	1.10	0.99	1.07	1.18	0.92	0.99	0.92	1.62	175
200	0.99	0.94	1.46	1.37	1.22	1.33	1.48	1.15	1.23	1.15	2.00	200
225	1.21	1.13	1.75	1.64	1.46	1.59	1.77	1.38	1.49	1.38	2.41	225
250	1.40	1.33	2.03	1.91	1.71	1.86	2.05	1.61	1.76	1.61	2.83	250
275	1.61	1.52	2.32	2.18	1.96	2.13	2.34	1.85	2.03	1.85	3.24	275
300	1.82	1.71	2.61	2.45	2.21	2.40	2.62	2.08	2.30	2.09	3.67	300
325	2.04	1.90	2.90	2.72	2.44	2.68	2.91	2.32	2.59	2.32	4.09	325
350	2.26	2.10	3.20	2.99	2.68	2.96	3.19	2.56	2.88	2.56	4.52	350
375	2.48	2.30	3.50	3.26	2.91	3.24	3.48	2.80	3.18	2.80	4.95	375
400	2.70	2.50	3.80	3.53	3.25	3.52	3.88	3.05	3.48	3.05	5.39	400
425	2.93	2.72	4.10	3.80	3.52	...	4.17	3.30	3.76	3.29	5.83	425
450	3.16	2.93	4.41	4.07	3.79	...	4.47	3.55	4.04	3.53	6.28	450
475	3.39	3.14	4.71	4.34	4.06	...	4.76	3.80	4.31	3.78	6.72	475
500	3.62	3.35	5.01	4.61	4.33	...	5.06	4.05	4.59	4.02	7.17	500
525	3.86	3.58	5.31	4.88	4.61	...	5.35	4.31	4.87	4.27	7.63	525
550	4.11	3.80	5.62	5.15	4.90	...	5.64	4.56	5.16	4.52	8.10	550
575	4.35	4.02	5.93	5.42	5.18	...	...	4.83	5.44	4.77	8.56	575
600	4.60	4.24	6.24	5.69	5.46	...	...	5.09	5.72	5.02	9.03	600
625	4.86	4.47	6.55	5.96	5.75	...	...	5.35	6.01	5.27	...	625
650	5.11	4.69	6.87	6.23	6.05	...	...	5.62	6.30	5.53	...	650

STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION, INC.

TABLE 1 (continued)
Thermal Expansion of Pipe in Inches per 100 Feet

Temp. Degrees F.	Carbon C-Mo. 3Cr-Mo Steels	5CR-Mo through 9Cr-Mo Steels	Austenitic Stainless Steels 18Cr-8Ni	310 SS 25 Cr- 20Ni	Alloy 400	Cu-30Ni	Copper	Nickel 200	Alloy 800, 825	Alloy 600, 625,691	Aluminum	Temp Degrees F.
675	5.37	4.92	7.18	6.50	6.34	...	...	5.89	6.58	5.79	...	675
700	5.63	5.14	7.50	6.77	6.64	...	...	6.16	6.88	6.05	...	700
725	5.90	5.38	7.82	7.04	6.94	...	...	6.44	7.17	6.31	...	725
750	6.16	5.62	8.15	7.31	7.25	...	...	6.71	7.47	6.57	...	750
775	6.43	5.86	8.47	7.58	7.55	...	...	6.99	7.76	6.84	...	775
800	6.70	6.10	8.80	7.85	7.85	...	...	7.27	8.06	7.10	...	800
825	6.97	6.34	9.13	8.15	8.16	...	...	7.54	8.35	7.38	...	825
850	7.25	6.59	9.46	8.45	8.48	...	...	7.82	8.66	7.67	...	850
875	7.53	6.83	9.79	8.75	8.80	...	...	8.09	8.95	7.95	...	875
900	7.81	7.07	10.12	9.05	9.12	...	...	8.37	9.26	8.23	...	900
925	8.08	7.31	10.46	9.35	9.44	...	...	8.64	9.56	8.52	...	925
950	8.35	7.56	10.80	9.65	9.77	...	...	8.92	9.87	8.80	...	950
975	8.62	7.81	11.14	9.95	10.09	...	...	9.20	10.18	9.09	...	975
1000	8.89	8.06	11.48	10.25	10.42	...	...	9.49	10.49	9.37	...	1000
1025	9.17	8.30	11.82	10.55	10.75	...	...	9.77	10.80	9.66	...	1025
1050	9.46	8.55	12.16	10.85	11.09	...	...	10.05	11.11	9.94	...	1050
1075	9.75	8.80	12.50	11.15	11.43	...	...	10.34	11.42	10.23	...	1075
1100	10.04	9.05	12.84	11.45	11.77	...	...	10.63	11.74	10.51	...	1100
1125	10.31	9.28	13.18	11.78	12.11	...	...	10.92	12.05	10.80	...	1125
1150	10.57	9.52	13.52	12.11	12.47	...	...	11.21	12.38	11.09	...	1150
1175	10.83	9.76	13.86	12.44	12.81	...	...	11.50	12.69	11.37	...	1175
1200	11.10	10.00	14.20	12.77	13.15	...	...	11.80	13.02	11.66	...	1200
1225	11.38	10.26	14.54	13.10	13.50	...	...	12.09	13.36	11.98	...	1225
1250	11.66	10.53	14.88	13.43	13.86	...	...	12.39	13.71	12.29	...	1250
1275	11.94	10.79	15.22	13.76	14.22	...	...	12.69	14.04	12.61	...	1275
1300	12.22	11.06	15.56	14.09	14.58	...	...	12.99	14.39	12.93	...	1300
1325	12.50	11.30	15.90	14.39	14.94	...	...	13.29	14.74	13.25	...	1325
1350	12.78	11.55	16.24	14.69	15.30	...	...	13.59	15.10	13.56	...	1350
1375	13.06	11.80	16.58	14.99	15.66	...	...	13.90	15.44	13.88	...	1375
1400	13.34	12.05	16.92	15.29	16.02	...	...	14.20	15.80	14.20	...	1400
1425	...	...	17.30	...	...	...	...	14.51	16.16	14.51	...	1425
1450	...	...	17.69	...	...	...	...	14.82	16.53	14.83	...	1450
1475	...	...	18.08	...	...	...	...	15.13	16.88	15.14	...	1475
1500	...	...	18.47	...	...	...	...	15.44	17.25	15.45	...	1500
1525	...	...	...	...	...	...	...	15.76	17.61	15.77	...	1525
1550	...	...	...	...	...	...	...	16.07	17.98	16.08	...	1550
1575	...	...	...	...	...	...	...	16.39	18.35	16.40	...	1575
1600	...	...	...	...	...	...	...	16.71	18.73	16.71	...	1600

- Notes: 1. Table shows expansion resulting from change in temperature from 70° F to indicated temperature
2. This table is for information only and it is not to be implied that materials are suitable for all the temperature ranges shown.
3. The thermal expansion values in this table may be interpolated to determine values for intermediate temperatures.

STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION, INC.

B-2.1.2 (continued)

This leaves 4.43 inches for compression from the installed position. Thus, the use of an Expansion Joint rated for 5 inches axial compression, installed pre-compressed 0.57 inches will provide a means for absorbing the contraction of the pipe from the installation temperature to the minimum temperature (0.48 in.) as well as the expansion of the pipe from the installation temperature to the maximum temperature (3.72 in.).

No allowance has been made in this sample calculation for conditions a, b, or c in Section B-2.1.1.

B-2.1.3 It may be necessary to field pre-compress Expansion Joints where information on thermal expansion coefficients is not available. When this occurs pre-compression may be approximated by the following formula:

$$\frac{(\text{Rated Movement} \times (T_{\text{inst.}} - T_{\text{min.}}))}{(T_{\text{max.}} - T_{\text{min.}})} \quad (\text{B-2})$$

B-2.2 APPLICATIONS FOR AXIAL MOVEMENT

(For an explanation of the symbols used in the diagrams, refer to the Appendix B.)

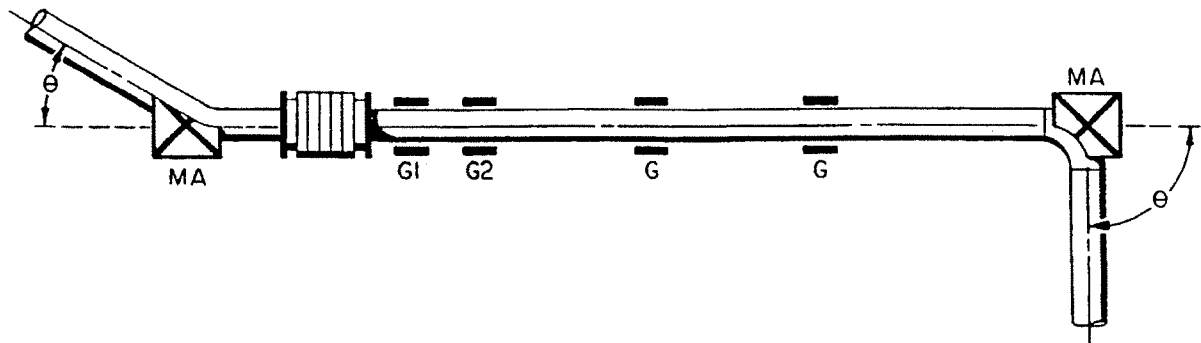


FIGURE B1

Figure B1 typifies good practice in the use of a single Expansion Joint to absorb axial pipe line expansion. Note the use of one Expansion Joint between two main anchors (MA), the nearness of the Expansion Joint to an anchor, the closeness of the first alignment guide (G1), the spacing between the first alignment guide and the second alignment guide (G2), and the spacing of intermediate guides (G) along the balance of the line. See Figures B30 and B31, and/or equation (B-9).

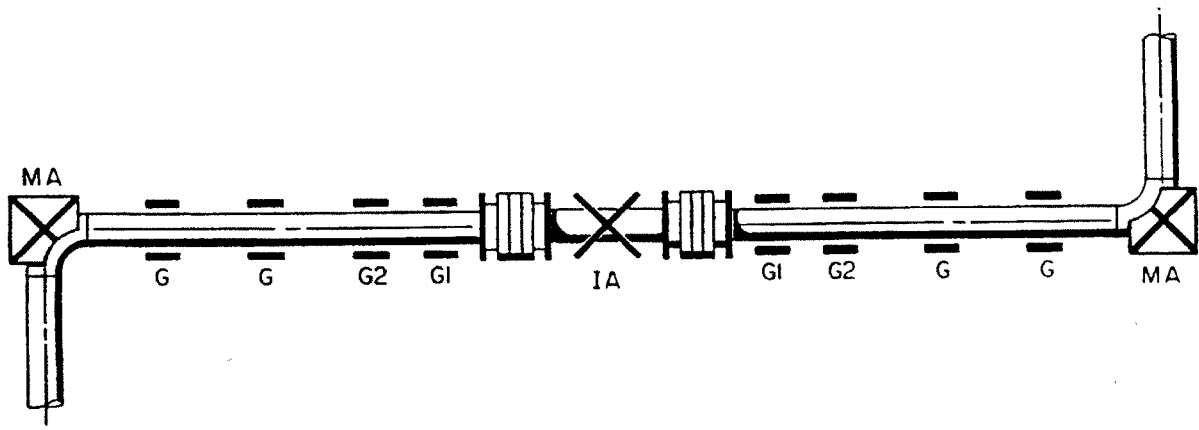


FIGURE B2

Figure B2 typifies good practice in the use of a double Expansion Joint to absorb axial pipe line expansion. Note the addition of the intermediate anchor (IA) which, in conjunction with the two main anchors, divides the pipe line into individual expanding sections, so that there is only one Expansion Joint between any two anchors. Note also the closeness of the first alignment guide (G1) to each Expansion Joint, the spacing between the first alignment guide and the second alignment guide (G2) and the spacing of intermediate guides (G) along the balance of each pipe section. See Figures B 30 and B31 and/or equation (B-9).

STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION, INC.

B-2.2 (continued)

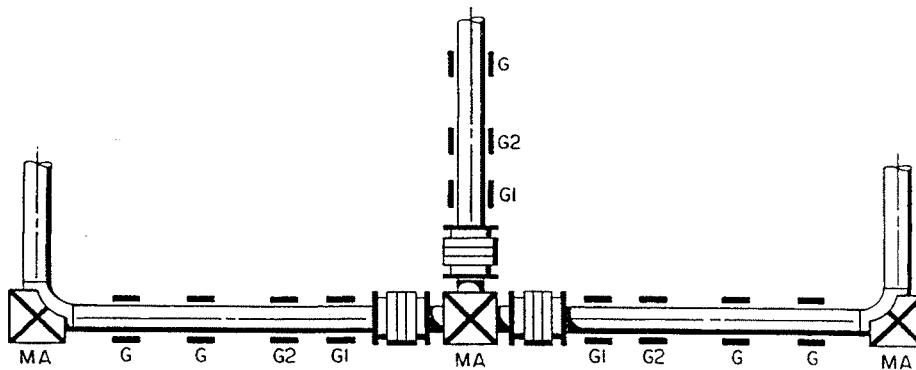


FIGURE B3

Figure B3 typifies good practice in the use of Expansion Joints to absorb axial pipe line expansion in a pipe line with a branch connection. The anchor at the junction, which in this case is a tee, is a main anchor (MA) designed to absorb the thrust from the Expansion Joint in the branch line. Note the nearness of each Expansion Joint to an anchor, the closeness of each first alignment guide (G1), the spacing between the first alignment guide and the second alignment guide (G2) and the spacing of intermediate guides (G) along the balance of each pipe section. See Figures B30 and B31 and/or equation (B-9).

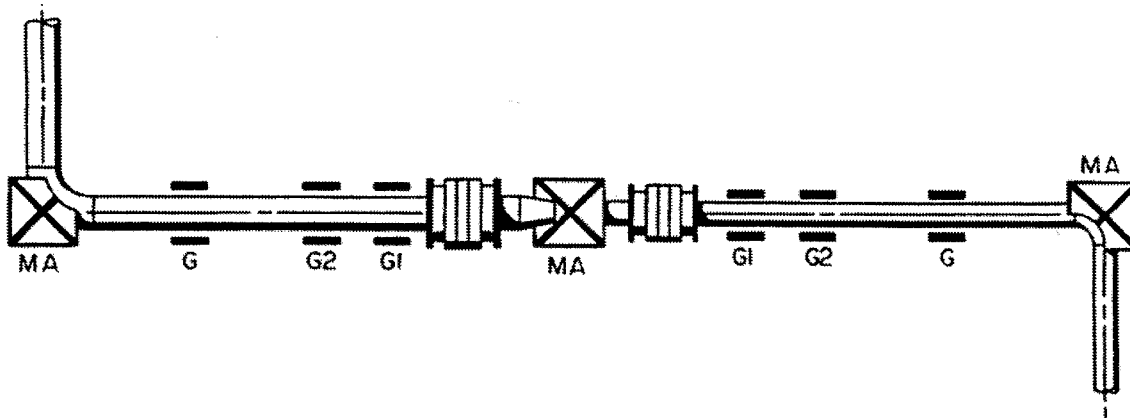


FIGURE B4

Figure B4 typifies good practice in the use of Expansion Joints to absorb axial pipe line expansion in a pipe line containing a reducer. The anchor at the reducer is a main anchor (MA) designed to absorb the difference in the thrusts of the Expansion Joints on each side of the reducer. Note the nearness of each Expansion Joint to an anchor, the closeness of each first alignment guide (G1), the spacing between the first alignment guide and the second alignment guide (G2) and the spacing of intermediate guides (G) along the balance of each pipe section. See Figures B30 and B31 and/or equation (B-9).

B-2.2 (continued)

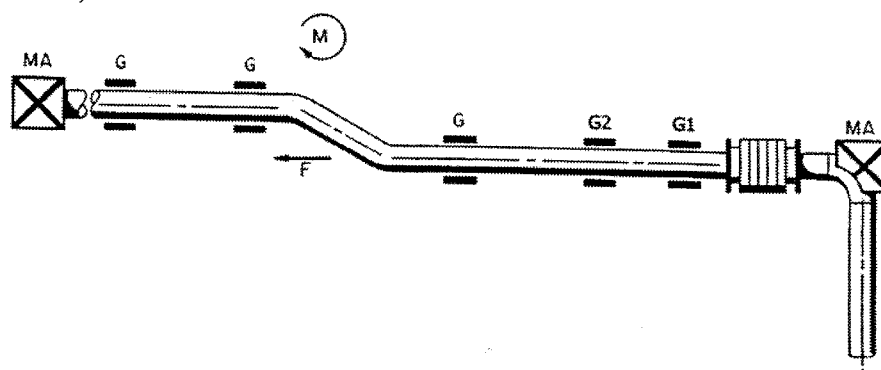


FIGURE B5

Figure B5 shows the application of a single Expansion Joint to a pipe line containing an offset. It should be noted that applications of this type are not usually recommended and will perform satisfactorily only within certain limits. As in Figure B1, the line is provided with main anchors at each end to absorb the pressure, movement loading, and guide friction. Where the line contains an offset, this load must first be transmitted through the offset leg, resulting in a moment on the piping. Where the line size is small, the offset appreciable, or where the pressure and movement forces are relatively high, this configuration may result in over-stressing, or distortion of the piping and guides.

Note the nearness of the Expansion Joint to an anchor (MA), the closeness of the first alignment guide (G1), the spacing between the first alignment guide and the second alignment guide (G2) and the spacing of intermediate guides (G) along the balance of the line. Guides should be installed near both ends of the offset leg to minimize the effects of the bending moment on the system. For spacing of other guides, see guide chart Figure B31, and/or equation (B-9).

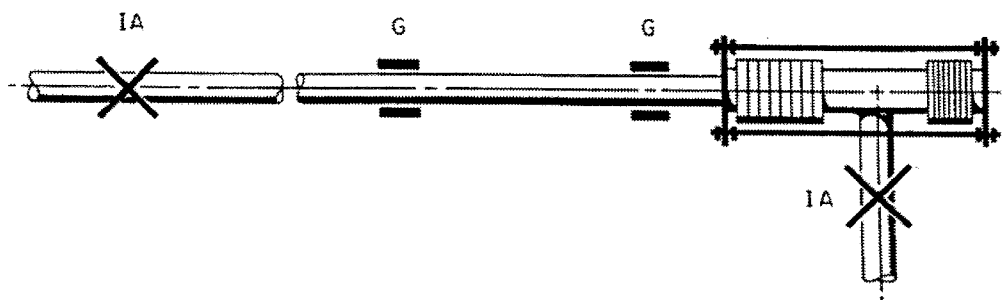


FIGURE B6

Figure B6 typifies good practice in the use of a pressure balanced Expansion Joint to absorb axial pipe line expansion. Note that the Expansion Joint is located at a change in direction of the piping and that the elbow and the end of the pipe line are secured by intermediate anchors. Since the pressure thrust is absorbed by the Expansion Joint itself, and only the forces required to deflect the Expansion Joint are imposed on the piping, a minimum of guiding is required. Frequently, directional guiding adjacent to the Expansion Joint, as shown, may suffice. In long, small-diameter pipe lines, additional guiding may be necessary.

B-2.2 (continued)

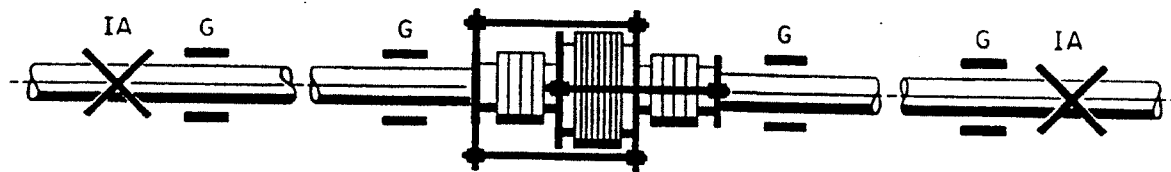


FIGURE B7

Figure B7 shows the use of an in-line pressure balanced Expansion Joints to absorb axial pipe line movements in a long, straight piping run. By utilizing this arrangement the two anchors shown are relieved of pressure loading and are designed as intermediate anchors. Since the piping is relieved of compressive pressure loading, a minimum of guiding is required, primarily to direct the thermal expansion of the piping into the Expansion Joints in an axial direction.

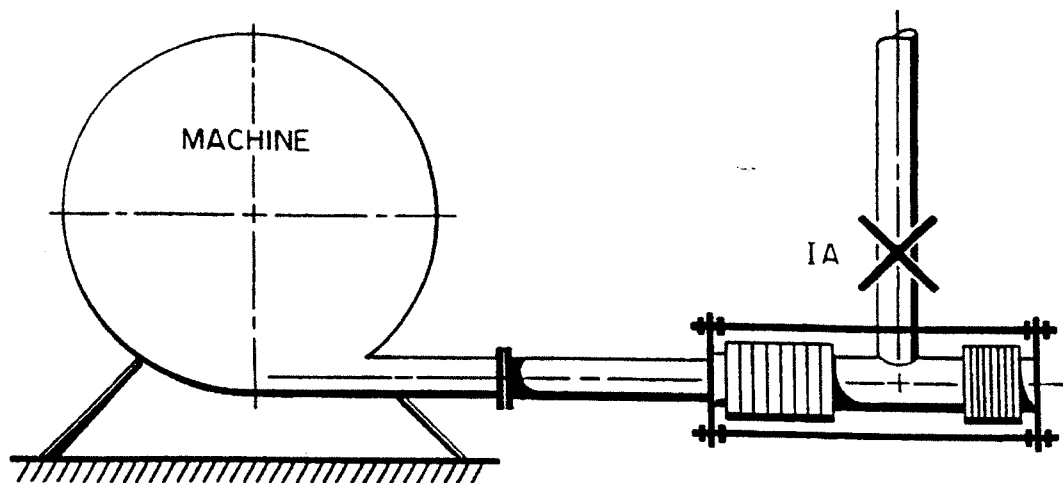


FIGURE B8

Figure B8 typifies good practice in the use of a pressure balanced Expansion Joint to absorb the thermal expansion of equipment such as turbines, pumps, compressors, etc. The primary function of the Expansion Joint is to minimize loading upon the equipment casing. Note that only an intermediate anchor is required at the change of piping direction and that, if the Expansion Joint is located immediately adjacent to the machine, no guiding is required. Care should be taken to provide sufficient flexibility in both the flow bellows and the balancing bellows, so that the forces required to compress the Expansion Joint do not exceed loading limits for the equipment as established by the equipment manufacturer. See Section B-2.3.3 for further information.

B-2.3 APPLICATIONS FOR LATERAL DEFLECTION, ANGULAR ROTATION AND COMBINED MOVEMENTS

The selection and proper application of Expansion Joints for lateral deflection, angular rotation and combined movements, involves the evaluation of a number of variables. These can include the piping configuration, the operating conditions, desired cyclic life, load limitations upon piping and equipment, and available supporting structure. In some cases, two or more types of Expansion Joints may be suitable for a particular application. The selection then becomes purely an economic one. More frequently one or the other of the available designs possesses unique characteristics which make it particularly suitable, for a given application.

B-2.3.1 SINGLE EXPANSION JOINTS

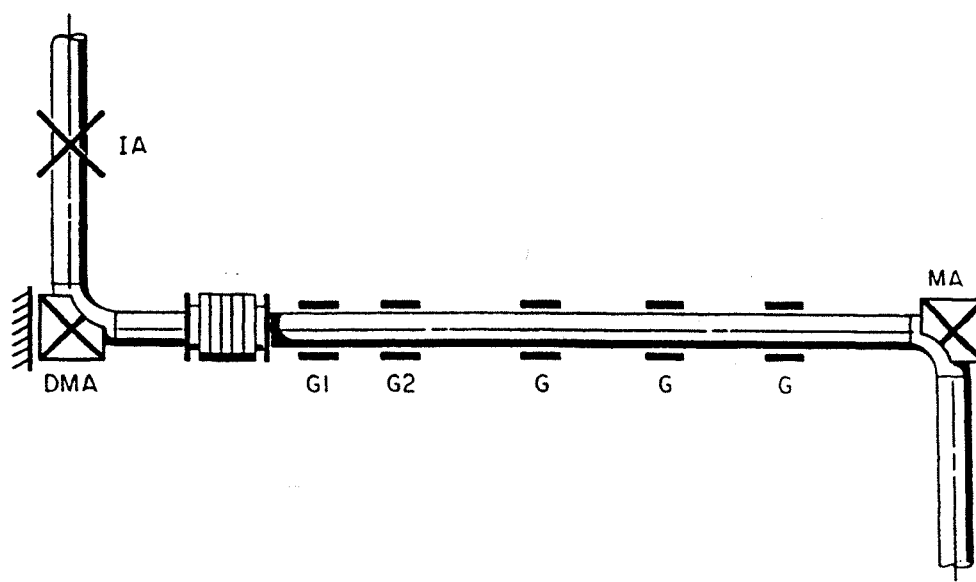


FIGURE B9

The single Expansion Joint is usually considered first for any application because it offers the lowest Expansion Joint cost. Figure B9 shows a typical application of a single Expansion Joint absorbing combined axial movement and lateral deflection. The system closely resembles the arrangements shown for axial movement only in the preceding section. The Expansion Joint is located at one end of the long piping leg with main anchors at each end and guides properly spaced for both movement control and protection of the piping against buckling. The anchor at the left end of the line is a directional main anchor (DMA) which, while absorbing the main anchor loading in the direction of the Expansion Joint axis, permits the thermal expansion of the short piping leg to act upon the Expansion Joint as lateral deflection. Because the main anchor loading exists only in the piping segment containing the expansion joint, the anchor at the end of the shorter piping leg is an intermediate anchor.

STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION, INC.

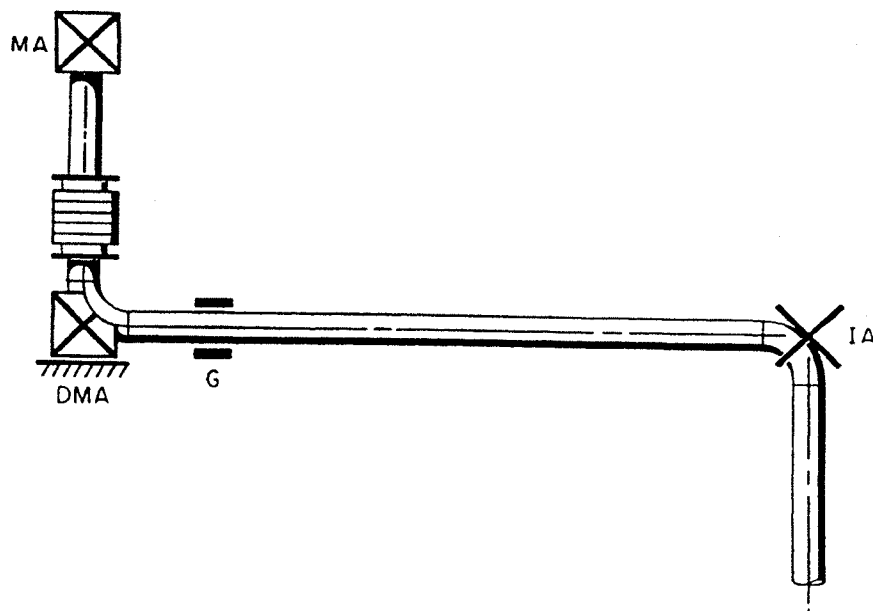


FIGURE B10

Figure B10 shows an alternate arrangement in which the Expansion Joint is installed in the short piping leg and the principal expansion is absorbed as lateral deflection. The longer piping leg is free of compressive pressure loading and requires only an intermediate anchor and directional guiding. The functions of the directional main anchor and the pipe guide may be combined in a single device.

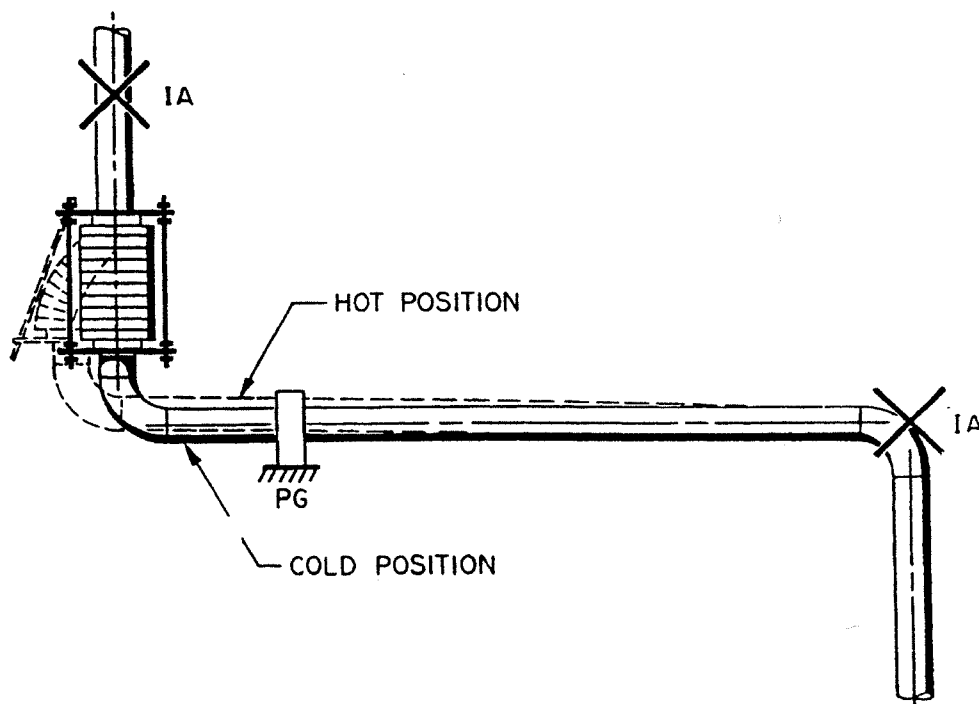


FIGURE B11

B-2.3.1 (continued)

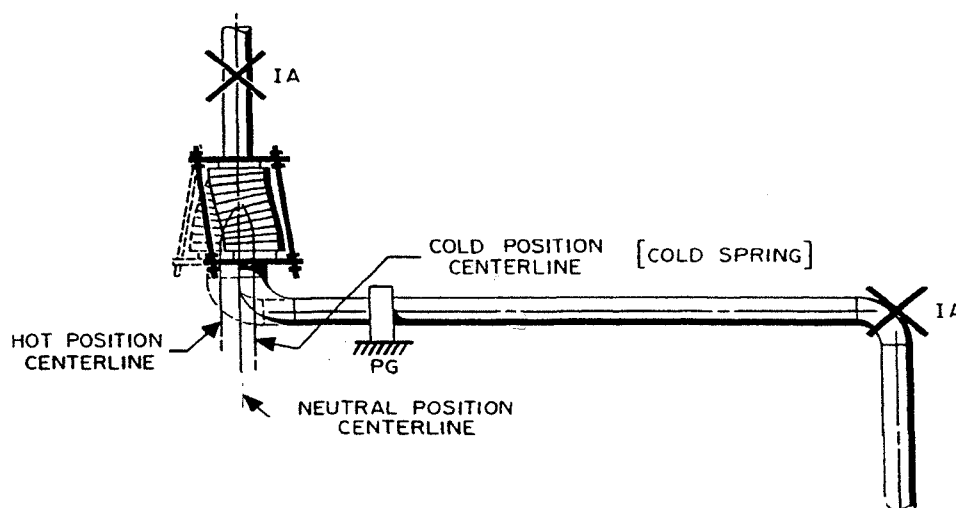


FIGURE B12

Figures B11 and B12 represent modifications of Figure B10 in which the main anchors at either end of the Expansion Joint are replaced by tie rods. Where the piping configuration permits, the use of tie rods adjusted to prevent axial movement frequently simplifies and reduces the cost of the installation. Because of these tie rods, the Expansion Joint is not capable of absorbing any axial movement other than its own thermal expansion. The thermal expansion of the piping in the shorter leg is, as a result, imposed as deflection on the longer piping leg. Where the longer piping leg is not sufficiently flexible and where the dimension of the shorter leg is suitable, tie rods may be installed spanning the entire short leg so that no deflection is imposed on the longer run from this source.

Where appreciable amounts of lateral deflection are imposed upon the Expansion Joint, some shortening of the Expansion Joint results from the displacement of the tie rods as shown in Figure B11. Care should be taken to insure that sufficient piping flexibility exists to absorb this deflection and that adequate clearances are provided in the guide to permit deflection of the piping. The amount of this deflection can be minimized by cold springing the Expansion Joint in the lateral direction as shown in Figure B12.

The principal restriction upon the use of single Expansion Joints for lateral deflection or combined axial movement and lateral deflection is the limited amount of lateral deflection which such an Expansion Joint can absorb. The allowable lateral deflection is directly proportional to the ratio of convoluted length to diameter which, in turn, is restricted by considerations of stability and manufacturing limitations. While eminently suitable for applications such as Figure B9 where the principal movement is axial, the relatively small available lateral movement severely limits the type of application illustrated in Figures B10, B11 and B12. Where operating pressures and temperatures are high, or where availability of suitable structures precludes the use of main anchors and multiple guides, the application shown in Figure B9 may not be feasible and another type of Expansion Joint may result in far more economical installation.

B-2.3.2 UNIVERSAL EXPANSION JOINTS

The universal Expansion Joint is particularly well adapted to the absorption of lateral deflection. In addition, this design may be used to absorb axial movement, angular rotation or any combination of the three. A common application of the universal Expansion Joint is its use as a tied Expansion Joint in a 90 degree piping offset with the tie rods adjusted to prevent external axial movement. Two such applications are shown in Figures B13 and B14.

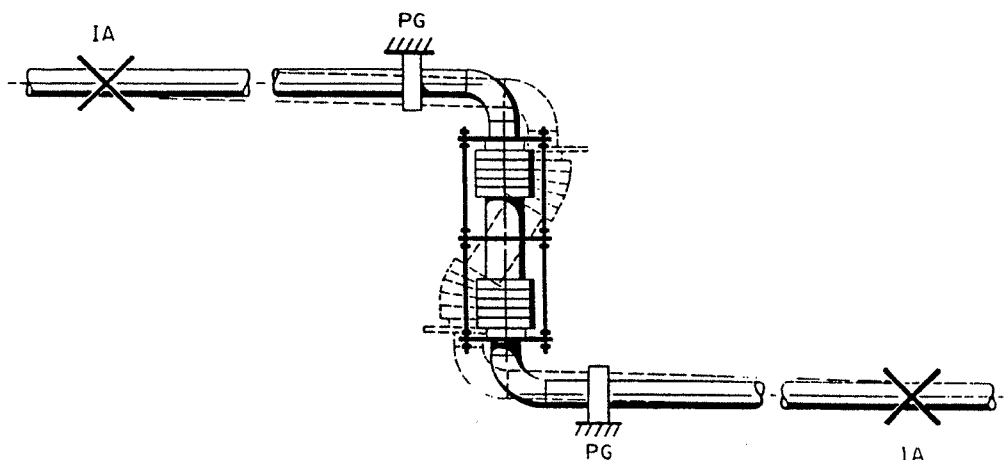


FIGURE B13

Figure B13 shows a tied universal Expansion Joint used to absorb lateral deflection in a single plane "Z" bend. Where dimensionally feasible, the Expansion Joint should be designed to fill the entire offset leg so that its expansion is absorbed within the tie rods as axial movement. The tie rod should be extended to the elbow center line when practical. The thermal movement of the horizontal lines is absorbed as lateral deflection by the Expansion Joint.

Both anchors are intermediate anchors since the pressure loading is absorbed by the tie rods. Only directional guiding is required since the compressive load on the pipe consists only of the force necessary to deflect the Expansion Joint. Any thermal expansion of the offset leg external to the tie rods, such as that of the elbows at either end, must be absorbed by bending of the horizontal pipe legs. Provision should be made in the design of the guides to allow for both this deflection and the reduced length of the Expansion joint in its deflected position. In addition, particularly in the case of long universal Expansion Joints under high pressure, additional allowance may be necessary to compensate for stretching of the tie rods under load. The Expansion Joint manufacturer should be consulted for recommended minimum guide clearances.

B-2.3.2 (continued)

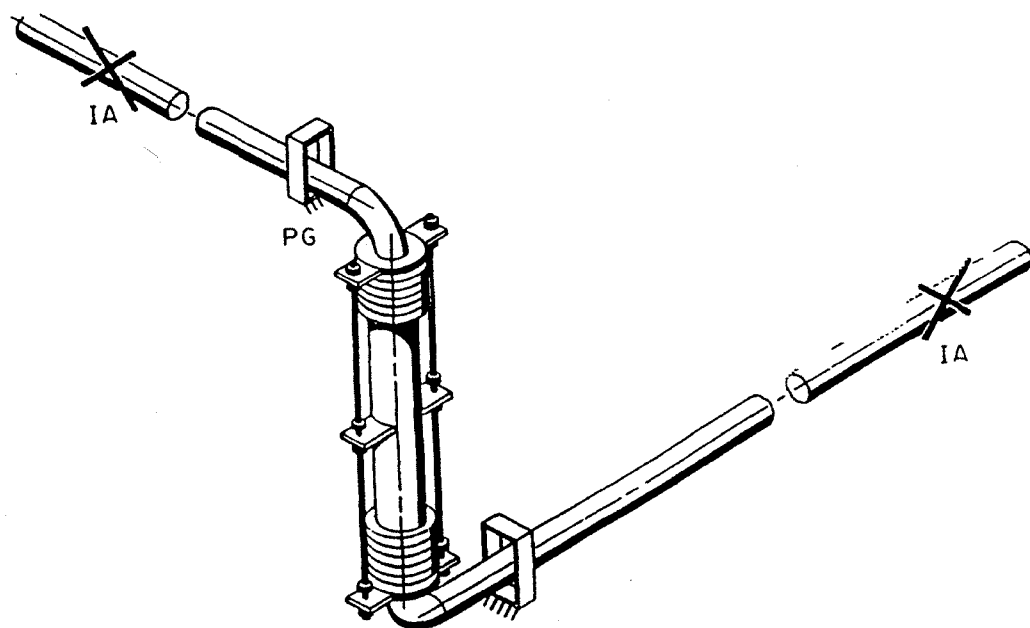


FIGURE B14

Figure B14 shows a typical application of a tied universal Expansion Joint in a three-plane "Z" bend. Since the universal Expansion Joint can absorb lateral deflection in any direction, the two horizontal piping legs may lie at any angle in the horizontal plane.

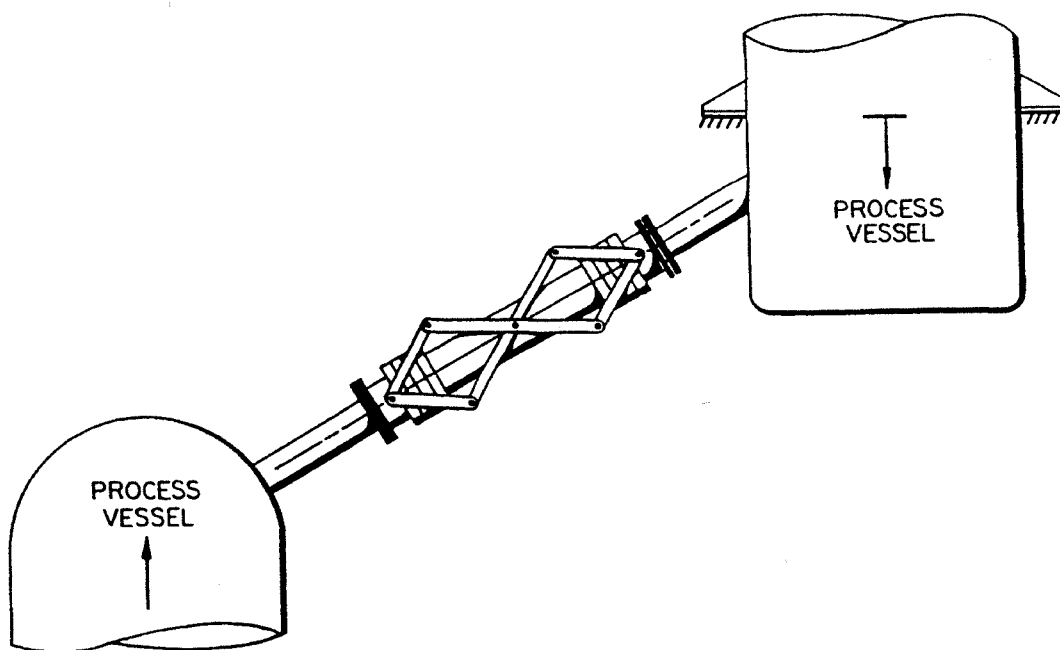


FIGURE B15

B-2.3.2 (continued)

In cases where a universal Expansion Joint must absorb axial movement other than its own thermal growth, it cannot function as a tied Expansion Joint and must be used in combination with main anchors to absorb pressure loading.

One such case is shown in Figure B15. The relative expansion between the two vessels results in both axial movement and lateral deflection on the Expansion Joint. Both vessels must be designed to absorb main anchor loading. Control rods or pantographic linkages may be used to distribute the movement between the bellows and control their movements.

Numerous variations are possible in the design of universal Expansion Joints. Rods, pantographic linkages, slotted hinges or external structural members may be used in a horizontal installation, for example, where it is desirable to support the center pipe section of the Expansion Joint independently of the bellows. In a single plane system, the rods may be replaced by two bars with pinned connections at either end of the Expansion Joint. This construction is so commonly used that it has been given the standard nomenclature of "Swing Expansion Joint". In some cases two sets of short control rods, each set spanning one of the two bellows in the universal Expansion Joint are used instead of the overall rods shown in most of the illustrations. This arrangement is frequently used where the Expansion Joint must absorb axial movement and where the control rods are used for control and stability and not for absorption of pressure loading. This can result when the universal Expansion Joint is very long in relation to its diameter, or a large number of convolutions are used at each bellows of the Expansion Joint, or where the Expansion Joint is subject to external forces.

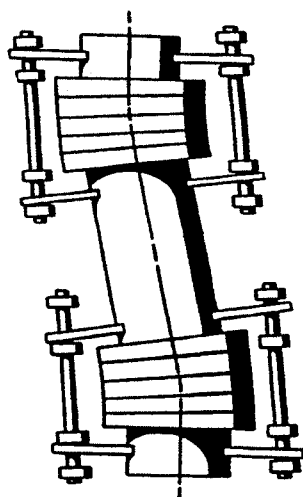


FIGURE B16

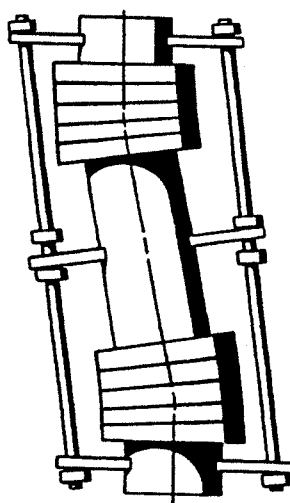


FIGURE B16B

B-2.3.2 (continued)

It may be desirable to incorporate control devices in the Expansion Joint to prevent excessive displacement of the bellows and the relatively free pipe section between them. Figures B16A and B16B show two forms of controls which may be used for this purpose. In Figure B16A, short rods are used spanning each of the bellows in the Expansion Joint. Stops are provided on the rods so that, once the Expansion Joint has reached its rated lateral deflection, the stops will be engaged by members rigidly fastened to the pipe portions of the Expansion Joint.

Figure B16B shows a similar device adapted to an Expansion Joint with overall rods. The rod stops are engaged by a plate or lug attached to the center pipe portion and movement of this part beyond its design deflection is restrained. In order to obtain maximum control from these devices, the stops are usually oriented to lie in the plane of resultant movement of the Expansion Joint, affording maximum leverage as well as greater sensitivity to small movement. Devices of this nature are usually furnished by the manufacturer dependent upon the design characteristics of the Expansion Joint.

Despite the versatility of the universal Expansion Joint, its use is sometimes precluded by the configuration of the piping, the operating conditions or even by manufacturing and transportation limitations. It may be undesirable or impossible to fabricate, ship to the job site and install a universal Expansion Joint which would span the full length of the offset where, for example, the length of the offset leg in a "Z" bend is extremely long. When the Expansion Joint is very long in relation to its diameter, the flexibility of overall rods may reduce the effectiveness of the control so that the center pipe section becomes unstable. Other types of Expansion Joints may offer a more desirable solution when such limits are encountered.

B-2.3.3 PRESSURE BALANCED EXPANSION JOINTS

The pressure balanced Expansion Joint is used most frequently in applications similar to those shown for the single Expansion Joint, but where pressure loading upon piping or equipment is considered excessive or objectionable. The major advantage of the pressure balanced design is its ability to absorb externally imposed axial movement without imposing pressure loading on the system. The force resulting from the bellows spring rate is not eliminated. In fact, it is usually increased over that of a single Expansion Joint, since both the flow bellows and the balancing bellows must be compressed or elongated and the combined axial force acts upon the piping or equipment. Since the forces to move the bellows are generally of a low order of magnitude, these are usually not objectionable, except in cases involving extremely light equipment with close clearance moving parts which might be affected by small forces.

B-2.3.3 (continued)

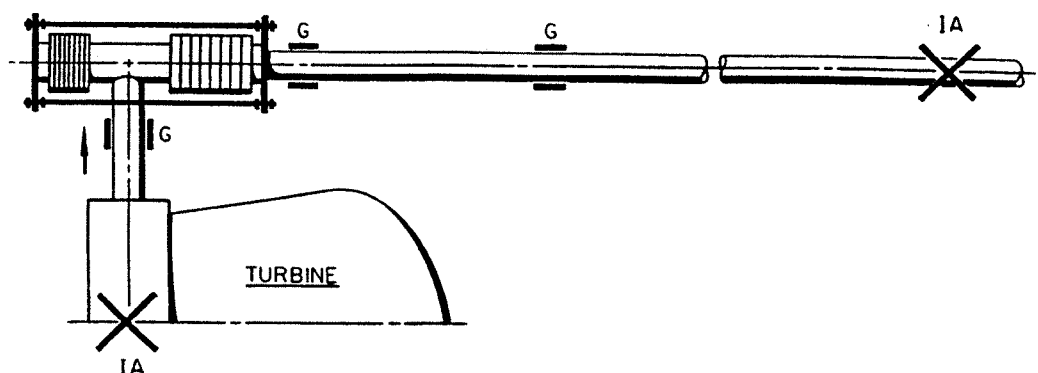


FIGURE B17

Figure B17 shows a typical application of a pressure balanced Expansion Joint for combined axial movement and lateral deflection. Both the anchor at the end of the piping run and that on the turbine are intermediate anchors and only directional guiding is required. By proper design, the guide directly above the turbine can be made to absorb the axial movement forces of the Expansion Joint without imposing these on the turbine. The only force imposed on the turbine is that which is required to deflect the Expansion Joint laterally.

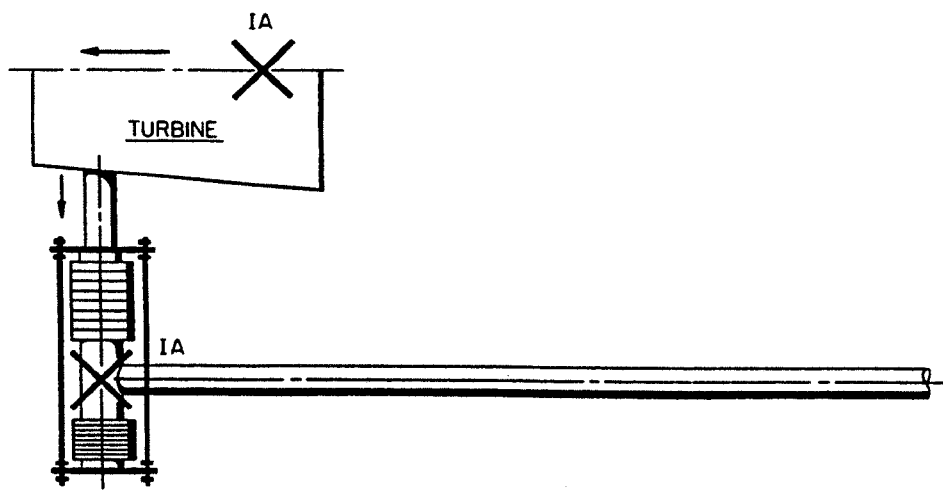


FIGURE B18

Figure B18 shows another turbine application but, in this case, the anchor point of the turbine is located some distance from the Expansion Joint and the expansion of the turbine between its anchor and the Expansion Joint is absorbed as lateral deflection. An intermediate anchor is used at the center fitting of the Expansion Joint. Since the Expansion Joint is located close to the turbine, guiding between the turbine and Expansion Joint is not required.

B-2.3.3 (continued)

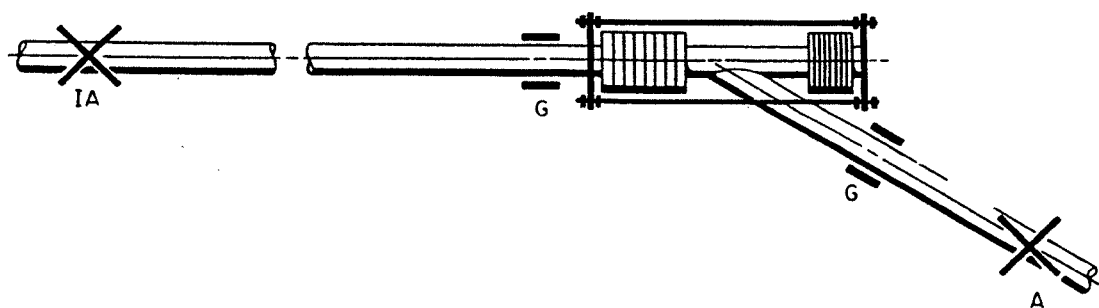


FIGURE B19

Figure B19 shows that a pressure balanced Expansion Joint can be used at changes in direction other than 90 degrees. In this case, the growth of the longer piping run is absorbed as axial movement on the Expansion Joint, while the thermal expansion of the offset piping run introduces both axial and lateral components or deflection on the Expansion Joint. Only intermediate anchors are required at the ends of the lines and directional guiding is used. The guide on the offset run may be used to absorb the axial movement forces of the Expansion Joint, if the piping is not sufficiently stiff to transmit this directly to the intermediate anchor.

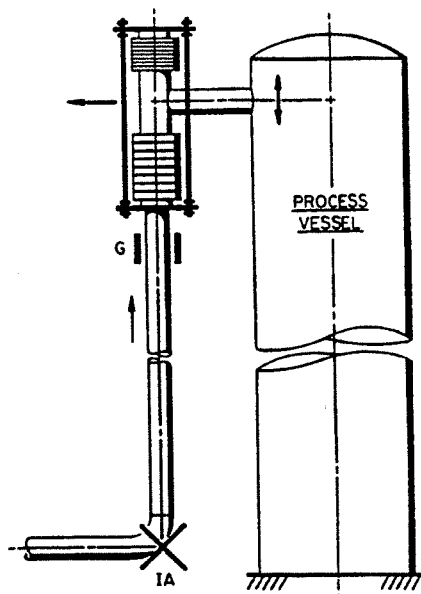


FIGURE B20

Figure B20 shows a common application for which a pressure balanced Expansion Joint is well suited. Under various process conditions, the vessel and the vertical pipe may expand at different rates. By installing a pressure balanced Expansion Joint as shown, the differential vertical movement is absorbed as axial movement on the Expansion Joint and the thermal expansion from the center line of the process vessel to the piping is absorbed as lateral deflection. The piping may then be secured by an intermediate anchor at the bottom and furnished with a directional guide adjacent to the Expansion Joint.

B-2.3.3 (continued)

In many cases, no external structure is available at the upper elevation of the process vessel and the guide must be connected to the vessel itself. Using this arrangement may result in some bending load upon the piping, especially where the vessel is tall and is subject to wind loading deflection or similar effects. Where the guide is attached to a rigid external structure, the Expansion Joint must be designed to absorb wind loading deflection, and other similar loading, as lateral deflection.

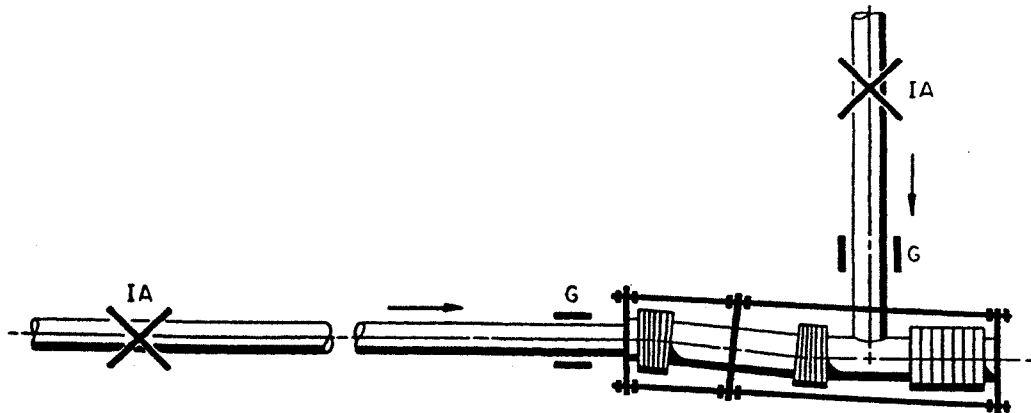


FIGURE B21

Where large amounts of lateral deflection are involved, a pressure balanced universal Expansion Joint must be used. In this design, two bellows are used in the flow end of the Expansion Joint and a single bellows in the balancing end. Normally, as shown in Figure B21, the balancing bellows will be subjected only to axial movement if the tie rods are properly designed to rotate or pivot at their attachment points.

In order for a pressure balanced Expansion Joint to function properly, the pressure thrust restrained by the tie rods must exceed the axial movement forces of the Expansion Joint. In a large diameter, low pressure application, it may be impossible to utilize the pressure balanced Expansion Joint to eliminate the pressure loading or, at best, the effect may be uncertain. In such cases, some other Expansion Joint design must be considered. Pressure balanced Expansion Joints are not recommended for use in services where the pressure equalizing connection between the flow bellows and the balancing bellows may become plugged or blocked by the flowing medium or by contaminants. Where flow considerations permit, this problem may be overcome by the use of a tee as a center fitting of the Expansion Joint, rather than an elbow. In some cases, the pressure for the balancing end of the Expansion Joint has been introduced from a separate pressure source, but this is considered somewhat hazardous. A control failure or even a slow control response might result in partial or full pressure loading being imposed upon the piping or equipment, thus overcoming the initial reason for using the pressure balanced Expansion Joint.

B-2.3.3 (continued)

The pressure balanced Expansion Joint is used to relieve loads on equipment such as pumps, compressors and turbines. In many cases, the cost of the pressure balanced Expansion Joint will be negligible when compared to the cost of additional equipment, piping and building space which would be necessary for safe functioning of the equipment without the Expansion Joint.

B-2.3.4 HINGED EXPANSION JOINTS

Hinged Expansion Joints are usually used in sets of two or three, to absorb lateral deflection in one or more directions in a single plane piping system. Each individual Expansion Joint in such a system is restricted to pure angular rotation by its hinges. Each pair of hinged Expansion Joints, separated by a segment of piping, will act in unison to absorb lateral deflection in much the same manner as a swing or universal Expansion Joint in a single plane application. For a given angular rotation of the individual Expansion Joints, the amount of lateral deflection which a pair of hinged Expansion Joints can absorb is directly proportional to the distance between their hinge pins. In order to utilize the Expansion Joints most efficiently, this distance should be made as large as possible.

Expansion Joint hinges are normally designed to absorb the full pressure thrust of the Expansion Joint and may be designed to support the weight of piping and equipment, wind loads or similar externally applied forces. Where such external forces are anticipated, their direction and magnitude must be indicated to the Expansion Joint manufacturer so that the hinges can be adequately designed to withstand these forces.

B-2.3.4 (continued)

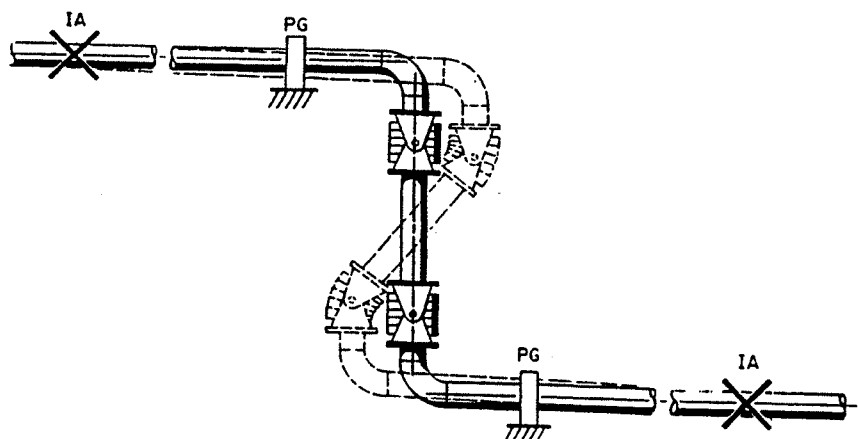


FIGURE B22

Figure B22 illustrates the use of a two-hinge system to absorb the major thermal expansions in a single-plane "Z" bend. Since the pressure thrust is absorbed by the hinges on the Expansion Joints, only intermediate anchors are required at each end of the piping system. The thermal expansion of the offset section containing the Expansion Joints must be absorbed by bending of the piping legs perpendicular to that segment, since the Expansion Joints are restricted to pure angular rotation by their hinges and cannot extend or compress. The amount of bending deflection imposed on each of the two long piping legs may be controlled by proper design of guides and supports. Where one long leg is sufficiently flexible to absorb the full thermal growth of the offset leg, the other long leg may be controlled to permit longitudinal movement only. The planar guides shown at the ends of the long piping runs near the elbows are intended to maintain the plane of the piping system only and must allow for the bending deflections of the long piping legs. In calculating guide clearances, consideration shall be given to the fact that the thermal expansion of the offset piping leg containing the Expansion Joints will be partially offset by the reduction in length resulting from the displacement of the center pipe section. The latter effect may be neglected only where the distance between hinge pins is very large and the lateral displacement small. This effect can be minimized by cold springing the Expansion Joints 50% of the full rated deflection.

Because of the ability of the hinges to transmit loads, support of a hinged piping system can frequently be simplified. Assuming that Figure B22 is an elevation view and that the upper piping leg is sufficiently flexible to absorb the total expansion of the vertical leg, it would be possible to use sliding supports on the lower horizontal run to support its weight and restrict it to longitudinal movement only. By utilizing the rigidity of the hinges, a substantial portion of the weight of the upper horizontal leg may also be carried on these lower supports. It should be noted that the sliding supports nearest the vertical leg must be designed to resist the force required to deflect the piping. Spring supports must be used throughout the length of the upper horizontal leg where bending occurs. Beyond that point, sliding supports may be used.