TECHNICAL HANDBOOK

DUCTING SYSTEMS

Non-Metallic Expansion Joints

4th EDITION

FLUID SEALING ASSOCIATION

FSA

Acknowledgements

The Fluid Sealing Association (FSA) is pleased to acknowledge the member companies and individuals who served on the Technical Committee of the Ducting Systems Non-Metallic Expansion Joints division, for making a particularly significant contribution to this publication.

The FSA is also pleased to acknowledge the cooperation of the European Sealing Association (ESA).

FLUID SEALING ASSOCIATION FSA

www.fluidsealing.com

Fluid Sealing Association Technical Handbook For

Non-Metallic Expansion Joints

We encourage qualified applicants to become members of the FSA. For information on eligibility criteria, or for more information about the FSA, call or write:

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WHO WE ARE

The Fluid Sealing Association (FSA) is an international trade association. Founded in 1933, the FSA membership today represents over 85% of the manufacturing capacity for fluid sealing devices in North America. Our membership is most heavily concentrated in North America, but also includes a number of companies in Europe, Asia and Central and South America. As international trade grows throughout the world and creates a need for universally accepted standards, we have become more international in scope. We actively seek and welcome new members from all parts of the world.

WHAT WE DO

Our objective is to serve as a focal point for worldwide efforts to improve the manufacture, understanding and application of fluid sealing devices. Our members provide expertise to outside organizations and government agencies involved in the establishment of standards and regulations which may affect the manufacture and application of fluid sealing devices. We publish handbooks and technical data on many aspects of fluid sealing and serve as a primary resource for engineers, students, government officials and others seeking technical information about fluid sealing devices. We also collect, analyze and disseminate information about trends in business, markets, materials, technology, government regulations and trade which may affect our membership.

OUR MISSION

- To be recognized as the primary source of technical information
- To take a leadership role in setting standards
- To influence and support the development of such standards
- To provide education in the fluid sealing area
- To promote a safe, clean environment for society and a safe workplace for our employees
- To monitor the economic, environmental and social changes that may impact our membership's business
- To develop a global forum for exchange of information

WHY BUY FROM AN FSA MEMBER

- Collective experiences of the major manufacturers in the industry
- Active participation in the development of the technological improvements
- Set codes and standards for the industry
- Reliability/proven technology
- Decades of field experience

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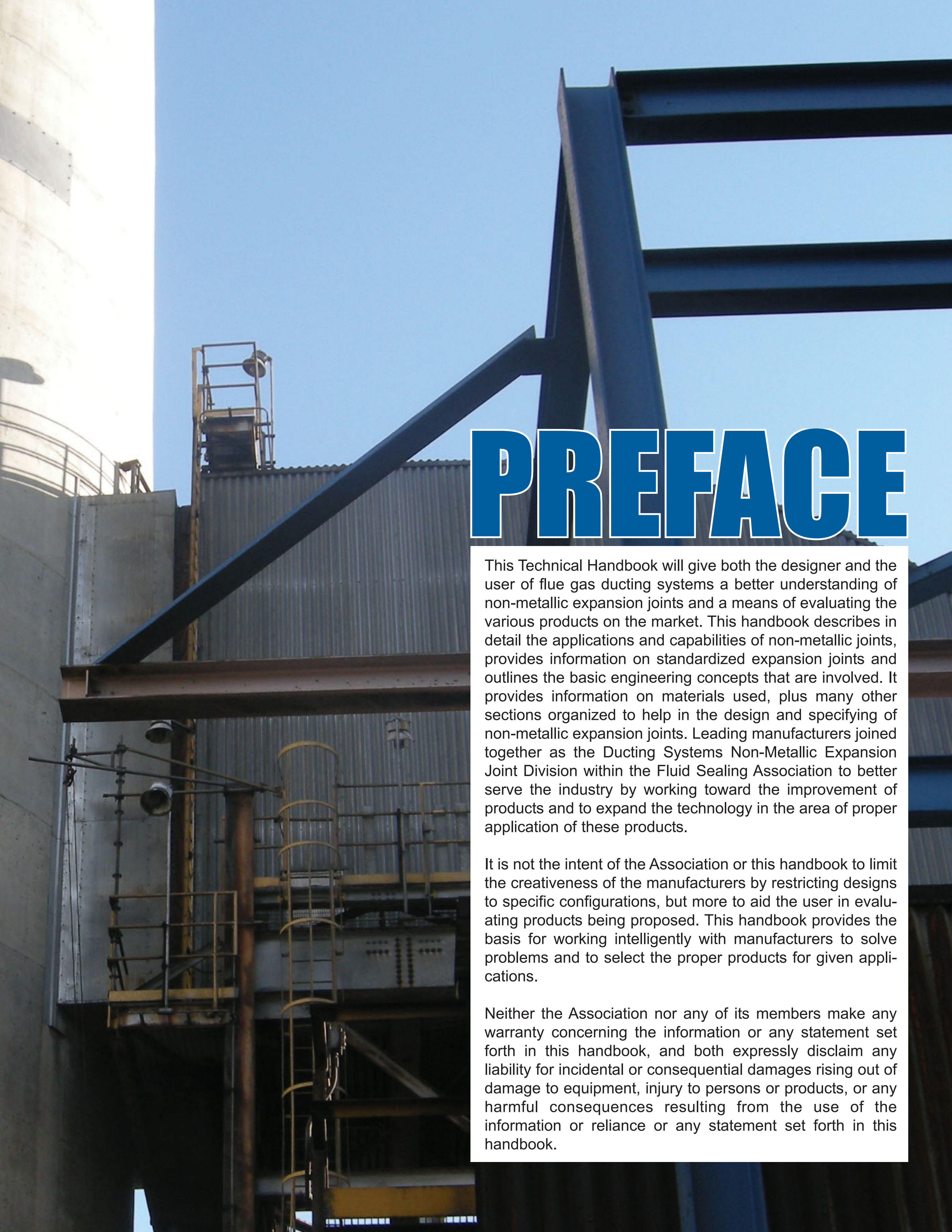
Table Of Contents



PREFACE

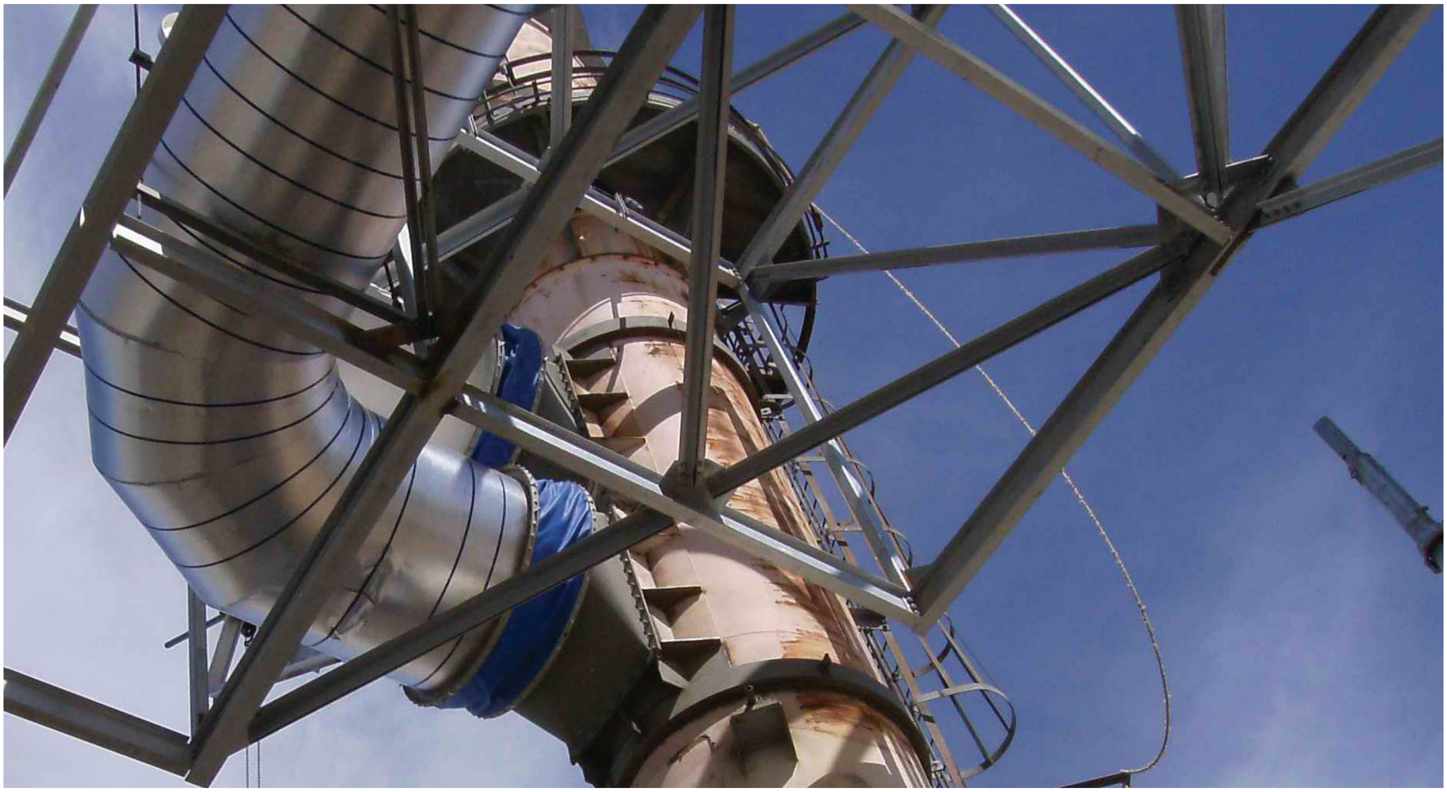
This Technical Handbook will give both the designer and the user of flue gas ducting systems a better understanding of non-metallic expansion joints and a means of evaluating the various products on the market. This handbook describes in detail the applications and capabilities of non-metallic joints, provides information on standardized expansion joints and outlines the basic engineering concepts that are involved. It provides information on materials used, plus many other sections organized to help in the design and specifying of non-metallic expansion joints. Leading manufacturers joined together as the Ducting Systems Non-Metallic Expansion Joint Division within the Fluid Sealing Association to better serve the industry by working toward the improvement of products and to expand the technology in the area of proper application of these products.

It is not the intent of the Association or this handbook to limit the creativeness of the manufacturers by restricting designs to specific configurations, but more to aid the user in evaluating products being proposed. This handbook provides the basis for working intelligently with manufacturers to solve problems and to select the proper products for given applications.

Neither the Association nor any of its members make any warranty concerning the information or any statement set forth in this handbook, and both expressly disclaim any liability for incidental or consequential damages rising out of damage to equipment, injury to persons or products, or any harmful consequences resulting from the use of the information or reliance or any statement set forth in this handbook.

Section A - What Are Ducting Non-Metallic Expansion Joints?

A-1. Definition of Product



Non-metallic expansion joints are flexible connectors designed to provide stress relief and seal in gaseous media in ducting systems. They are fabricated from a wide variety of non-metallic materials, including synthetic elastomers, fabrics, insulation materials and fluoroplastics, depending on the designs.

A-2. Industries/Processes

Non-metallic expansion joints have over 40 years of operating experience in the following industries and processes.

- **Power Generation;**
    - Fossil Fuel Fired Plants
    - Gas Turbine Plants
    - Cogeneration Plants

- **Nuclear Power Plants**
- **Bio-Mass Plants**
- **Pollution Abatement Systems**
- **Pulp and Paper Plants**
- **Chemical and Petrochemical**
- **Primary Metal Processing**
- **Cement Plants**
- **Waste Incineration**
- **Marine, Shipboard and Offshore**
- **Vapor/Heat/Dust Recovery**

A-3. Expansion Joint Capabilities & Advantages

Expansion joints provide flexibility in ductwork and are used to allow for 4 main situations:

- expansion or contraction of the duct due to temperature changes.
- isolation of components to minimize the effects of vibration or noise.
- movement of components during process operations.
- installation or removal of large components and erection tolerances.

Advantages of non-metallic expansion joints include:

Large movements in a short length
Requires fewer expansion joints, reducing the overall number of units and providing additional economies.

Ability to absorb simultaneous movements easily in more than one plane
Allows the duct designer to accommodate composite movements in fewer and simpler expansion joints.

Very low forces required to move the expansion joint
The low spring rate enables their use to isolate stresses on large, relatively lightweight, equipment. A particular example is a gas turbine exhaust where it is crucial to minimize the forces from the duct expansion on the turbine frame.

Corrosion Resistant Materials of Construction
Modern technology materials enable the use in aggressive chemical conditions.

Noise and Vibration Resistance
Non-metallic expansion joints provide a high degree of noise isolation and vibration damping.

Ease of Installation
Non-metallic expansion joints are relatively lightweight and can be hoisted into place with a minimum of field assembly required.

Minimal Replacement Cost
The flexible element portion of the expansion joint assembly can be replaced simply and economically.

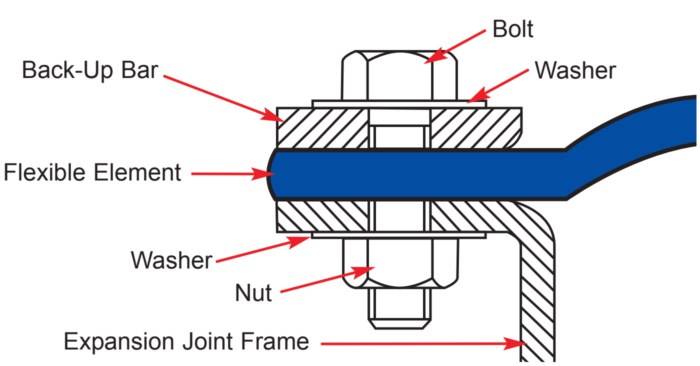
Design Freedom
Non-metallic expansion joints can be tailored to suit the duct application with taper, transition or irregular shape, allowing the designer the maximum variety of options.

Thermal Breaks
Self-insulating properties of the fabric allow simple hot-to-cold transition.

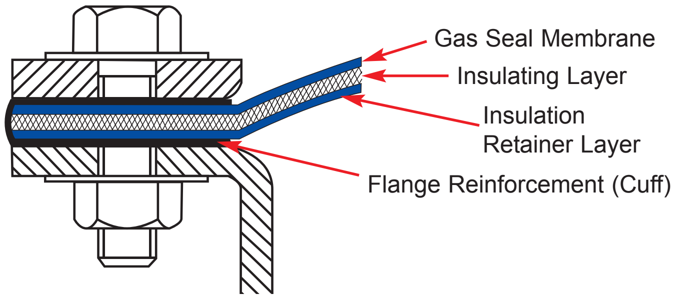
A-4. Expansion Joint Construction and Configuration

A-4.1 Construction
There are two basic forms of construction depending on the number of layers in the expansion joint; single layer construction and multi-layer construction.

A-4.1.1. Single Layer Construction
An expansion joint formed of one consolidated layer, often constructed from elastomers and reinforcement materials or fluoroplastics and reinforcement materials:



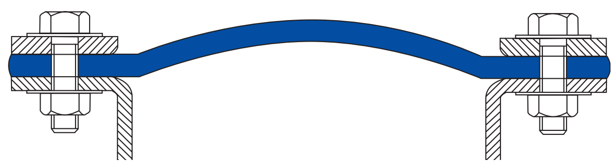
A-4.1.2. Multi-Layer Construction
An expansion joint in which the various plies are of different materials which are not integrally bonded together.



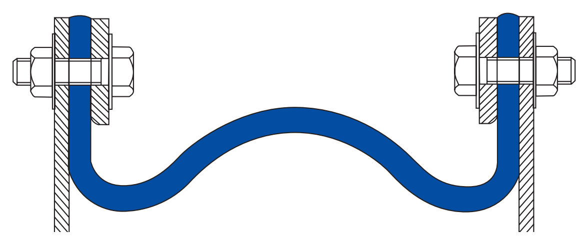
A-4.2. Clamping Configurations
There are three types of clamping configurations that may employ one of the above constructions;

- Belt type expansion joint configuration
- Flanged expansion joint configuration
- Combination type expansion joint configuration

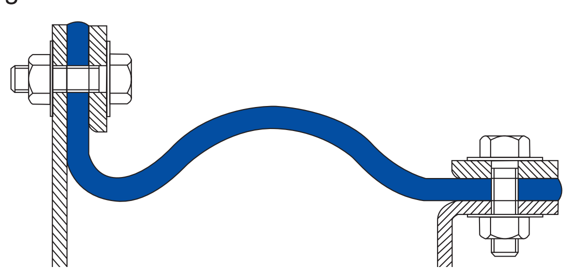
A-4.2.1. Belt-Type Expansion Joint Configuration
An expansion joint in which the flexible element is made like a flat belt:



A-4.2.2. Flanged-Type Expansion Joint Configuration
An expansion joint in which the flexible element has flanges formed at right angles.



A-4.2.3. Expansion Joint Clamping Configuration
An expansion joint that utilizes both belt type and flanged configurations.



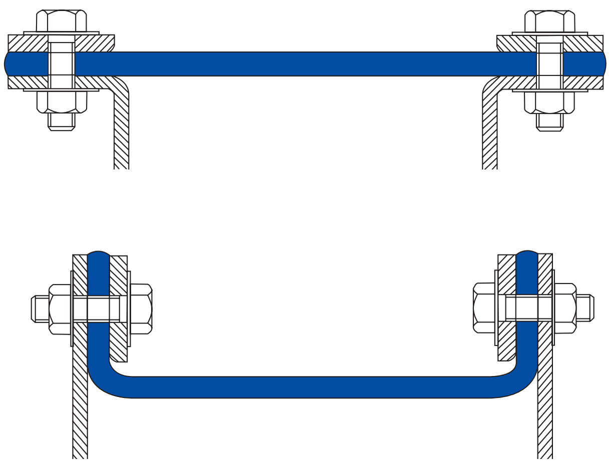
Section A - What Are Ducting Non-Metallic Expansion Joints?

A-4.3. Flexible Element Configurations
In addition to the clamping configurations shown, the flexible element may be manufactured in a variety of configurations, depending on application and performance requirements:

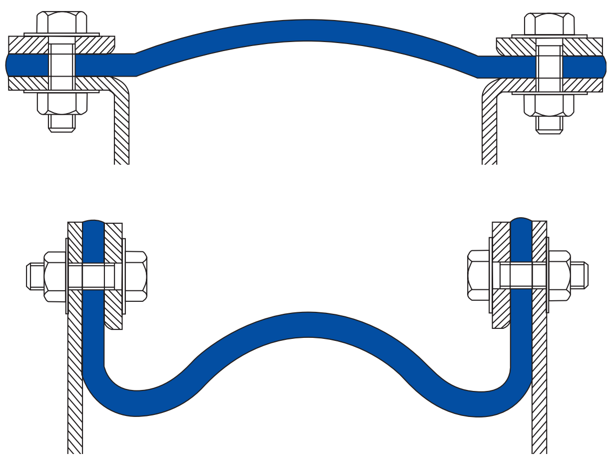
Flat • Convex • Concave • Convoluted

In the section below, the upper diagram represents flat belt type configuration and the lower diagram represents a flanged clamping configuration.

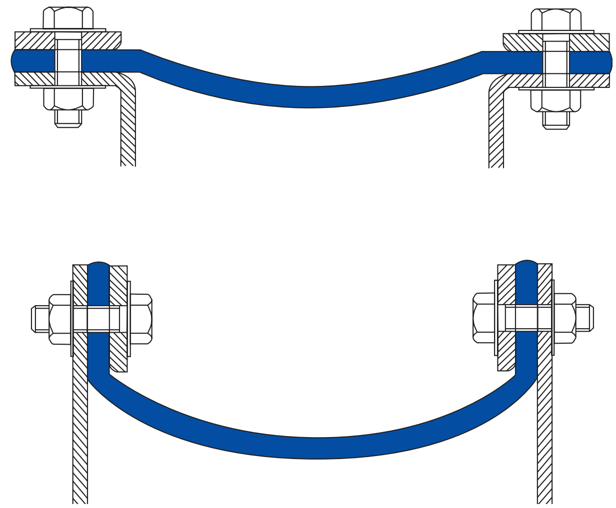
A-4.3.1. Flat-Type Flexible Element Configuration
An expansion joint where the flexible element is a flat belt with two alternate clamping configurations.



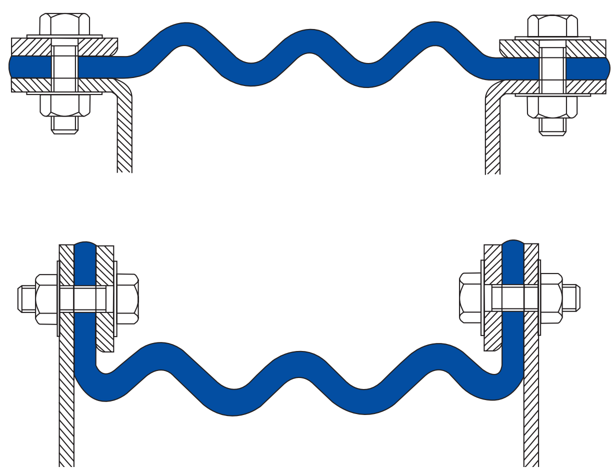
A-4.3.2. Convex-Type Flexible Element Configuration
An expansion joint where the arch is pre-formed to provide additional movement capability and prevent folding of the flexible element.



A-4.3.3. Concave Type Flexible Element Configuration
Expansion joints where the flexible element is formed into a "U" or conical shape.



A-4.3.4. Convoluted Type Flexible Element Configuration
Expansion joints where large movements are accommodated through the use of multiple convolutions.



Section B - Expansion Joint System Design Criteria

B

Introduction
In order to design the expansion joint with optimum life and operating reliability, there are certain criteria which must be considered. (See Appendix-5 on page 38)

B-1. Customer Data
Customer name and qualifier (OEM, End-user)
Address
City, State, Zip Code
Name of person submitting data, Phone, Fax
Project name & country
New or replacement

B-2. Service
Information concerning service, type of plant and location in the plant is probably the most important information to obtain. In most cases this information will give the supplier details of the demands put on the expansion joints that the supplier will not get from all the other data on the specification sheet. The supplier's experience with the different plant types and technologies is important knowledge to utilize.

Type of fuel (*B-2.2*) is important for determining the aggressiveness of the flue gas. In particular, finding the contents of sulphur (SO_2, SO_3) as it may have a negative influence on the expansion joints material, if not considered in the initial design.

B-2.1 Type of plant & in plant location.
(GT, Boiler, Precipitator, Scrubber, etc.)
B-2.2 Type of fuel
B-2.3 Peak load or base load
B-2.4 Number of start/stop cycles per year
B-2.5 Installation inside or outside

B-3. Medium
Knowing the medium is essential for deciding on materials and design of baffle (flow liner) construction, drain, etc.

Medium (*B-3.1*) requires a detailed description (e.g. air should be described as combustion air, not just air).

Medium Condition (*B-3.3*) should be specified with relative humidity rate since it is important to know if the flue gas is continuously wet (i.e. condensating water, as the combination of H_2O with SO_2 or SO_3 from the medium will form H_2SO_4).

Dust Contents (*B-3.4*) combined with flow velocity (*B-3.5*) will determine whether a baffle (flow liner) is required. The supplier may also decide to install a pillow between the baffle (flow liner) and expansion joint to limit dust collection.

In connection with the operation of a plant, it may be necessary to perform washing to clean fly ash build-up in the ducting, washing of the heat exchangers or washing the gas turbine propellers.

In all cases it will be necessary to prevent liquids from soaking the expansion joints. The only exception is single layer expansion joints (i.e. of elastomeric or fluoroplastic materials installed in flue gas cleaning plants).

B-3.1 Medium (air, flue gas, etc.)
B-3.2 Chemical composition (SO_2, SO_3, HF etc.)
B-3.3 Medium condition (dry/wet)
B-3.4 Dust contents and load (type, lbs/ft^3 (mg/m^3))
B-3.5 Flow velocity/volume (ft/s (m/s))
B-3.6 Washing of duct/gas turbine (yes/no)

B-4. Pressure - Pulsation & Flutter
The system operating pressure is a crucial factor affecting the design of expansion joints. The very flexible nature of the materials brings a number of design issues which must be addressed. Although maximum operating pressures in duct systems are low by comparison with pipeline systems, wide variations of pressure, such as a change from positive to negative, or short term peak pressures can occur. Such variations should be reflected in the design pressure specified by the customer. Particular care in the choice and construction of materials must allow for:

- Containment of the stated design pressure under all conditions of movement and temperature, without over-stressing the expansion joint assembly.
- Changes from positive to negative pressure which could entrap materials under compression or cause them to be in contact with sharp or hot components of a duct.
- High positive pressure and compression allowing materials to abrade on bolt heads of back-up bars.
- Changes in pressure causing significant air spaces between layers of composite joint materials which could allow circulation of hot gas.
- Pressure surges occurring as a result of system operation.

Section B - Expansion Joint System Design Criteria

B-4.1. Pulsation
Pressure pulsation in a duct or pipeline can be detrimental to an expansion joint, particularly those manufactured from plies of woven glass-cloth or ceramics. Rapid variation in pressure causes fatigue of the fibers that can lead to premature failure of the expansion joint. Particular caution is required when designing expansion joints for combustion engine exhaust systems to ensure that the joint is not installed too close to the engine. A sufficient distance is required to allow the pressure fluctuations to subside.

B-4.2. Flutter
Flutter can be induced by fans, particularly where the system is unbalanced. The expansion joint materials connected to the adjoining fans must be selected with this in mind. To overcome flutter of the joint materials, which could lead to premature failure, the materials must be of sufficient thickness and density to damp out the oscillations. Reinforced elastomeric materials are commonly specified for expansion joints installed on the fan inlet or outlet.

Flutter in expansion joint seals can also be induced by high gas velocity, but is usually eliminated by careful design of a suitable flow liner attached to the duct or joint frame. The inclusion of a cavity pillow can help to minimize flutter.

B-5. Temperature
By knowing operating temperature, design temperature and ambient temperature, the expansion joint manufacturer can calculate the temperature gradient through the expansion joint construction.

Ambient temperature means surrounding air temperature without considering other factors such as radiation.

An important piece of information is the dew point temperature. It is naturally possible to reach dew point temperature during start-up and shut-down of the system (*refer to Service, B-2.4*), and it is therefore important to give the following details:

B-5.1. Temperature of medium (°F) (°C)
B-5.2. Design temperature (°F) (°C) Max ____ Min ____
B-5.3. Operating temperature (°F) (°C)
B-5.4. Ambient temperature (°F) (°C)
B-5.5. Dew point temperature (°F) (°C)
B-5.6. Max excursion temperature ____
Duration/Occurrence ____

B-6. Movements
In general, the greater the movements, the larger the active length required. The supplier has information on the relevant flexibility of the individual product, as the flexibility depends on the material for number of layers and types.

B-6.1. Axial Compression
B-6.2. Axial Extension
B-6.3. Lateral
B-6.4. Torsional (°)
B-6.5. Angular (°)
B-6.6. Vibration

B-7. Duct Geometry
The duct geometry details all physical considerations that must be taken before completing a quotation. The manufacturer will be able to give good input to the design of flange heights, back-up bars, corners, etc.

B-7.1. Duct size (external measurements)
B-7.2. Duct thickness
B-7.3. Duct material
B-7.4. Flange connection size and material
B-7.5. Duct corner: radius or square
B-7.6. Duct insulation: (Internal/external)
- inlet
- outlet

B-7.7. Flow direction through the duct (up, down, horizontal, angular up, angular down)
B-7.8. Internal and external interferences.

B-8. Scope of Supply
Some or all of the requirements listed below can be supplied by the manufacturer;

B-8.1. Expansion joint: belt type, flange type
B-8.2. Insulation pillow
B-8.3. Internal baffle (flow liner)
B-8.4. Gaskets
B-8.5. Back-up bars, bolts, nuts, etc.
B-8.6. Installation
B-8.7. Supervision
B-8.8. Mounting/attachment frame
B-8.9. Splicing

Section C - Expansion Joint Ductwork Interface Considerations

Introduction
The interface connection of the expansion joint is very critical. As important as material selection, the expansion joint flange (mounting frame or integral) and the connecting flanges are of equal importance.

When the system is being designed for anchors, supports, and guides, the expansion joint movement capabilities must also be considered.

Caution: The flexible element must not be used as an anchor, support, or guide. However, the frames can be designed to accommodate these requirements.

To facilitate the interface design the following conditions should be considered;

C-1. Movements

The face-to-face dimension of the expansion joint, as installed, is a major design consideration. In general, an increased face-to-face dimension results in greater movement capabilities.

C-1.1. Types of Movements

Three dimensional system movements can occur five ways and in any combination. These movements are outlined below;

(a) Axial Compression: The dimensional shortening of the expansion joint face-to-face gap parallel to its longitudinal axis.

(b) Axial Extension: The dimensional lengthening of the expansion joint parallel to its longitudinal axis.

(c) Lateral: The dimensional displacement of the inlet and the outlet flanges of the expansion joint perpendicular to its longitudinal axis.

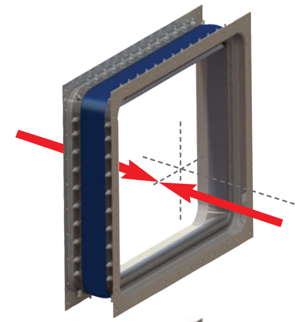
(d) Torsional: The twisting of one end of the expansion joint with respect to the other end along its longitudinal axis.

(e) Angular: The movement which occurs when one flange of the expansion joint is moved to an out-of-parallel position with the opposite flange.

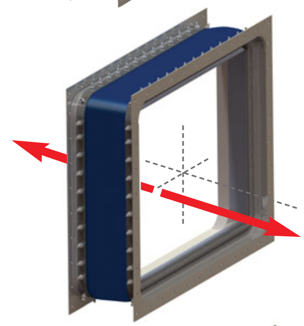
(f) Vibration: The rapid, small movements back and forth that can occur in any single plane or multi-planes.

Note: Torsional and angular movements are usually given in degrees which can be calculated into inches, which in turn can be added to or subtracted from the three basic movements; compression, extension and lateral.

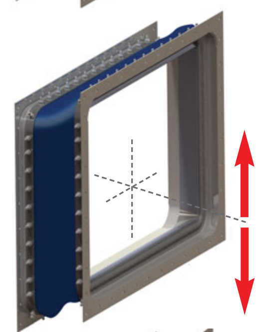
A. Axial Movement (Compression)



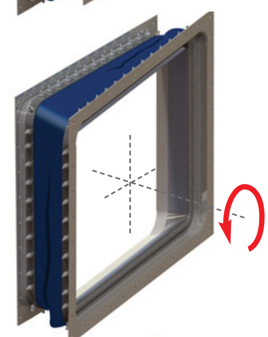
B. Axial Movement (Extension)



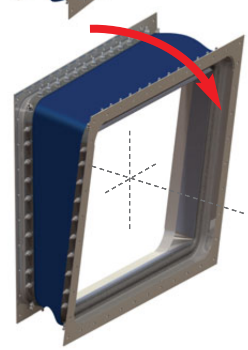
C. Lateral Movement



D. Torsion (Rotation)



E. Angular Deflection (Bending)



Section C - Expansion Joint Ductwork Interface Considerations

C-1.2. Independent or Concurrent Movement
In designing the expansion joint it is necessary for the expansion joint manufacturer to be advised if the specified movements are independent or concurrent.

(a) Independent Movement is defined as acting alone and in only one direction at one time.

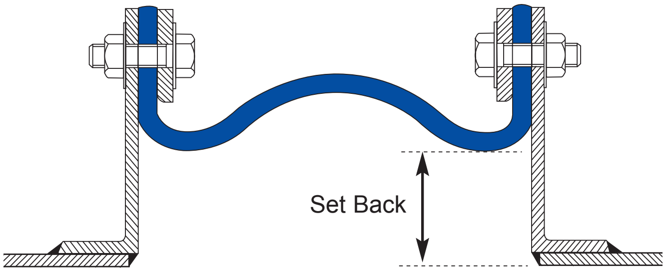
(b) Concurrent Movement is defined as any two or more movements acting simultaneously.

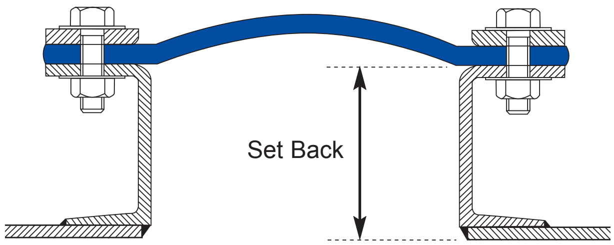
When concurrent movements exist, the manufacturer must be advised as to the magnitude of the various movements in which combination they will occur and if possible the sequence of occurrence (axial then lateral, etc.).

C-1.3. Normal Operating and Excursion Movement
The expansion joint manufacturer should be advised of the normal movement and the excursion movement data.

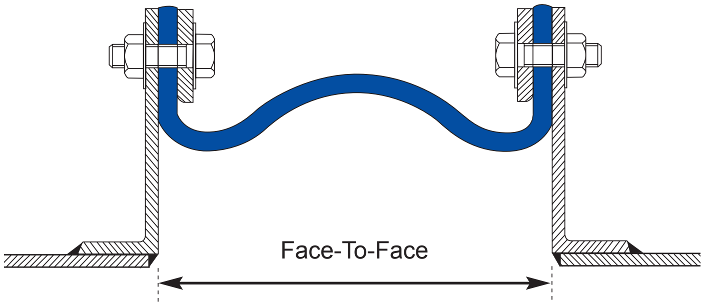
Caution: Non-metallic expansion joints can accommodate multiple movements in a single opening, however caution should be exercised in locating and selecting the number of expansion joints based on movement and temperature requirements.

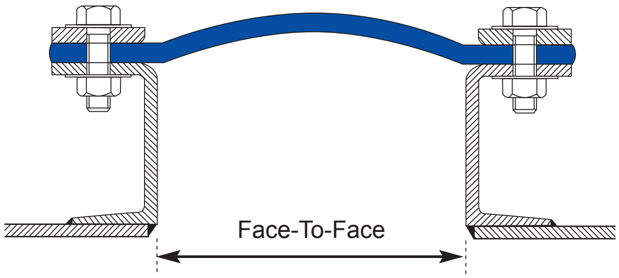
C-2. Setback (Stand-off Height)
When establishing the dimensions of the duct mounting surfaces, setback (stand-off height) must be considered. Setback (stand-off height) is the distance the expansion joint (flexible element) is moved outward from the gas stream.





C-3. Breach Opening or Face-To-Face Distance
The breach opening or face-to-face distance is the distance between the mating duct flanges in which the expansion joint is to be installed.





Note: The active length of the flexible element is a major design consideration. When determining the active length, both movements and system pressure must be considered.

C-4. Location of Expansion Joints

C-4.1. Equipment Interface
When the expansion joint is to be mounted to a piece of equipment (i.e. fan, air heater, damper, etc.) special attention must be paid to the possible interferences from equipment appendages.

C-4.2. Ductwork Interface
When the expansion joint is to be mounted to a duct flange, attention must be paid to possible interferences from ductwork stiffeners. To prevent possible damage the expansion joint should be located away from adjacent support structures, beams, auxiliary equipment, etc.

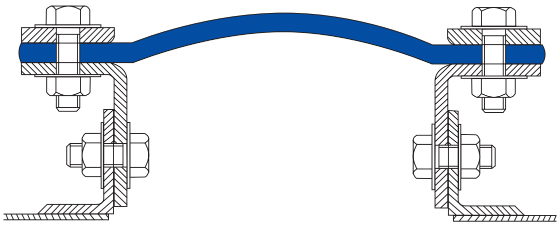
Caution:
Special care should be used when locating an expansion joint in an area which does not allow for adequate air movement around the exterior of the expansion joint.

C-5. Expansion Joint Frame Attachment

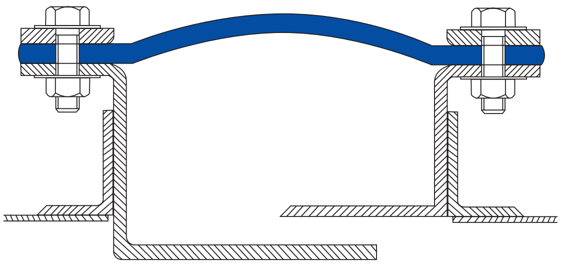
Method of attaching the expansion joint frame to the duct work.

C-5.1. Attachment Methods

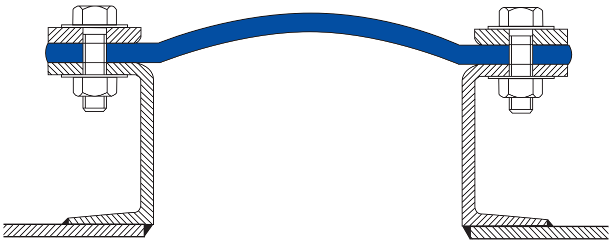
(a) Bolt frame to mating flange



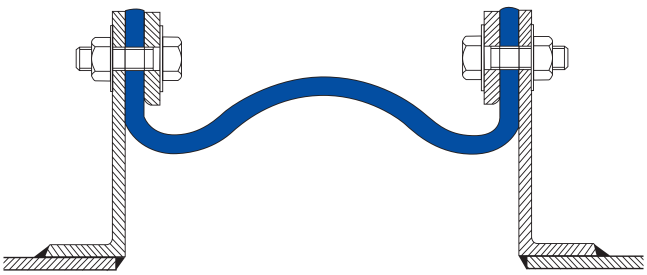
(b) Weld frame to mating flange



(c) Weld frame to duct end



(d) Weld frame to duct end



C-5.2. Stiffening

The expansion joint frame and or duct flange may require stiffening depending on design conditions.

C-5.3. Metallurgy

Care must be taken when dissimilar metals are being joined by welding. Material selections need to be considered based on operating and design conditions. (See Appendix-6 “Thermal Expansion Chart” on page 39).

C-5.4. Baffles (Flow Liners)

Designs which require the use of baffles (flow liners) need to be reviewed as to the method of attachment;

- Integral
- Bolt-in
- Weld-in

C-5.5. Expansion Joint Frame Loads

- Thermal and non-thermal
- Pressure
- Structural

C-6. Interface Tolerances

The flexible nature of expansion joints reduces the need for very tight manufacturing tolerances for the flexible element. However, it is necessary to define the interface tolerances for expansion joints and their frames for their connection to ducts or other components.

Consult the following standards for general tolerances:

- **ISO 2768-1 (1989)** Tolerances for linear and angular dimensions without individual tolerance indications.

- **EN ISO 13920 (1996)** General tolerances for welded constructions - dimensions for lengths and angles.

Other national and international standards may apply in different countries. Check with the manufacturer or your local standards authority for advice.

The following tolerances apply to the interface between the client's duct and the expansion joint.

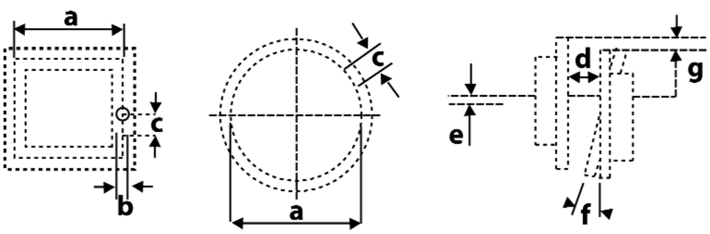
(a) Overall Duct Length and Width

1. Up to 10' ± 1/8" (3m ± 3mm)
2. 10' to 20' ± 1/4" (3m to 6m ± 6mm)
3. Over 20' ± 3/8" (6m ± 9mm)

(b) Overall Duct Diameter

1. Up to 5' dia. ± 1/4" (1.5m dia. ± 6mm)
2. 5' to 10' dia. ± 3/8" (1.5m to 3m dia. ± 9mm)
3. Over 10' dia. ± 1/2" (3m dia. ± 13mm)

Section C - Expansion Joint Ductwork Interface Considerations



Bolt Hole Circle:	**a** = ±1/8” (±3mm) up to 60” (1.5m) ±1/4” (±6mm) over 60” (1.5m)
Bolt Hole Diameter:	**b** = -0, +1/32” (-0, +1mm)
Bolt Pitch:	**c** = ±1/16” (±1.5mm)
FF Distance (including “f”):	**d** = ±1/2” (±13mm)
Preset of Axis:	**e** = ±1/8” (±3mm)
Flange Alignment:	**g** = ±1/2” (±13mm)
Duct Internal Diameter:	**ID** = ±3/16” (±5mm) under 78” (2m) ±5/16” (±8mm) from 78” (2m) to 16’ (5m) ±1/2” (±13mm) over 16’ (5m)
Mating Flange Flatness:	**Fl-F** = ±1/16” (±1.5mm) in any length of 40” (1m)

C-6.1. Other Tolerances

Duct Internal Diameter or Side Length

Under 6.5 ft (2m)	±3/16” (±5mm)
6.5 ft (2m) to 16.5 ft (5m)	±5/16” (±8mm)
Over 16.5 ft (5m)	±1/2” (±13mm)

Mating Flange Surface

Flatness:	±1/16” (±1.5mm) in any 40” (1m) length
Sag at Outer Edge:	1/16” (1.5mm) per 4” (100mm) width

C-6.2. Mating Flange Surface Flatness
± 1/16" (1.5mm) in any 40” (1m) length

C-6.3. Mating Flange Sag/Sweep
The sag and/or sweep of the mating flange shall not exceed the tolerance as allowed by the AISC Structural Steel Code. EN/ISO 13920 ISO

C-6.4. Breach Opening
Axial: +1/4" (6mm) extension, -1/2" (-13mm) compression
Lateral: 1/2" (13mm)

C-6.5. Bolt Hole Tolerances
±1/16" (±1.5mm) between each hole cumulative of ±1/8" (±3mm) in any 10ft (3m) length.

Please contact the expansion joint manufacturer if any of the above tolerances cannot be achieved.

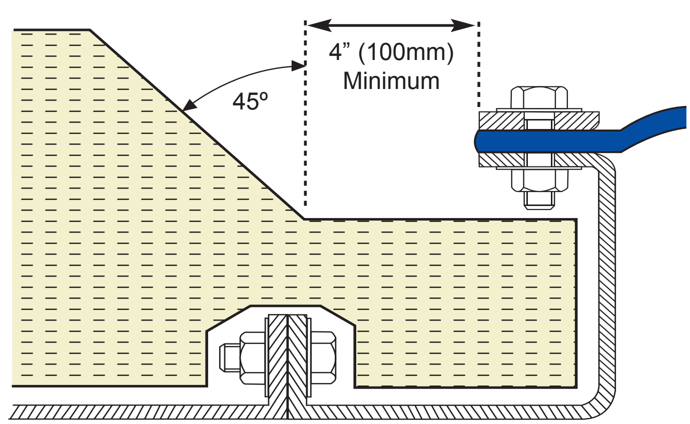
C-7. Ambient Conditions

C-7.1. Ambient Temperature
An expansion joint should not be located in an area of poor air circulation or subject to high temperature radiation. Expansion joints working at elevated temperatures (above 500ºF/260°C) depending on a temperature gradient across the joint, is the difference between the high internal temperature (hot face) and colder external temperature (cold face) of the joint. High ambient temperatures in the vicinity of the joint will reduce this temperature gradient reducing the rate at which heat can be radiated from the external surface of the joint.

This in turn may lead to reduced service life of the expansion joint. Therefore, it is important to ensure that adequate provision is made to keep local ambient temperatures within manufacturer's recommendations. External lagging or insulating of joints is not allowed. Where cold external ambient conditions prevail, consideration should be given to the possibility of condensation forming inside fabric expansion joints. Counter measures such as internal or external insulation may be considered appropriate.

C-7.2. Environment
Expansion joints are very often situated in arduous industrial locations such as power generation plants, chemical works, cement plants etc. In such locations they may be subjected to higher than normal levels of pollutants, some of which may attack the outer cover of the joint. If the type and concentration of such pollutants are known at the design stage, it is possible to design a joint which will resist such attack by selection of an appropriate outer cover, resistant to specific agents.

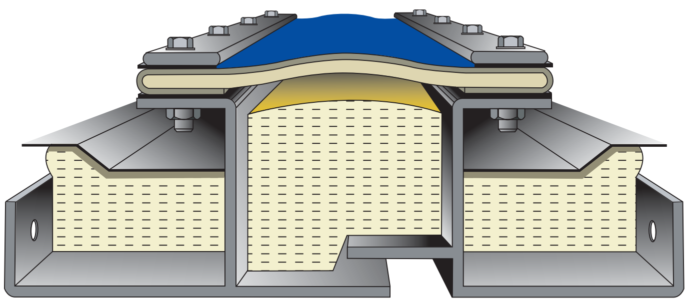
C-8. Insulation
When insulating the ductwork, care should be taken to properly insulate around the expansion joint assembly. Low temperature expansion joints, (below 500°F/260ºC), may be insulated over with the concurrence of the expansion joint manufacturer. Consult Manufacturer if insulating high temperature expansion joints (over 500°F/260ºC). The connection point between the expansion joint element and the mounting frame should allow for adequate cooling.



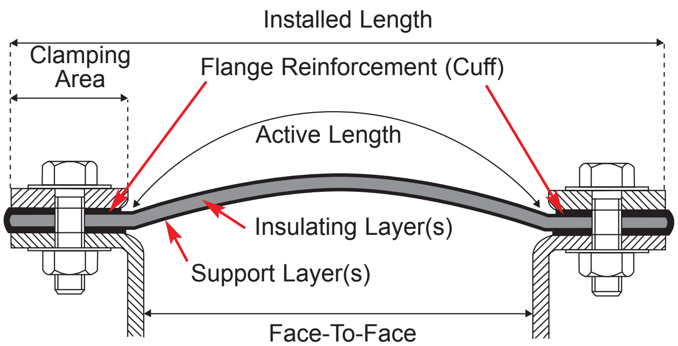
Section D - Expansion Joint Design Considerations

D

D-1. Non-Metallic Expansion Joint Components



In this section we describe the various components which contribute to the flexible elements' performance. The diagram represents the flexible element of a belt-type expansion joint with multi-layer construction.



Note: The active length of the flexible element is a major design consideration. When designing active length, both movements and system pressure must be considered.

D-2. Flexible Element Major Components

The Active Length is the portion of the flexible part of the joint that is free to move. The flexible element consists of a gas seal membrane with optional insulating and support layer(s) and flange reinforcement.

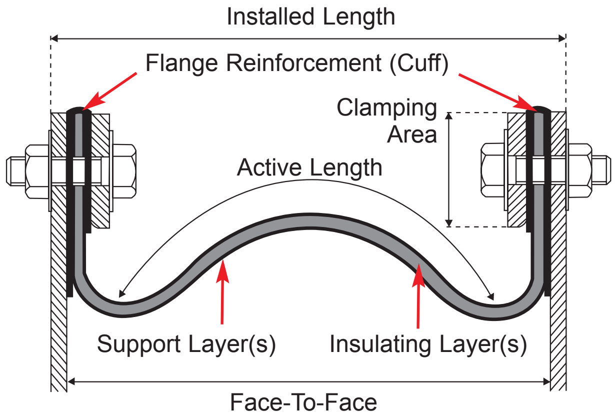
The Gas Seal is the specific ply in the expansion joint which is designed to prevent gas penetration through the expansion joint body. It should be designed to cope with the internal system pressure and resist chemical attack. Gas seal flexibility is crucial in order to handle movements of the ductwork. In some cases the gas seal may be complemented by a chemical barrier to improve chemical resistance.

The Outer Cover is the ply exposed to, and providing protection from, the external environment. In some cases the outer cover may also be combined with the gas seal or act as a secondary seal.

The Insulation (or insulating layers) provides a thermal barrier to ensure that the inside surface temperature of the gas seal does not exceed its maximum service temperature. Insulation can also help to reduce and/or eliminate condensate problems.

The Support Layers keep the insulation in place and provide protection during handling and system operation. Careful selection of suitable materials (capable of withstanding system operating temperatures and chemical attack) is critical to successful design. Support layers can also be used to assist in creating arched or convoluted expansion joint configurations where a specific shape is required.

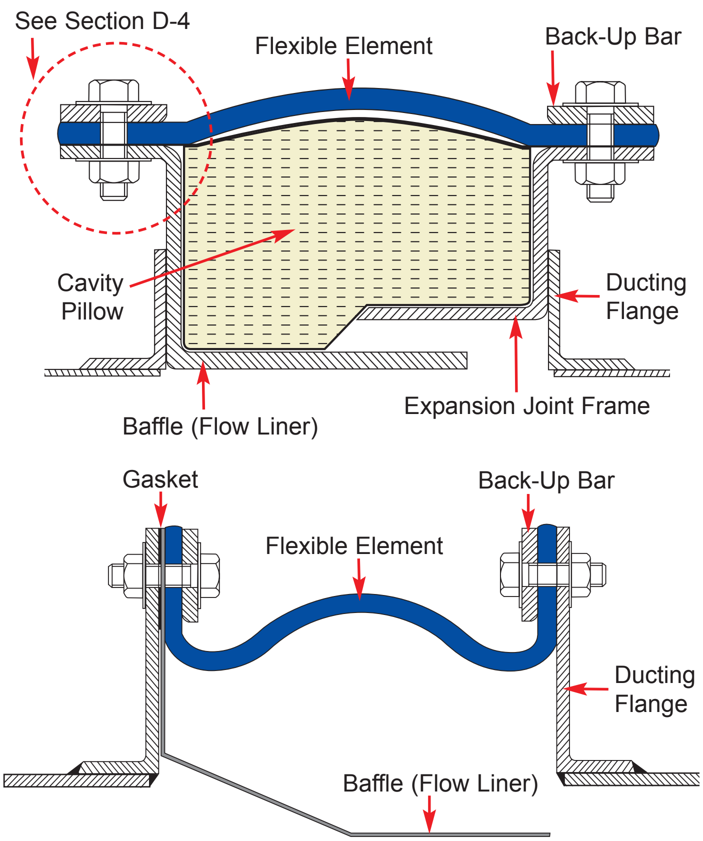
The Flange Reinforcement (cuff) is an additional sheath of fabric to protect the expansion joint from thermal and/or mechanical degradation.



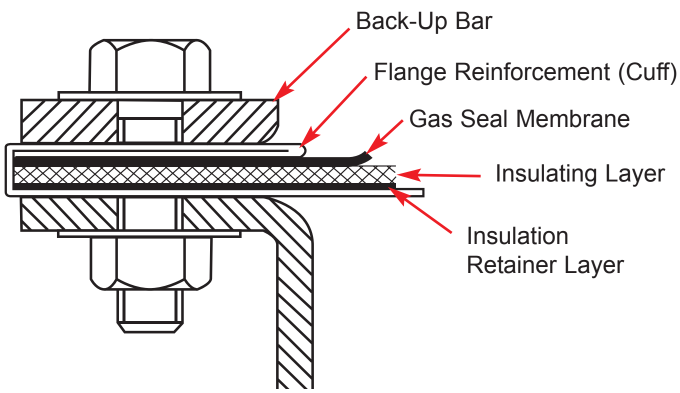
The diagram above represents the flexible element of a flanged expansion joint with multi-layer construction.

Section D - Expansion Joint Design Considerations

D-3. Anatomy of a Typical Non-Metallic Expansion Joint



D-4. Function of Non-Metallic Expansion Joint Components



D-4.1. Flexible Element is the portion of the expansion joint which absorbs vibration and the thermal movements of the ductwork. The flexible element should consist of a gas seal membrane with optional insulating layer(s), insulation retainer layer(s) and flange gasket. The optional layers are required where the system temperature exceeds the temperature range of the gas seal membrane.

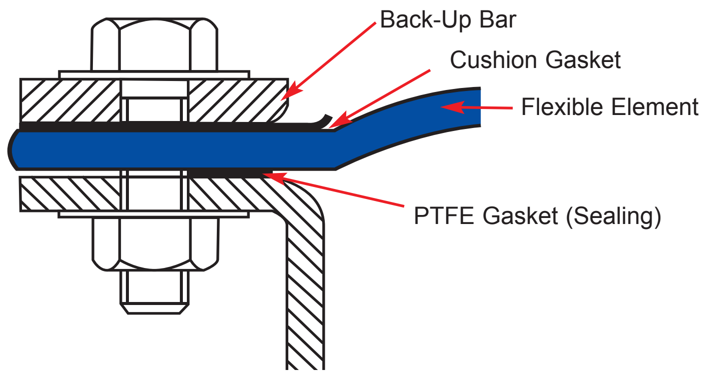
(a) The Gas Seal Membrane should be designed to handle the internal system pressure and resist chemical attack. The gas seal membrane flexibility is crucial in order to handle the thermal movements of the ductwork. Since the present gas seal membranes used in flue duct applications have temperature limitations, additional thermal protection may be required. Please refer to (Section E) for assistance in selecting a suitable gas seal membrane.

(b) The Insulating Layers provide a thermal barrier to ensure that the inside surface temperature of the gas seal membrane does not exceed its maximum service temperature. Insulation can also help reduce and/or eliminate condensate problems.

(c) The Insulation Retainer Layers keep the insulating layers in place and provide protection during handling and system operation. Proper selection of suitable materials capable of withstanding system temperatures and chemical attack is critical to a successful design.

(d) The Flange Reinforcement (Cuff) protects the gas seal membrane on a multi-layered flexible element from thermal degradation caused by hot metal flanges, back-up bars and bolting hardware.

Cushion Gasket, Single Membrane
Due to the high density of fluoroplastics, a flexible gasket compatible with the flow media is required between the metal attachment flange and the fluoroplastic gas seal membrane in order to provide an adequate seal.



All sharp edges which may come in contact with the flexible element should be ground smooth or radiused to prevent damage to the flexible element.

D-5. Clamping Devices
There are several methods of clamping expansion joints. Some of the most common are detailed below:

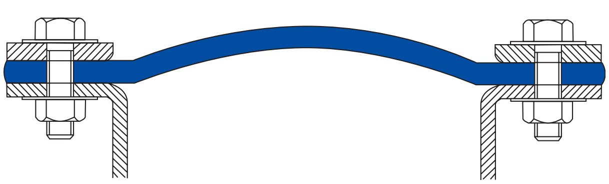
Table D-A: Clamping Devices

Expansion Joint Type	Clamping Device	Duct Cross Section	Duct Size	Operating Pressure	Cost of method
BELT	Worm Drive	Circular	Small	Low	Low
	Comment: Fast installation				
	T-Bolt	Circular	Small /Large	Low	Low
	Comment: Fast installation. Use toggle in several segments for larger diameters, to ensure even clamping pressure				
	Back-up Bar	Circ /Rect	Small /Large	Low /High	Medium
	Comment: High temperature capability				
FLANGED	Back-up Bar	Circ /Rect	Small /Large	Low /High	Medium
	Comment: Moderate temperature capability				

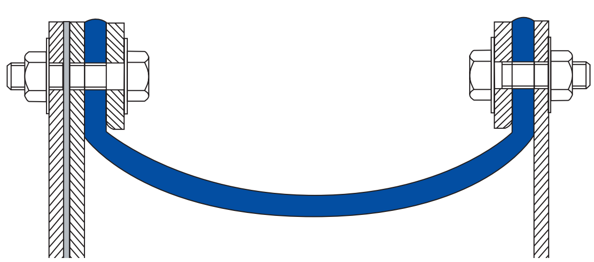
D-5.1. Worm Gear ("Jubilee Clip") or Bolt-Type (T-Bolt) Clamp Bands
Used on small diameter circular belt type expansion joints, and usually manufactured from stainless steel strip.

D-5.2. Back-Up Bars
Metal bars used for the purpose of clamping the flexible element of the expansion joint to mating ductwork flanges or to expansion joint frames. Back-up bar selection depends upon the bolt spacing, bolt hole size and expansion joint flange width. *Please see Table G-A; Bolt loading guide on Page 28.*

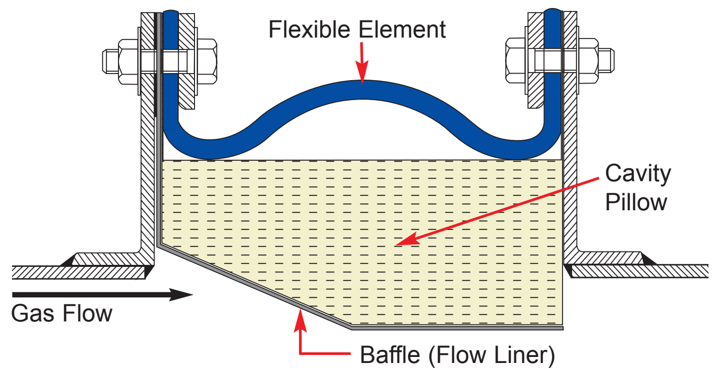
(a) Belt Type



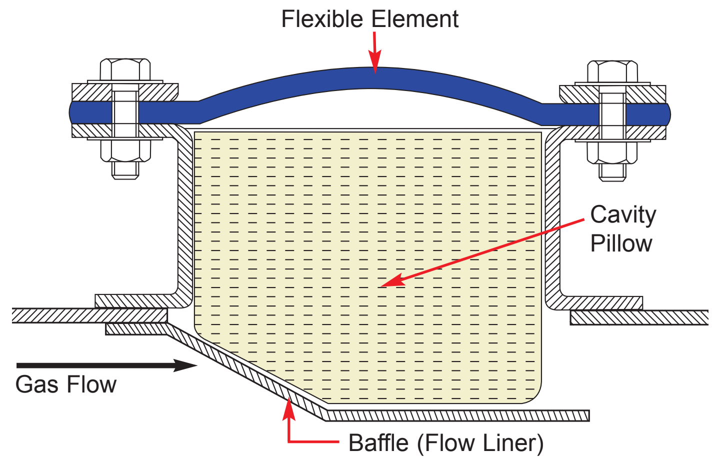
(b) Flanged Type



D-6. Cavity Pillow, Attached by tabs or pins, fills the cavity between the flexible element and the baffle (flow liner) and helps prevent the accumulation of particulate matter. The cavity pillow minimizes unburned fuel, fly ash or other solid particulates from accumulating in the expansion joint cavity in such quantities that they can cause damage to the



flexible element if they solidify to a cementitious state. Also, certain particles (fly ash) can create a severe corrosive (acidic) environment when subjected to cooling (below H_2SO_4 dew point) during a maintenance outage.

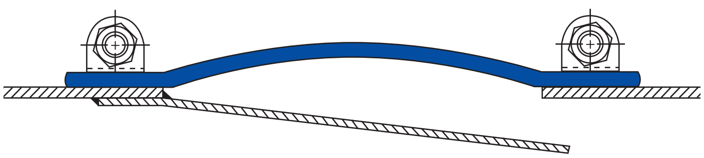


Section D - Expansion Joint Design Considerations

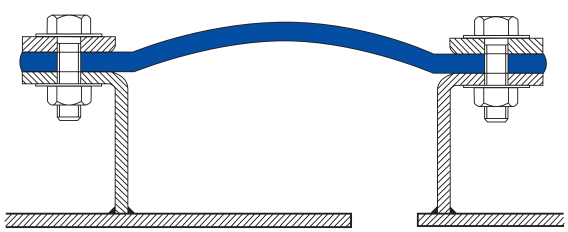
D-7. Frames
Effective sealing is dependent upon the design of the frames to which the flexible element is attached. Many variations of frames are possible, depending on the structure to which the expansion joints are attached, but there are some basic configurations which cover the majority of applications.

D-7.1. Belt Type Expansion Joint Frames

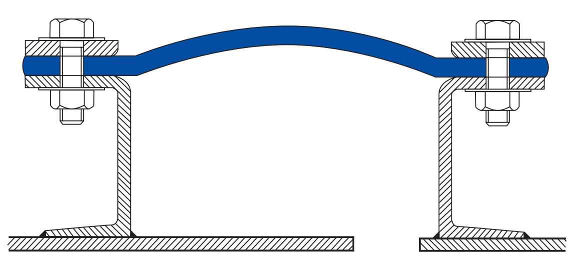
(a) Simple Duct Attachment
Can be used effectively only for circular ducts operating at low pressure. For large diameters, clamp bands must be installed in several sections in order to ensure even clamping pressure.



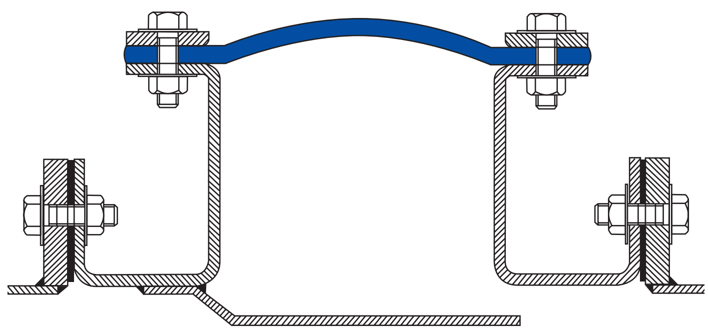
(b) Angle Frame
A simple frame attachment for existing ductwork. For circular ducts the angles would be rolled toe-out in suitable lengths for welding. For rectangular ducts a fabricated, radiused corner would be used to join the straight lengths.



(C) Channel Frame
When rolled steel (C type) channels are used, tapered (wedge) washers should be used under the flange. For rectangular ducts, radiused corners should be used.

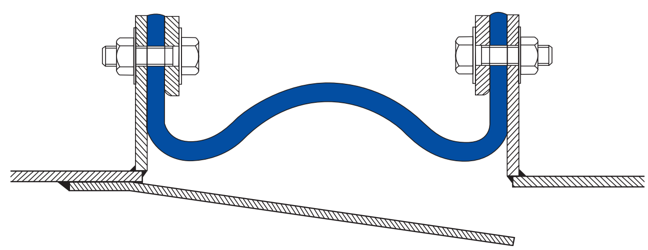


(d) Fabricated "J or G" Frame for Slip In Service

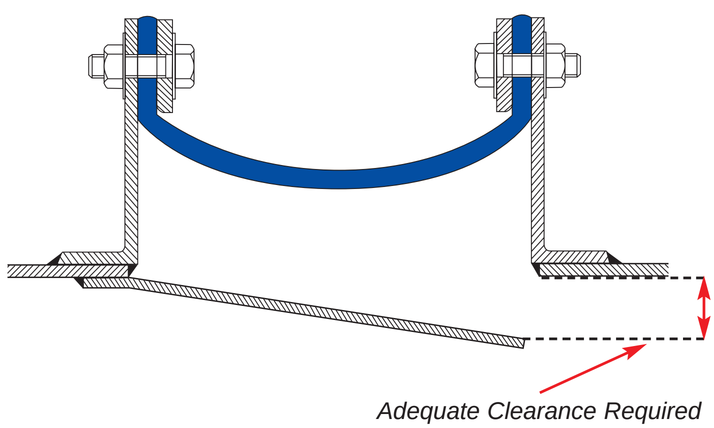


D-7.2. Flanged Type Expansion Joint Frames

(a) Simple Frame Design Using Flat Bar
Where internal baffles (flow liners) are fitted in this configuration they must be clear of the seal material, especially for rectangular joints at the corners.



(b) Simple Frame Design Using "L" Shapes
Where internal baffles (flow liners) are fitted in this configuration, they must be clear of the seal material, especially for rectangular joints at the corners.

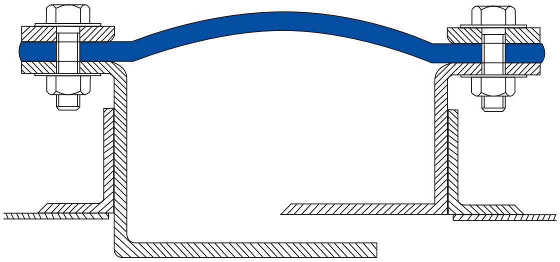


Note: For hot frame designs (above 750ºF / 400 ºC) your FSA member manufacturer should be consulted for designs applicable for the application under consideration.

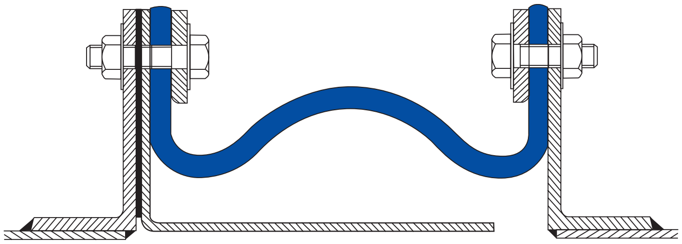
D-8. Baffles (Flow Liners)
Design of baffles (flow liners) is closely associated with the expansion joint frame design, and the baffle (flow liner) is often formed by part of the frame. Many variations are possible, but a range of common types are defined below.

The shape of a baffle (flow liner) is an important design aspect to ensure that the movement is not restricted. The main function is preventing the erosion of the flexible element and pillow.

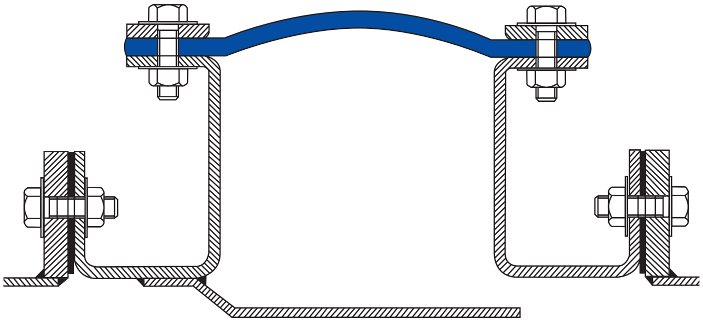
(a) Telescopic Baffle (Flow Liner)
The overlap allows the use of secondary fly ash barrier when required.



(b) Simple Flanged Type with Single Baffle (Flow Liner)



(c) Weld In Baffle (Flow Liner)
The frame design and movement requirements govern the shape of this baffle (flow liner). The gap between the baffle (flow liner) and the frame and/or duct is usually limited to that required for lateral movement and both frame and ductwork tolerances to ensure that there are no interferences.



Other important considerations are:

- The type and thickness of material in relationship to the possibility of erosion and corrosion.
- The length of each section of baffle (flow liner) must be addressed to compensate for thermal growth.
- Requirements for duct washing, and the need to protect pillows (fly ash barrier) and flexible elements.
- Baffles (flow liners) that are attached by welding must consider operating temperature before designing the welded connection.
- The gap between the baffle (flow liner) and all other components must be considered to prevent interference.
- Internal baffles (flow liners) must be designed so that they will not entrap dust or condensation.

Section D - Expansion Joint Design Considerations

D-9. Design Considerations

D-9.1. Typical Movement Capabilities
Once the supporting structural steel and ducting system has been laid out, ducting anchor points should be located so that the ducting movements can be calculated at both the design and maximum excursion temperatures as well as any mechanical and structural drift, seismic and wind effects which affect the operation of the expansion joint assembly.

Expansion joints can handle combined axial, lateral, angular and torsional movements within one unit. The expansion joint locations should be carefully selected to keep the number of expansion joints in the system to a minimum and still absorb all of the duct movements. Should an expansion joint location have very large axial and/or lateral movements, consult manufacturers for a recommendation on how these large movements can best be handled.

When all movements and expansion joint locations have been determined, the expansion joint geometry (type) should be selected for the application. The breach opening required at each location depends on the movement criteria and the geometry (style) selected.

The active length of the flexible element is a major design consideration. In general, by increasing the active length of the expansion joint, greater movements can be accommodated (See Table D-B). The amount of "extra" material must be considered when figuring "expansion joint life". These movements are shown solely as an example and do not reflect concurrent movements. Contact expansion joint manufacturers for specific movement capabilities.

Note:
1. Manufacturers recommend that active length not exceed 16" (405 mm). For additional active length, consult an FSA member.

2. Breach Opening Tolerances:
Axial: 1/4" (6m) extension, 1/2" (13mm) compression
Lateral: 1/2" (13mm).

3. Lateral movement exceeding 3" (75mm). The ductwork and/or expansion joint frame should be pre-offset one half the expected movement. Review offset requirements with manufacturer.

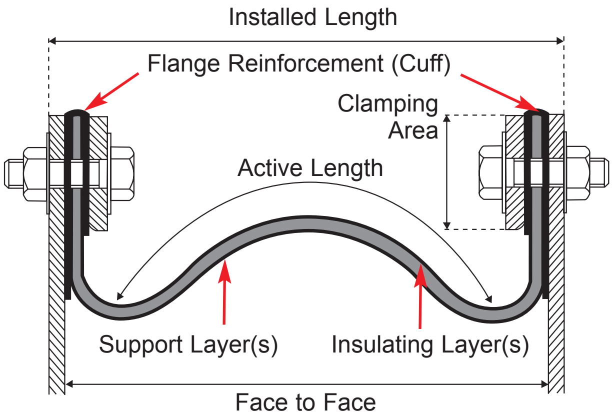


Table D-B: Typical Movement Chart

TYPE	FACE TO FACE	AXIAL COMPRESSION	AXIAL EXTENSION	LATERAL MOVEMENT
Single Layer Elastomer or Fluoroplastic Flexible Element	06" (150mm)	2" (50mm)	1/2" (13mm)	+/- 1 " (25mm)
	09" (230mm)	3" (75mm)	1/2" (13mm)	+/- 1 1/2" (38mm)
	12" (305mm)	4" (100mm)	1" (25mm)	+/- 2" (50mm)
	16" (405mm)	5" (125mm)	1" (25mm)	+/- 2 1/2" (63mm)
Composite Type Flexible Element	06" (150mm)	1" (25mm)	1/2" (13mm)	+/- 1/2" (13mm)
	09" (230mm)	2" (50mm)	1/2" (13mm)	+/- 1 " (25mm)
	12" (305mm)	3" (75mm)	1" (25mm)	+/- 1 1/2" (38mm)
	16" (405mm)	4" (100mm)	1" (25mm)	+/- 2" (50mm)

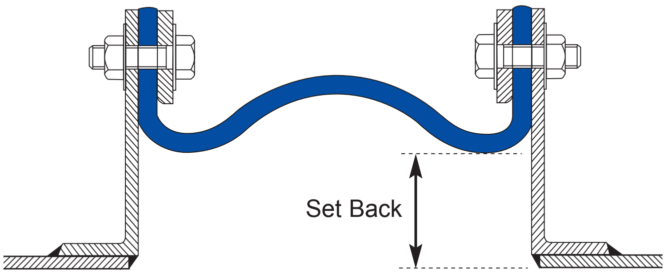
* Active Length is based on movement requirements and is longer than the face to face dimension shown above.

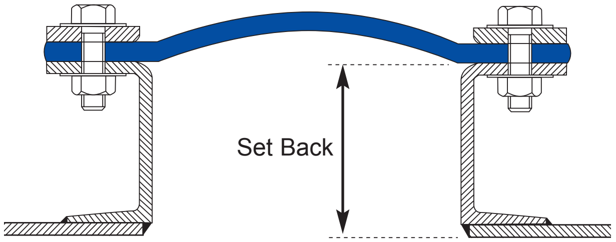
Table D-C: Typical Setback Requirements

ACTIVE LENGTH	6" (150mm)	9" (230mm)	12" (305mm)	16" (405mm)
SETBACK: Flat Belt Positive Pressure	3" (75mm)	3" (75mm)	4" (100mm)	6" (150mm)
Flat Belt Negative Pressure	4" (100mm)	6" (150mm)	6" (150mm)	7" (175mm)
Integral Flange Positive Pressure	1" (25mm)	1 1/2" (38mm)	2" (50mm)	2 1/2" (63mm)
Integral Flange Negative Pressure	2" (50mm)	3" (75mm)	4" (100mm)	5" (125mm)

D-9.2. Setback and Flange Height
When establishing the dimensions of the flexible element mounting surfaces, the following must be considered;

(a) Setback (Stand-Off Height)
Setback is the distance the flexible element is moved outward from the gas stream to allow for system movements and to prevent the joint from protruding into the gas stream or rubbing on the flow liner when operating under negative pressures. Proper setback also reduces the thermal transfer effect on the inner face of the expansion joint and prevents abrasion from particles in the gas stream.





(b) Flange Height
The minimum flange height/width for the integrally flange type is three inches. This dimension varies with the system movement to ensure proper setback. To determine the overall mating duct flange height, the expansion joint flange height/width plus the manufacturer's recommended setback must be considered. To accommodate deviations from standard dimensions, custom modifications to standard sizes are available.

D-9.3. Methods of Decreasing Fly Ash and Abrasive Particulate Build-Up

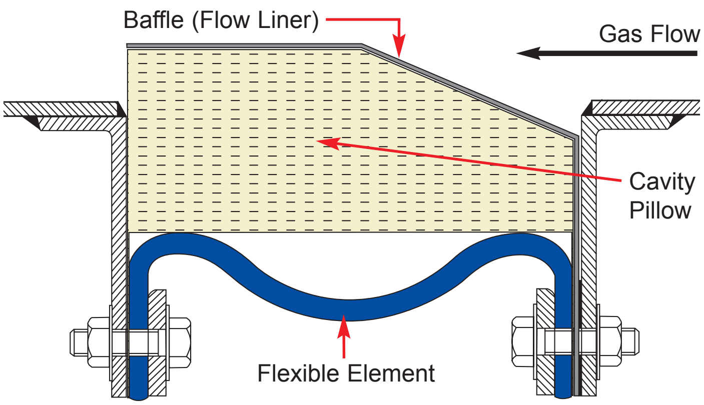
Fly ash or other solid particulates can accumulate in the expansion joint cavity in such quantities that they can cause damage to the expansion joint if they solidify to a cementatious state. Also, certain particles (fly ash) can create a severe, corrosive (acidic) environment when subjected to cooling (below H_2SO_4 dew point) during a maintenance outage.

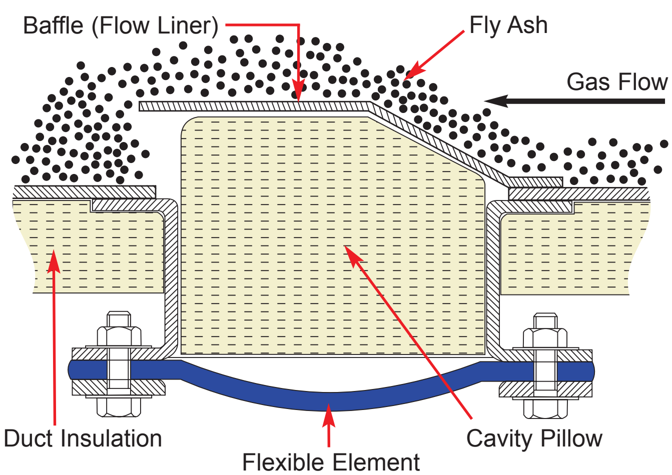
Direct impingement of abrasive gas stream onto fabric expansion joints furnished without baffles (flow liners) can cause deterioration of the expansion joint. To protect against erosion, baffles (flow liners) should be specified.

Designs or accessories can be included that will aid in decreasing the accumulation of particulate. Such designs could include placing insulating materials in the cavity between the expansion joint and baffle (flow liner) or by installing the elastomeric expansion joint flush with the ductwork I.D.

Section D - Expansion Joint Design Considerations

In some systems during abnormal operating conditions there is incomplete combustion, allowing the accumulation of unburned fuel in the baffle (flow liner) cavities which can cause fires resulting in damage to the expansion joint.





D-9.4. System Temperature
High temperature ducting systems are frequently insulated to conserve energy and help prevent internal condensation and corrosion of the ducting.

D-9.4.1. Insulating Layers
The thermal barrier and additional retaining layers of a multi-layer fabric element must remain strong and flexible when exposed to high temperatures.

D-9.5. System Consideration
System consideration include the gas composition, corrosion, the process and dew point temperatures.

(a) Gas/Air Composition
Generally the fuel being utilized will determine the pH of the exhaust gas. Fossil fuels like coal and oil will generate corrosive low pH environments. The paper industry, however, generates a caustic high pH gas from recovery boilers. Refuse to energy systems operate with undefined media. Selection of the gas membrane should be with full consideration of the fuel being used and media generated.

(b) Corrosion
Concern should be directed in two areas; the fabric expansion joint element/insulation and the metal components. Any glass reinforced element or insulation system must be protected from aqueous media. Wetted metal components are also suspect to corrosion, therefore appropriate materials should be selected to optimize performance.

(c) The Process
Processes such as wet scrubbers generate a saturated media and the need for a gas membrane that is specifically designed for wet conditions. It is important to understand whether the process contributes to a wet or dry environment.

(d) Dew Point Temperatures
Whether dew point occurs continuously or cyclically the expansion joint system will get wet. Understanding dew point temperatures will facilitate selection of the proper expansion joint materials.

D-9.6. System Pressure
In the same way as temperature, pressure will affect the structure (type of fabric and number of layers) as well as the type and geometry of the expansion joint assembly. The following types of pressures must all be taken into account when designing a suitable expansion joint. Elastomeric flue duct type expansion joints can be designed to a maximum pressure of 5 PSI@400°F, with Fluoroplastic types to 3 PSI@500°F. As temperatures rise, maximum allowable operating pressures drop.

- Positive Pressure
- Negative Pressure
- Variations in Pressure (Pulsation)
- Pressure Surges
- Design/Test Pressure

D-9.7. Expansion Joint Leakage
Fabric expansion joints are designed to be as leak tight as practical. When an unusual amount of liquid is present within the ducting, or leakage requirements are specified, special caulking or gasket materials can be used when attaching the fabric element to attain the desired results. In many industrial applications, minor leakage detectable by soap bubble solution is considered acceptable.

When replacing a fabric element, leakage through bolt holes is minimized if holes are aligned and punched in the field as opposed to pre-punching the holes at the factory. Back-up bar bolts should be tightened to the manufacturer's specified torque to ensure optimum clamping pressure. Contact manufacturers for details.

High temperature composite expansion joints should not be considered leak-tight or zero leakage.

D-9.8. External Environment

Correct operation of high temperature expansion joints requires that a portion of the system heat be dissipated to the external environment. Abnormally hot ambient conditions or an adjacent heat source, reflective surface, or duct insulation may create temperatures which exceed the limits of the gas seal membrane and should be considered when designing the system.

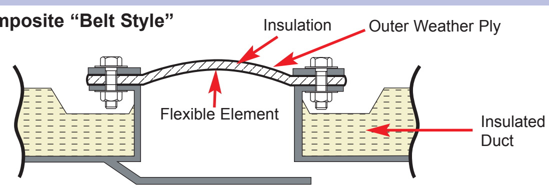
An external cover may be desirable to help protect against falling objects or the accumulation of combustible materials such as coal or saw dust. Covers should be designed by the expansion joint manufacturer to ensure that proper air circulation requirements are satisfied.

Good Design Vs. Poor Design

WHEN THE MAXIMUM CONTINUOUS SYSTEM OPERATING TEMPERATURE IS NEAR THE GAS DEW POINT AND LESS THAN THE ALLOWABLE SERVICE TEMPERATURE OF THE FLEXIBLE ELEMENT

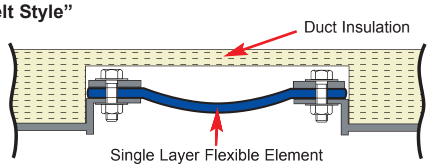
Good Design

Dew Point Composite "Belt Style"



- *Expansion joint flexible element is fully insulated to conserve energy, yet easily accessible for inspection and replacement*

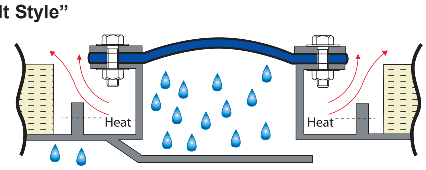
Single Ply "Belt Style"



- *Expansion joint flexible element is externality insulated to minimize acid condensation and heat loss.*

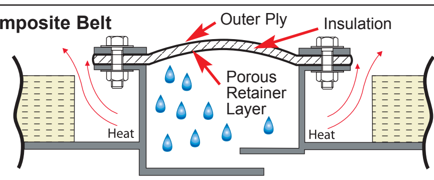
Poor Design

Single Ply "Belt Style"



- *Ducting and expansion joint are not properly insulated*
- *Severe condensation is possible*
- *costly heat energy is lost*

High Temp Composite Belt



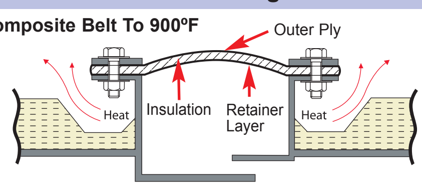
Misapplication of a "High Temp" Composite Belt Causes:

- *Saturation of insulation by condensates*
- *Heat loss*
- *Accelerated deterioration of fabric materials*

WHEN THE MAXIMUM CONTINUOUS SYSTEM OPERATING TEMPERATURE EXCEEDS THE ALLOWABLE SERVICE TEMPERATURE OF THE FLEXIBLE ELEMENT

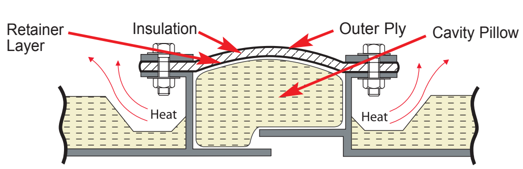
Good Design

High Temp Composite Belt To 900ºF



- *Minimizes heat loss and permits optimum cooling of the flexible element*
- *Flange stand off reduces the temperature of the belt and the critical attachment area, thereby maximizing service life*

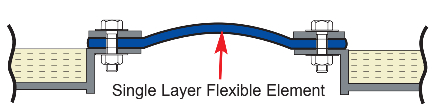
Extreme High Temp Construction To 1200ºF



- *Additional insulation reduces the temperature in the expansion joint cavity to an acceptable level*

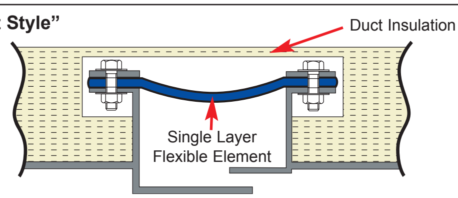
Poor Design

Single Ply "Belt Style"



- *Flexible element is exposed to full system temperature*
- *Attachment flanges are insulated and turned-in, preventing adequate cooling and accelerating deterioration of the flexible element*

Single Ply "Belt Style"



- *Exterior insulation prevents the necessary cooling of the flexible element and attachment flanges, resulting in severe degradation of the expansion joint*

Section E - Materials Used In The Manufacture Of Expansion Joints

E

Introduction

The performance of non-metallic expansion joints for various gas ducting systems is determined by the severity of the environment and by the selection of the materials for each component of the expansion joint. Selection of materials must be used based on functional requirements as well as temperature and chemical compatibility. A corrosive atmosphere that might not have a noticeable effect at low temperature could have a disastrous effect at higher temperatures still within the basic heat resistance capability of the material. Conversely, systems at or below the dew point can result in highly corrosive condensates.

The proper engineering of materials or material combinations can provide successful long-term performance of non-metallic expansion joints in even the most adverse ducting system environment. Elastomers and fluoroplastics are specifically compounded for gas seals and barriers and for protection against mechanical damage such as erosion and/or abrasion.

Fabrics are used for the reinforcement of elastomers and fluoroplastics to yield the mechanical properties necessary to withstand the movements and pressures exerted upon the expansion joint by the ducting system. In addition, fabrics are used in inner and intermediate layers in composite style joints as thermal barriers and mechanical reinforcements. The selection of fabric is based upon compatibility with the specific thermal, chemical and mechanical requirements of the system.

Insulating materials are used to reduce interface temperatures to a level which permits satisfactory performance and life of the elastomeric and fluoroplastics in the gas seal layer. Fiberglass blankets perform very well to 1000ºF (540ºC) and ceramic blankets are rated above 1000ºF (540ºC), but do have mechanical and chemical limitations.

Metal flanges are used to connect the flexible element to the ductwork. Metal flow liners or baffles are used to protect the gas seal membrane and insulation layers of the flexible element from abrasive particles which may be present in the gas stream. A liner also helps control fly ash accumulation in the expansion joint cavity and it helps reduce flutter of the flexible element caused by turbulence. As with fabrics, selection of the metal is based upon compatibility with the specific thermal, chemical and mechanical requirements of the system.

The information presented in this section is derived from published materials data and from testing results compiled by the Ducting Division's regular and associate members. In some instances where published data is unavailable and testing is not feasible, the consensus of opinion of member manufacturers is presented.

Where specific data is not available because too many variables affect the data, a word evaluation of the material is used to better describe the performance capability of the material.

E-1. Elastomers and Fluoroplastics Commonly Used in Expansion Joints

E-1.1. Chloroprene (CR) better known as neoprene, is made from chlorine and butadiene. These rubbers are very resistant to oils, greases and many other petroleum products. Properly compounded chloroprenes have excellent ozone and weather resistance. The chloroprenes have excellent resistance to abrasion, impact and damage from flexing and twisting.

E-1.2. Chlorosulfonated Polyethylene (CSM) These rubbers have good tensile strength, elongation and excellent ozone resistance. The CSM rubbers are very resistant to oxidizing chemicals such as sulfuric acid. Special compounding enhances heat resistance and provides excursion temperature capability.

E-1.3. Ethylene Propylene (EPDM) are low cost terpolymers have high tensile strength and elongation with excellent resistance to oxygen and ozone. They also have good flexing characteristics, low compression set and good heat resistance. Conventional compounding produces formulations with very good chemical resistance.

E-1.4. Chloronated Isobutylene Isoprene (CIIR) is better known as chlorobutyl, is inherently resistant to ozone and oxidizing chemicals including some mineral acids and ketones. Chlorobutyl rubbers have good tensile strength, elongation, dampening characteristics and low gas permeability.

E-1.5. Fluoroelastomers (FKM) are high performance elastomers which have outstanding resistance to chemicals, oils and heat compared to any other elastomer. These elastomers are available as copolymers (vinylidene fluoride hexafluoropropylene) or terpolymers (vinylidene fluoride tetrafluoroethylene, hexafluoroproplene). Specifically compounded terpolymers are used in the expansion joint industry. The fluoroelastomers have excellent abrasion resistance and generally do not require protection from flue gas media.

Section E - Materials Used In The Manufacture Of Expansion Joints

E-1.6. Silicone Rubbers (SL) have good ozone and weather resistance, but poor resistance to flue gas constituents. Therefore, reinforced silicone material use is restricted to hot air duct expansion joints and composite joint outer covers requiring low temperature flexibility.

E-1.7. Fluoroplastics are thermoplastic resins of general paraffin structures that have all or some of the hydrogen replaced with fluorine. Polytetrafluoroethylene resin, commonly called PTFE, is the main fluoroplastic used in the production of expansion joints. Perfluoroalkoxy copolymer resin, commonly called PFA, is used to a much lesser extent, generally to facilitate the heat sealing of PTFE materials.

Commercial PTFE Fluoroplastics Include:
TEFLON® - POLYFLON™ - ALGOFLON® - DYNEON™

Commercial PFA Fluoroplastics Include:
TEFLON® - NEO-FLON™ - HYFLON® - DYNEON™

PTFE and PFA are available as both aqueous dispersions and films. PTFE dispersion is used in the dip coating of fiberglass fabrics. The dispersion coating is applied to the fiberglass reinforcement for the purpose of providing both mechanical and chemical protection. Because PTFE coated composites are porous materials, PTFE films are often laminated to the composites for added chemical protection. Fluoroplastic materials require protection from abrasive media in the form of a baffle (flow liner) or deflector plate. A variety of PTFE coated and laminated composites have been used in expansion joint service for over 30 years.

Note: Over the last three decades numerous products have been manufactured by combining the various polymers and reinforcements discussed in this section. For example, the individual polymers or polymer blends can be coated or laminated onto the reinforcement materials, creating a wide range of laminated and/or coated composites for expansion joint production. Additionally, the polymers can be processed into unreinforced films and laminates to achieve materials with unique properties. These products have been designed to handle specific thermal, chemical and mechanical requirements. Consult an FSA member manufacturer for details.

TEFLON® is a registered trademark of DuPont

POLYFLON™ is a registered trademark of Daikin Industries, Ltd.

ALGOFLON® is a registered trademark of Solvay Solexis, Inc.

DYNEON™ is a registered trademark of Dyneon LLC, A 3M Company

NEOFLON™ is a registered trademark of Daikin Industries, Ltd.

HYFLON® is a registered trademark of Solvay Solexis, Inc.

E

TABLE E-A defines the capabilities of elastomers and fluoroplastics commonly used in the manufacture of expansion joints. Compounding variations can significantly affect the properties and performance capabilities of the elastomeric material and fluoroplastics.

Table E-A: Properties Of Elastomers And Fluoroplastics

	Chloroprene	Chlorosulfonated Ployethylene	EPDM	Chlorobutyl	Fluoroelastomer	Silicone	PolyTetra Fluoro Ethylene
ASTM Designations	(CR)	(CSM)	(EPDM)	(CIIR)	(FKM)	(SL)	(PTFE)
Material Temperature:							
Minimum (Low Temperature Brittle Point)	-40ºF(-40ºC)	-40ºF(-40ºC)	-40ºF(-40ºC)	-40ºF(-40ºC)	-30ºF(-34ºC)	-60ºF(-51ºC)	-110ºF(-79ºC)
Continuous	225ºF(107ºC)	250ºF(121ºC)	300ºF(149ºC)	300ºF(149ºC)	400ºF(204ºC)	480ºF(249ºC)	500ºF(260ºC)
**Intermittent Operating Temperature/ (Accumulative Time in Hours)	250ºF(121ºC) /168	350ºF(177ºC) /70	350ºF(177ºC)/200 325ºF(163ºC)/300 350ºF(177ºC)/150 375ºF(191ºC)/70	350ºF(177ºC) /150	550ºF(288ºC)/240 600ºF(316ºC)/48 650ºF(343ºC)/16 * 700ºF(371ºC)/4 * 750ºF(399ºC)/2	-	700ºF(371ºC) /75
Chemical Resistance:							
H_2S0_4 Acid Hot (+) Less Than 50% Concentration	B-C	A	A	A	A	C	A
H_2S0_4 Acid Hot (+) over 50% Concentration	C	B	B-C	B-C	A	C	A
HCL Acid Hot (+) less than 20% Concentration	C	B	B	B	A	C	A
HCL Acid Hot (+) over 20% Concentration	C	C	C	C	A-B	C	A
Anhydrous Ammonia	A	B	A	A	C	C	-
NAOH Less than 20% concentration	A	A	A	A	A	A	A
Over 20% concentration	A	A	A	A	B	B	A
Abrasion Resistance	A	A	A	A	A	C	C
Environmental Resistance:							
Ozone	B	A	A	A	A	A	A
Oxidation	B	A	A	A	A	A	A
Sunlight	B	A	A	A	A	A	A
***Radiation	A	A	A	C	B	B	C

* Fluoroelastomers when reinforced with non-reactive materials have an intermittent temperature capability of 4 hours at 700°F (371ºC) and 2 hours at 750°F (399ºC)

** Excursions at high temperatures will have a detrimental effect on useful life of the product.

*** Any nuclear application should be referred to expansion joint manufacturer for specific elastomer recommendation.

Rating Code:
A = Little or no effect
B = Minor to moderate effect
C = Severe effect

Section E - Materials Used In The Manufacture Of Expansion Joints

E-2. Reinforcing Materials Commonly Used in Expansion Joints

The information in Table E-B is provided only as a guideline so non-metallic expansion joint customers may have a general knowledge of performance to be expected from materials typically used. Since the actual conditions in many applications require materials engineering, effective communications between the systems designer and manufacturer is essential. Ultimately it is the unique performance requirements of each specific application that will dictate the best materials to be used.

The major expansion joint manufacturers associated with the FSA are extremely knowledgeable about textile and polymer technology. They have accumulated and documented case histories of expansion joints placed in service under a broad variety of conditions. End users are encouraged to take advantage of this practical design and engineering experience by discussing material selection with member manufacturers.

It is anticipated that aggressive research and development activities by expansion joint manufacturers will continue to provide new materials. Materials engineering expertise of member companies may allow them to provide materials that may exceed the performance limits indicated. When these limits are exceeded or new materials are offered, data to confirm performance should be requested.

Table E-B defines the capabilities of commonly used for reinforcing materials in the manufacture of expansion joints. The capabilities listed below are considered important to product application in flue gas systems. Chemical compatibility on an uncoated fabric is critical in a composite type joint.

Table E-B: Typical Temperature Properties of Reinforcement Materials

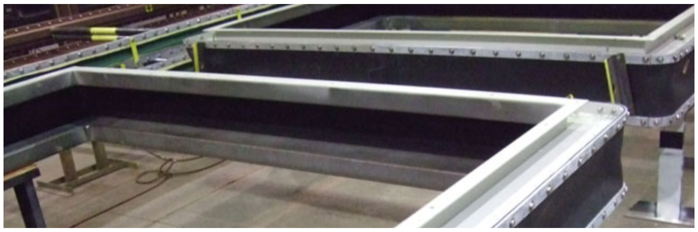
Reinforcing Materials	Aramid	Fiberglass	Corrosion Resistant Alloy Wire	Polyester
* Temperature Capability (ºF)	450	1000	2500	250
* Temperature Capability (ºC)	232	538	1371	121

* These temperatures are the maximum continuous temperatures that the reinforcement material can handle. Aramid has shown a loss of 10% in properties at 600ºF (316ºC) and a loss of 50% in properties above 700ºF (371ºC).

Section F - Storage

F

F-1. General Storage



The storage environment and storage time can be important factors in the condition and performance of a fabric expansion joint. The materials used in fabric expansion joints exhibit excellent resistance to various forms of environmental attack; however, recommended storage practices must be observed and an awareness of deviations must be maintained.

F-1.1. Length of Storage

The storage warranty period is specified by the manufacturer based upon the expansion joint style. Notify the manufacturer for inspection if storage period exceeds one year. Inspections should be made at least sixty (60) days before anticipated installation. Notify the manufacture if the start-up date is to be more than twelve (12) months after the installation of the expansion joints.

Notify the manufacturer, regardless of storage time, if any unusual appearances are noticed when unpacking or installing the expansion joints. In case of storage over one year, re-inspection by the expansion joint manufacturer can assure that performance will not be affected. In cases of storage abuse, expansion joint warranties may be invalid. Special storage methods should be used when long term field storage is anticipated for spare expansion joints.

F-1.2. Indoor Storage Recommendations

(a) Store the expansion joints in their original shipping containers in cool, dry areas where the temperature is between 32ºF to 150ºF (0ºC to 65ºC) until the expansion joints are ready for installation.

(b) During storage the flexible element and pillow insulation (bolster) must be protected against the humidity and dampness from the ground.

(c) The unpacked expansion joint must be placed on a secure base (pallet) and must be protected from physical damage and abuse during storage or site transportation.

(d) Expansion joints should not be stored near sources of heat, moisture laden areas, temperatures greater than 150ºF (65ºC), dirt and petro-chemicals.

(e) Do not store equipment on top of the expansion joints.

(f) Do not store the expansion joints in a heavy traffic area.

(g) Do not remove the expansion joint from the original shipping containers or protection pads until the expansion joint is ready for installation.

(h) Do not remove the shipping bars of the expansion joint until the expansion joint is installed in the ducting system.

F-1.3. Outdoor Storage Recommendations

(a) Protect the expansion joints from physical damage and abuse.

(b) Store the expansion joints in their original shipping containers at least one (1) foot above the ground in a dry area where flooding will not occur.

(c) Cover the expansion joints and protective packaging with a tarpaulin or heavy plastic to protect them from the weather.

(d) During storage the flexible element and pillow insulation must be covered with a water proof shield to protect against rain, humidity and dampness from the ground.

(e) Expansion joints should not be stored near sources of heat greater than 150°F (65°C), or damaging environments which contain moisture, dirt, and petro-chemicals.

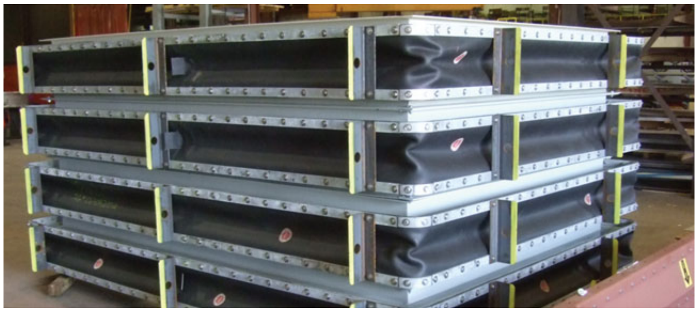
(f) In a low temperature environment (32ºF-0ºC), expansion joints have an increased resistance to bending. Under these conditions it is recommended that the expansion joint should be stored inside a warmer environment immediately prior to installation.

(g) Do not store equipment on top of the expansion joints.

(h) Do not store the expansion joints in a heavy traffic area.

(i) Do not remove the expansion joint from the original shipping containers or protection pads until the expansion joint is ready for installation.

(j) Do not remove the shipping bars of the expansion joint until the expansion joint is installed in the ducting system.



Section G - Handling, Installation, Commissioning & Inspection

G-1. Handling and Installation
Expansion joints, whether ordered assembled, unassembled or as components, must be packaged to arrive at the jobsite in good condition. Immediately after receipt at the jobsite, the purchaser should verify that all parts shown on the packing slip have been received undamaged. All expansion joint manufacturers provide detailed instructions with each shipment and these instructions should be reviewed before installation. To insure proper performance and service life it is important to prevent damage by careful handling and by supporting the expansion joint during installation.

(a) Unpack the expansion joint carefully without banging, dropping, striking or dragging the expansion joint on the floor.

(b) Verify the flow direction marked on the expansion joint or flow liners. The expansion joint should be installed with the flow arrows pointing in the direction of flow. If marking is not visible, install the expansion joint with liner gap on the downstream side.

(c) Large and heavy expansion joints must be supported during the installation and should be installed with appropriate lifting equipment such as cranes or pulleys.

(d) Do not lift expansion joints by attaching the lifting device directly to the flexible element. The expansion joint should rest on a supporting base, to which lifting tackles can be attached.

(e) Expansion joints which have been pre-assembled by the manufacturer must be lifted by the lifting points and not by their shipping straps unless the manufacturer has specifically combined the two.

(f) Any protective covering must not be removed until installation is complete.

(g) Protect the expansion joint from welding sparks and sharp objects.

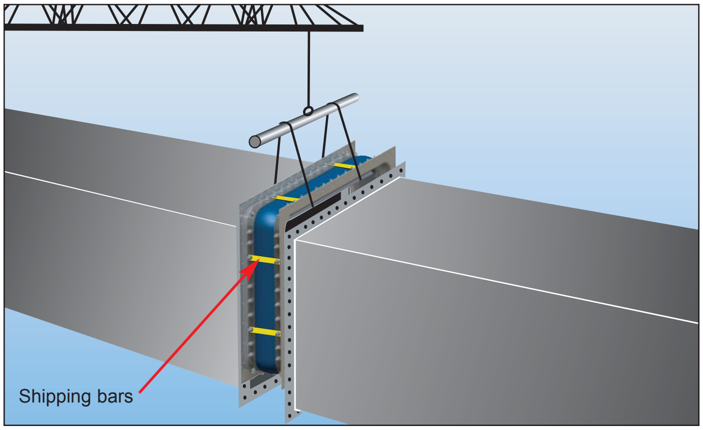
(h) All back-up bars, including their bolts and nuts, must be in place and hand-tightened first before tightening further.

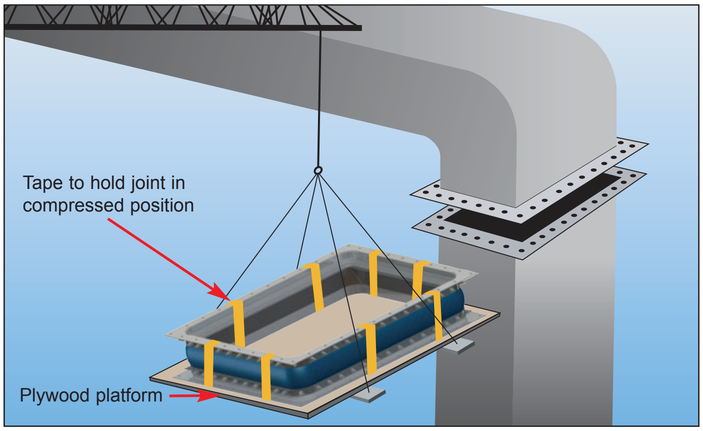
(i) Bolt loading requirements depend on the type of expansion joint, bolt dimensions, bolt lubrication, bolt distance, etc. Please see bolt loading guide (Table G-A, Page 28)

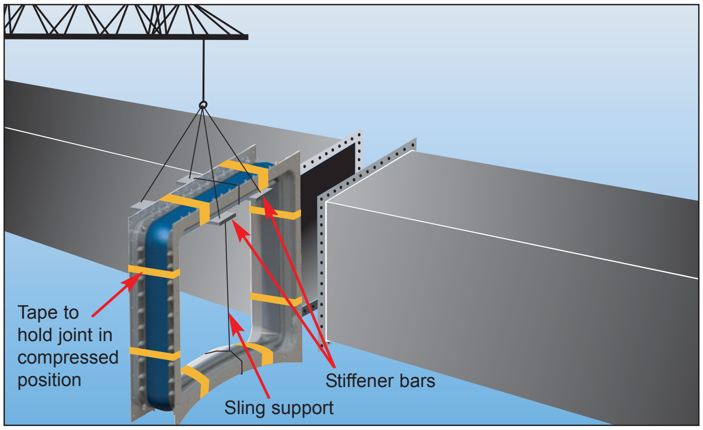
(j) Do not remove the shipping bars until after the expansion joint is installed. The intent of shipping bars is to hold the expansion joint in its installation position.

(k) Never walk or place scaffolding on top of the expansion joint.

(l) The holes in the expansion joint flange should never be used as a lug to lift the expansion joint.







G-2. Pre-Installation Verifications

G-2.1. General Verifications

(a) Confirm expansion joint location and verify the part number and tag number against the installation drawings.

(b) The breach opening and ducting should be checked for proper alignment. The opening should not exceed the following tolerances; Axial +1/4" (6mm), -1/2" (13mm); Lateral 1/2 (13mm)". If the breach opening exceeds these tolerances then the expansion joint manufacturer must be consulted.

(c) Verify that the system anchors, supports and guides, are in accordance with the piping/ducting system drawings. Any field variance from planed installation may affect the expansion joint parameters and reduce life expectancy.

G-2.2. Duct Mating Flange Verifications

(a) Verify that the mating flanges or expansion joint attachment area of the ductwork must be smooth, clean, flat, and parallel.

(b) Verify that the mating flanges are in a good condition and are fully and continuously welded and free of sharp edges, burrs etc.

(c) Verify that the mating flange dimensions and holes and clamp bars are correct.

G-2.3. Expansion Joint Frame Verifications

(a) Verify that the expansion joint frame flanges are in good condition, flat, fully welded and free of sharp edges burrs, etc.

(b) Verify the expansion joint frame flange dimensions (inside dimensions, bolt holes, face-to-face, flange straightness and parallelism).

(c) All welded areas must be ground smooth at attachment points.

G-2.4. Duct Work and Expansion Joint Verifications

(a) The area around the ductwork must be cleared of any sharp objects and protrusions. If not removable they should be marked for avoidance.

(b) The expansion joint and components should be kept packaged until installation.

(c) Verify all edges that might touch the flexible materials of the expansion joint have a radius.

(d) If any handling devices such as crane hooks or fork lifts are utilized in handling the expansion joints, the contact surface must be protected by cushioning materials.

(e) Internal baffles (flow liners) must be in good order and in the correct orientation.

(f) Verify that bolting will not damage the outer layers of the expansion joint during operation.

(g) If welding or burning operations are being performed in the vicinity of the exposed expansion joint, fabric welding blankets or other protective covering must be used to protect the flexible element. These covers must be removed before system start-up.

G-3. Installation

(a) It is important that the expansion joints be installed at the proper face-to-face dimension as specified by the manufacturer. Never extend, compress or laterally distort expansion joints past the breach opening tolerances to compensate for dimensional errors without obtaining written approval from the manufacturer.

(b) When an expansion joint must be pre-compressed or laterally preset, follow the manufacturer's detailed instructions for installation.

(c) All expansion joints provided with baffles (flow liners) should have flow arrows or other suitable means of assisting the installer to properly orient the expansion joint to flow direction.

(d) Care must be taken to assure that back-up bars mate up with a 1/16" (1.5mm) to 1/8" (3mm) gap between bar ends.

(e) Installers must follow the manufacturer's bolt installation and torque recommendations. If impact tools are used then they must have torque limiting devices properly set before use.

(f) Do not install insulation over the expansion joint or mounting area unless it is in accordance with the manufacturer's instructions.

(g) In areas where coal or sulfur dust can collect on the expansion joint outer cover, protective shields may be required. Coal or sulfur dust can cause spontaneous combustion, resulting in burning outer covers of expansion joints. Consult the expansion joint manufacturer for details and requirements for a shield.

(h) The installation parameters of the manufacturer is critical to the service of the product and should be checked carefully by the installer.

Section G - Handling, Installation, Commissioning & Inspection

G-3.1. Bolted Flange
(a) Verify that the expansion joints' internal liner does not interfere with expansion joints' mating flange ID.

(b) Install gasket between the expansion joint and mating flanges which are compatible with system flow pressure, temperature and chemical composition.

(c) Care should be taken during the flange bolt-up to avoid damaging the flexible element close to the flange.

(d) All backing bars, including their bolts and nuts, must be in place and hand tightened before torquing them with a wrench or power tool.

(e) The bolt threads should be lubricated before installing the nuts to facilitate installation and provide proper clamping force.

(f) Recommended bolt torque is given in the table below for MoS_2 lubricated bolting. These values will provide an equivalent flange loading of 435 psi (3 MPa).

(g) Ensure that the duct breach cavity is free of all debris.

G-3.2. Welded Flange
The non-metallic expansion joints' metallic frame may be welded against the ducting mating flange to provide zero leakage seal between flanges. The following special measures should be taken before and during the welding of the non-metallic expansion joint flanges.

(a) Protect the flexible element of the expansion joint with fire proof blankets during welding of the expansion joint or in its adjacent area. Welding splatter, scratches, or abrasion of the flexible element could cause premature failure.

(b) Welding of the expansion joint frame to the ducting mating flange could generate sufficient heat which will damage the flexible element.

G-3.3. Tolerances
The flexible nature of the non-metallic expansion joint reduces the need for very tight manufacturing tolerances. However, it is necessary to maintain the following tolerances for the expansion joint and their connection to ducts or other equipment. Axial +1/4" (6mm), -1/2" (13mm); Lateral 1/2" (13mm).

Table G-A: Bolt Loading Guide

Imperial (inches)								
Width of Clamp Bar	1 1/2		2		2 1/2		3	
Thickness of Clamp Bar	1/4	3/8	1/4	3/8	3/8	1/2	3/8	1/2
Bolt Spacing	4		4 - 6		4 - 6		4 - 6	
Bolts	3/8	1/2	1/2	5/8	5/8	3/4	5/8	3/4
Recommended Tightening Torque (ft.lbs):								
Loading for Fabric Expansion Joint	36	59	74	88	85	103	96	118
Loading for Elastomeric Expansion Joint	31	44	55	66	66	81	74	92

Metric (mm)								
Width of Clamp Bar	50		60		70		80	
Thickness of Clamp Bar	8	10	10	12	10	12	12	
Bolt Spacing	100		100		120		120	
Bolts	M12	M16	M16	M20	M16	M20	M16	M20
Recommended Tightening Torque (Nm):								
Loading for Fabric Expansion Joint	60	80	100	120	115	140	130	160
Loading for Elastomeric Expansion Joint	50	65	75	90	90	110	100	125

G-3.4. Commissioning

It is very desirable to have a representative of the manufacturer provide a "Final Walk Down" inspection of the installation prior to system start-up. This inspection should consist of verifying installed dimensions, bolt torques, and general condition of installation.

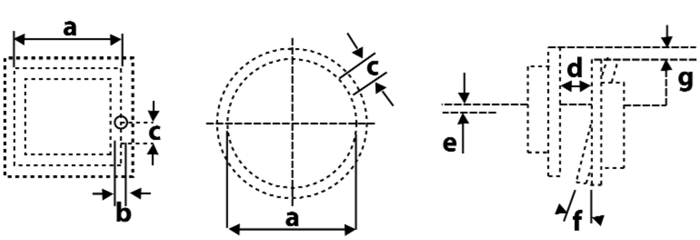
G-3.5. Post Commissioning Inspection

When the expansion joint is heated (such as during plant start-up), the expansion joint components will settle. Therefore, expansion joint bolts should be re-tightened as soon as possible after start-up and not later than at the first shut down. Tighten only to the manufacturer's recommended bolt torque.

Like any other component in an industrial plant, an expansion joint requires supervision to ensure maximum reliability. Expansion joints should be regarded as wearing parts, meaning those parts which need to be replaced at regular intervals. Costly shut downs and emergency situations can often be avoided by replacing wearing parts in a timely fashion.

In general, non-metallic expansion joints do not require actual maintenance. They should be inspected regularly for signs of damage. The first sign of damage will be visible on the surface of the flexible element. The coating may start to discolor or peel, depending on the type of damage (thermal or chemical). If any of these signs appear, contact the expansion joint manufacturer immediately.

(a) Inspect the entire ducting system for compliance with the design drawings and instructions. Check that misalignment and offsets do not exceed installation tolerances.



Bolt Hole Circle:	**a** = ±1/8” (±3mm) up to 60” (1.5m) ±1/4” (±6mm) over 60” (1.5m)
Bolt Hole Diameter:	**b** = -0, +1/32” (-0, +1mm)
Bolt Pitch:	**c** = ±1/16” (±1.5mm)
FF Distance (including “f”):	**d** = ±1/2” (±13mm)
Preset of Axis:	**e** = ±1/8” (±3mm)
Flange Alignment:	**g** = ±1/2” (±13mm)
Duct Internal Diameter:	**ID** = ±3/16” (±5mm) under 78” (2m) ±5/16” (±8mm) from 78” (2m) to 16’ (5m) ±1/2” (±13mm) over 16’ (5m)
Mating Flange Flatness:	**Fl-F** = ±1/16” (±1.5mm) in any length of 40” (1m)

(b) Verify the expansion joint location, installed face-to-face and flow directions.

(c) Verify if the expansion joint shipping bars were removed after installation.

(d) Ensure that all bolts and flanges are tightened correctly.

(e) Inspect the surface of the flexible element and make sure that is free of defects or damages or surface debris.

(f) Ensure there are no obstructions around the expansion joint which could prevent air flow and cause overheating of the flexible element.

(g) Ensure that the duct breach cavity is free of all debris.

G-3.6. Periodic In-Service Inspection

(a) Visual inspection must be conducted to verify that the expansion joint is in the hot position, immediately after starting the system.

(b) Periodic visual inspection of the expansion joint must be conducted through the operating life of the expansion joint. The frequency of the inspection should be minimum three per year. The system designer and owner should establish the inspection schedule based upon the systems operating parameters and environmental conditions.

(c) Regular inspection should include checks for loose bolts, discoloration of the flexible elements outer surface, signs of leakage, mechanical damage, condensation and cracks in the frame of the expansion joint.

(d) When inspection reveals evidence of malfunction, damage or deterioration, contact the manufacturer immediately.

(e) Non-metallic expansion joints are considered wearing parts which need to be replaced at regular intervals. Costly shutdowns and emergency situations may be avoided by replacing the non-metallic expansion joint when early signs of wear or damage appear.

APPENDIX 1 - FSA-DSJ-401-09 Specification For High Temperature & Acid Resistant Terpolymer Fluoroelastomer

1. Scope

1.1 This specification provides requirements for the terpolymer fluorocarbon elastomer used in the manufacture of expansion joints for application in coal fired utility and other high temperature industrial applications where corrosive flue gases are present.

1.2. While the materials, methods, applications and processes described or referenced in this standard may involve the use of hazardous materials, this standard does not address the hazards which may be involved in such use. It is the sole responsibility of the user/tester to ensure familiarity with the safe and proper use of any hazardous materials and testing and to take the necessary precautionary measures to ensure the health and safety of all personnel involved.

2. Referenced Documents

2.1. ASTM International

ASTM D-412	Rubber Properties in Tension
ASTM D-471	Rubber Property - Effect of Liquids
ASTM D-573	Rubber - Deterioration in an Air Oven
ASTM D-2240	Rubber Property - Durometer Hardness
ASTM D-297	Rubber Products - Chemical Analysis
ASTM D-1765	Standard Classification System for Carbon Blacks Used in Rubber Products

2.2. Fluid Sealing Association

FSA DJS-402-~~06~~ Fluoroelastomer Belt Recommendation

3. Significance and Use

This specification is intended as a reference procedure for evaluating the performance of vulcanizates based on terpolymer fluorocarbon elastomers used in expansion joints. It can be used for quality assurance testing prior to release of a lot based on agreement between supplier and purchaser.

4. Material Requirements

4.1. Elastomer shall be 100% virgin fluoroelastomer terpolymer with a minimum of 68% by weight fluorine content. The compound shall contain no less than 70% by weight of the fluoroelastomer terpolymer. The remaining 30% by weight shall be comprised of Medium Thermal (MT) carbon black, ASTM designation N990, as reinforcing filler. No mineral fillers shall be used. The fluoroelastomer curative shall be either of the dihydroxy, bisphenol or peroxide types. No amount of reprocessed fluoroelastomer scrap or non-fluoroelastomer polymer is acceptable.

4.1.1 Four products known to meet 4.1 are DAI-EL™, Dyneon™, Tecnoflon® and Viton® brands terpolymer fluoroelastomer products. Other equivalent fluoroelastomer terpolymers of at least 68% by weight fluorine content with equivalent curatives are acceptable.

4.2. As received virgin fluoroelastomer sampled in accordance with Section 5.4 shall be fully pressure cured, typically for 20 minutes at 150°C (302°F), but not post cured. Other time/temperature conditions may be acceptable providing they produce vulcanizates that meet the property requirements. The samples' mean value for each measured property must meet the physical and chemical property requirements shown in **Table I**.

Table I - Properties

Paragraph	Property	Requirement	Test Methods
4.2.1	Hardness, Durometer Shore "A" or Equivalent	77 ± 5	ASTM D-2240
4.2.2	Tensile Strength, Minimum	1015 psi (7 Mpa)	ASTM D-412
4.2.3	Elongation, Minimum	275%	ASTM D-412
4.2.4	Density at 25±0.5ºC	1.86 ± 0.04 g/cm³	ASTM D-297
4.2.5	Methanol Volume Swell 70 ± 0.5 Hrs at 23 ± 3ºC	30% Maximum	ASTM D-471
4.2.6	Toluenel Volume Swell 70 ± 0.5 Hrs at 23 ± 3ºC	10% Maximum	ASTM D-471
4.3	A sample shall be exposed to 260ºC (500ºF ± 5º) for 70 ± 0.5 hours per ASTM D-573 and conform to the following property change requirements for Dry Heat Resistance.		
4.3.1	Hardness Change Durometer Shore "A" or Equivalent	± 10 Points	ASTM D-573
4.3.2	Tensile Strength Change, Maximum	+50%	ASTM D-573
4.3.3	Elongation-Ultimate, Minimum	225%	ASTM D-573
4.3.4	Weight Change,	±7%	ASTM D-573

4.4. The material color shall be black.

5. Quality Assurance Provisions

5.1. Quality

The product, as received, shall be uniform in quality and condition, smooth, as free from foreign materials as commercially practical, and free from imperfections detrimental to use as intended.

5.1.1. Responsibility for Inspection

The seller of the expansion joint shall be responsible for having all the required property tests performed. The buyer reserves the right to obtain additional batch samples and perform all confirmatory testing necessary to ensure the product conforms to the full requirements of this specification.

5.2. Classification of Tests

5.2.1. Acceptance Tests

The seller of the expansion joint shall be responsible for checking the batch sample test results, confirming that the results are in accordance with this specification and preparation of the "Batch Test Certification" report. The buyer reserves the right to perform confirmatory tests necessary to ensure that the product conforms to the "Batch Test Certification" and the full requirements of this specification.

Table II - Acceptance Tests

Paragraph	Property
4.2.1	Hardness, As Received
4.2.2	Tensile Strength, As Received
4.2.3	Elongation, As Received
4.2.4	Density, As Received
4.2.5	Methanol Swell , As Received
4.2.6	Toluene Swell, As Received
4.3	Hardness, Tensile & Density Changes & Ultimate Elongation after heat aging, As Received

5.2.2. Traceability

Shipments and certification with test values from test in **Table II** shall include traceability back to polymer, grade, and lot number.

5.3. Preproduction Tests

Tests for all technical requirements are preproduction tests and shall be performed prior to or on the initial shipment of the expansion joints to the buyer or when a change of ingredients and/or processing requires reapproval or when buyer deems confirmatory testing is required.

5.4. Sampling and Testing Shall Be As Follows:

5.4.1. For acceptance tests, sufficient product shall be taken at random from each lot to perform all required tests. The number of samples for each property tested per lot shall be no less than 3. A test result is the mean of the individual samples.

5.4.2. ASTM test specimens shall be prepared from the same batch of polymer/compound as the material being supplied and shall be fully pressure cured as specified in **4.2.**

5.4.3. A lot is the entire product from the same batch of compound processed in one continuous run and presented to the purchaser at one time.

5.4.4. A batch is the quantity of compound run through a mill or mixer at one time.

5.4.5. Ingredients and manufacturing processes used on specification test samples shall be the same as those on the approved product.

5.5. Reports

Report shall be furnished showing the test results on each lot to determine conformance to acceptance requirements. Documentation must include traceability back to polymer type, supplier, and supplier's lot number.

6. Appendix

DAI-EL™ is a registered trademark of Daikin America Inc., a division of Daikin Industries.

Dyneon™ is a registered trade name of Dyneon (a 3M Company).

Tecnoflon® is a registered trademark of Solvay Solexis, Inc.

Viton® is a registered trademark of DuPont Performance Elastomers, L.L.C.

APPENDIX 2 - FSA-DSJ-402-15
Fluoroelastomer Belt Recommendation

1. Definition
1.1. Fluoroelastomers (FKM) are specifically compounded terpolymers (vinylidene fluoride/tetrafluoroethylene/hexafluoropropylene) as designated in the specification FSA-DSJ-401-09 (ASTM-D6909-10). This compound is used as the gas seal and chemical barrier of a multi-layer buildup expansion joint flexible element.

1.2. Fluoroelastomer belts are recommended for flue duct applications with maximum operating / design temperatures of 400°F at maximum pressures of ±3 psig.

1.3. Terpolymer fluoroelastomers have been used for flue duct expansion joints due to their outstanding resistance to chemicals, oils and heat compared to any other elastomer. Fluoroelastomers are especially effective in flue duct applications where condensation and sulfuric acid is a problem such as in coal fired power plants.

2. Styles
2.1. Fluoroelastomer belts can be provided as a flat belt type or integrally flanged "U"-type expansion joint. These belts work well as a single layer type with reinforcement plies given the excellent abrasion resistance and durability of the fluoroelastomer.

3. Requirements (Minimum Recommended)

- Fluoroelastomer compound shall be per the FSA-DSJ-401-09 specification and can be supplied by FSA member companies.
- 0.250" Minimum overall finished belt thickness after press cure.
- Two (2) layers of textile woven cloth reinforcement sandwiched between three (3) layers of fluoroelastomer.
- Recommended reinforcement cloth materials include fiberglass, Nomex® or aramid blends.
- Reinforcement shall be minimum 32oz. per sq. yard weight (34oz. max.) with 240x450 lbs warp x fill minimum breaking strength.
- Minimum adhesion strength between reinforcement layers and compound shall be 23 lbs/linear in (pli).
- Fluoroelastomer layers shall include minimum: 0.070" thick. gas side layer, 0.050" thick. center layer, and 0.050" thick. external cover. Gas side shall be clearly marked for installation.
- Bolt holes shall be slotted on 1" gauge for 1/2" or 5/8" diameter hex bolt sets on 4" to 6" centers, respectively. Bolt torque for fluoroelastomer belt should not exceed 35 to 55 ft- lbs. Typical back-up bars are 3/8"x 2" rounded edge A36 C.S. minimum grade bar stock.
- All metal surfaces in contact with belt shall be smooth with no sharp edges. Consult manufacturer when free belt width exceeds 16".
- Consult manufacturer for applications where ammonia is present.
- Thermal movements per single layer elastomer guidelines given in Table D-B on page 16 of the FSA Ducting Systems Technical Handbook.

4. Testing
- Tensile testing shall be performed per ASTM D-412
- Adhesion testing shall be per ASTM D-413
- Methanol and Toluene Volume Swell Tests per ASTM D-471

5. Quality Control
5.1. All fluoroelastomer belts shall have material batch certification with full traceability to original compound polymers, grade, and lot number.

5.2. Belt, as received, shall be uniform in quality and condition, smooth, as free from foreign materials as commercially practical, and free from imperfections detrimental to use as intended.

6. Warranty
Standard manufacturers warranty to apply.

APPENDIX 3 - FSA-DSJ-403-07 Fluoroplastic Belt Guidelines

3

1. Scope

1.1. This standard describes composition and property recommendations for a single layer fluoroplastic/fiberglass fabric belt. The standard is not applicable for higher temperature rated multi-layer composite belt build-ups. Fluoroplastics have been used for flue duct expansion joints because of their outstanding resistance to chemicals and heat. Fluoroplastic materials are particularly effective in applications where condensation and chemical attack are problems, such as sulfuric acid bearing flue gas in coal-fired power plants.

1.2. While the materials, methods, applications and processes described or referenced in this standard may involve the use of hazardous materials, this standard does not address the hazards which may be involved in such use. It is the sole responsibility of the user/tester to ensure familiarity with the safe and proper use of any hazardous materials and testing and to take the necessary precautionary measures to ensure the health and safety of all personnel involved.

2. Definitions

Fluoroplastics are thermoplastic resins of general paraffin structures that have all or some of the hydrogen replaced with fluorine. Polytetrafluoroethylene, commonly called PTFE, and perfluoroalkoxy copolymer resin, commonly called PFA, are the major fluoroplastic resins used in expansion joints. Commercial PTFE fluoroplastics include TEFLON,® POLYFLON,™ ALGOFLON,® and DYNEON™ brands and commercial PFA fluoroplastics include TEFLON,® NEOFLON,™ HYFLON,® and DYNEON™ brands.

The fluoroplastic component of the flexible element provides:
1) a gas seal layer with minimal to zero porosity.
2) mechanical strength and resistance to flex failures.
3) resistance to attack from most chemicals.

Single layer fluoroplastic belts are used for flue duct applications with continuous operating/design temperatures ranging from -75 °F (- 60°C) up to 600 °F (316°C) at maximum pressures of ±3 psig (±20kPa).

3. Components

A) Fiberglass Substrate The base for the fluoroplastic belt is the woven fiberglass matrix which acts as the reinforcement and support for the fluoroplastic resin that is applied as the gas seal layer.

- Fiberglass cloth reinforcement shall be a minimum of 30 oz/sq yd (1020 g/sq m) in weight with a 1000 lbs/in x 1000 lbs/in (8900 N/50 mm x 8900 N/50 mm) (warp x fill) tensile strength.

- Woven fiberglass cloth shall be a minimum of E Grade glass.

B) Fluoroplastic Coating Barrier protection for the fiberglass fabric is required for chemical resistance, mechanical support, and thermal protection. Proper coating will surround and encase the individual fabric fibers to protect and prevent flex fatigue failures. This barrier must contain, as a minimum, 35% – 40% by weight PTFE resin when using a 30 oz/sq yd (1020 g/sq m) fiberglass base. The suggested minimum fluoroplastic coating compound weight is 18 oz/sq yd (610 g/sq m).

- Compound must be 100% virgin PTFE with no reprocessed materials.

- Fiberglass substrate shall be thoroughly coated on both sides with the PTFE compound.

- Overall suggested minimum weight of fiberglass substrate and PTFE coating should be 48 oz/sq yd (1600 g/sqm).

C) Chemical Barrier Layer Due to extremely aggressive chemical environments caused by corrosive flue gas operating at or below dew point, significant protection is required for the fiberglass fabric reinforcement. The suggested minimum weight for the fluoroplastic compound gas film barrier layer is 6.4 oz/sq yd (220 g/sq m).

- Minimum thickness for the fluoroplastic chemical barrier laminated to gas side of coated fiberglass belt should be 0.004 in (0.1 mm).

- Overall weight of fiberglass substrate, PTFE coating, and fluoroplastic chemical barrier layer 54.4 oz/sq yd (1850 g/sq m) minimum.

- Chemical barrier to be non-porous.

- Minimum adhesion strength between laminated films and fiberglass substrate shall be 5 lbs/in (45 N/50 mm).

4. Styles

Fluoroplastic flexible elements can be provided to accommodate either the Flat Belt or Integrally Flanged "U" expansion joint designs.

APPENDIX 3 - FSA-DSJ-403-07
Fluoroplastic Belt Guidelines

5. General Requirements

- Expanded PTFE joint sealant is required between the fluoroplastic belt and attachment flange to provide adequate sealing.

- Bolt holes shall be slotted on 1 inch (25 mm) gauge for 1/2 inch (12 mm) or 5/8 inch (16 mm) diameter hex bolt sets on 4 inch (100 mm) and 6 inch (150 mm) centers respectively. Bolt torque should not exceed 35 foot-pounds (47 N m) to 55 foot-pounds (74 N m).

- All metal surfaces in contact with the belt shall be smooth with no sharp edges.

- Typical back-up bars shall be 3/8 in x 2 in (10 mm x 50 mm) rounded edge ASTM A36 Carbon Steel, minimum grade, bar stock with rust inhibitive primer.

- Consult manufacturer when overall belt free width exceeds 16 in (410 mm).

- Thermal movement guidelines are the same as those listed for single layer fluoroplastics shown in Table D-B of the FSA Technical Handbook, Fourth Edition.

6. Abrasion

The presence of dust in the flue gas stream justifies the installation of a liner/baffle for non-metallic expansion joints with fluoroplastic belts. Fluoroplastic elements are susceptible to wear due to the poor abrasion resistance properties of PTFE.

7. Testing (Refer to Table-1 on Page 35)

This section describes a number of useful standardized test methods and typical property values for the fluoroplastic fiberglass-fabric belt.

Not All Tests May Be Applicable

8. Flutter / Vibration

Fluctuating flue gas pressure, often referred to as flutter or flow-induced vibration, can cause premature failure of fluoroplastic flexible elements in non-metallic expansion joint service through fatigue of the fabric. Often, the operating parameters associated with flutter in a typical flue gas application, such as the range and rate of pressure change, cannot be established. Thus, it is typically not possible to determine the forces that might be imposed on a fluoroplastic flexible element in flutter service. For these reasons, the conditions dealing with flutter/vibration are best addressed through the design and engineering of the non-metallic expansion joint. Contact the manufacturer for design details.

9. Quality Control

As documented evidence of product quality, manufacturers should either certify the belt materials to a defined product specification or provide test results for the specific rolls to be delivered. When selecting fluoroplastic expansion joints, one should compare the product specifications or roll test results for compliance with the standards previously described.

In-process component tests can and should be conducted by the manufacturers to ensure the integrity of the final product prior to testing. Specifiers may wish to discuss the in-process tests and process controls present during manufacture with the supplier in order to judge the quality of the product produced.

10. Warranty

Standard manufacturer’s warranty to apply.

11. Appendix

TEFLON®
is a registered trademark of DuPont

POLYFLON™
is a registered trademark of Daikin Industries, Ltd.

ALGOFLON®
is a registered trademark of Solvay Solexis, Inc.

DYNEON™
is a registered trademark of Dyneon LLC, A 3M Company

NEOFLON™
is a registered trademark of Daikin Industries, Ltd.

HYFLON®
is a registered trademark of Solvay Solexis, Inc.

Table-1- Standardized Test Methods For Fluoroplastic Fiberglass Fabric Belts

Property	Typical Minimum Values (Units)	Test Methods	Comments
Weight / Unit Area	54.4 oz/sq yd (1850 g/sq m)	ASTM D4851	
Thickness	0.045 in (1.14 mm)	ASTM D751	
Breaking Strength, Machine & Transverse Directions	1000 lbs/in x 1000 lbs/in (8900 N/50 mm x 8900 N/50 mm)	ASTM D4851	Cut strip method; Constant rate of extension = 2 in/min.
Trapezoidal Tear Strength, Machine & Transverse Directions	50 lbs x 50 lbs (44 N x 222 N)	ASTM D4851	Average of five high peaks or average value.
Seam Peel Integrity/Coating Adhesion	5 lbs/in (44 N/50 mm)	ASTM D4851	Suitable for adhesive or thermal bonds only; Seam specimen as for actual use; Average of five high & five low peaks.
Flexural Endurance	60% (Retaining Breaking Strength)	**ASTM D4851	Suitable for thin reinforced materials.

** (1) ASTM D4851 Crease fold test.
(2) After 5000 cycles, MIT Folding Endurance Tester or similar, as described in ASTM D2176.

Other test methods unique to specific manufacturers exist and may be useful. Such test methods often measure retention of product properties. Product integrity can be determined, when possible, by the application of the standard test methods listed above.

Note: Comparisons between belts tested with different test methods cannot be accurately made.

APPENDIX 4 - Quality Management In Design, Development, Production, Installation & Servicing

Scope Of Section
International standards for quality management systems, such as the ISO 9001 standard, specify requirements for use where a supplier's capability to design and supply conforming products needs to be demonstrated. The requirements are aimed at achieving customer satisfaction by preventing non-conformity at all stages from design through to servicing.

The standard is applicable in situations when:
a) The required design and the product requirements are stated principally in the performance terms.

b) Confidence in product conformance can be attained by adequate demonstration of a supplier's capabilities in design, development, production, installation and servicing.

Certification to conformance with the ISO 9001 standard assures verification and documentation of all procedures for managing quality assurance in expansion joint manufacture, from the selection of material through manufacturing, testing and preparation for delivery.

If such an internationally approved quality management system does not exist, written procedures shall be maintained as a minimum by each manufacturer for each of the following categories:

• Identification and control of materials
• Drawing and document control
• Manufacturing processes and control
• Testing, inspection and documentation
• Preparation for delivery

A. Identification And Control Of Materials
A system shall be used to assure that the materials used in construction of the expansion joint meet the requirements of the drawing, specifications, etc. Documented procedures shall exist for identification and traceability of the materials used for the finished product.

Raw material components and finished parts shall be properly stored and protected to avoid damage.

B. Drawing And Document Control
Assembly drawings shall be made from customer specifications, drawings, purchase order requirements, or other specified information. Documented procedures shall be established to control all documents and data that relate to above documents.

When drawing approval is required , the manufacturer shall submit drawings showing basic dimensions, operating conditions, movements, materials and other related information. The manufacturer shall maintain a record of all purchase approved drawings and specifications, which identify the current revision status of all documents. Customer approval of drawings shall not relieve the manufacturer of responsibility for compliance with this handbook.

C. Manufacturing Processes And Control
A system shall be used to ensure that only the applicable drawings and procedures are employed in manufacture. The manufacturer shall document procedures for production, installation and servicing processes to ensure uniform and constant product quality.

D. Testing, Inspection And Documentation

D-1. General
Each manufacturer shall prepare, maintain and use written procedures covering the in-process and inspection operations that are used in the course of manufacturing methods, dimensional checks, visual inspections, non-destructive tests and other pertinent operations that are to be performed to assure that the expansion joint meets the specifications. The procedure shall specify the applicable acceptance standards and shall provide for a means to document that operations have in fact been performed and the results determined to be satisfactory.

D-2. Physical Testing
Since flue gas expansion joints are so large, it is virtually impossible to set up an in-plant testing procedure for each

Flexible element tensile test

expansion joint as the cost of such a testing program would be prohibitive compared to the value gained. Small leakage in an installation is normally acceptable. In most flue gas duct systems the expansion joint pressure capacity is generally greater than the capacity of the ductwork; therefore, structural pressure tests should not be required.

Materials used in the manufacture of the expansion joints shall be tested for quality assurance and written procedures shall be established to record the findings. The product shall be checked at each manufacturing step to assure the product is capable of performing satisfactorily in its recommended service.

The manufacturer shall establish and maintain records which document that the product has been inspected and that the product has met project requirements.

D-3. Thermal Testing

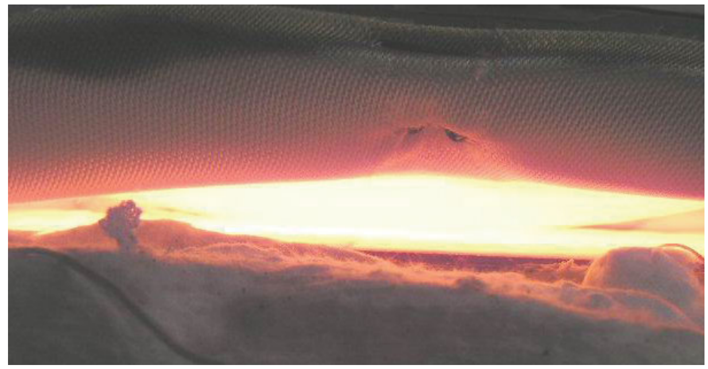
Manufacturers can, on request, provide test data demonstrating the ability of the overall design and combination of materials to withstand the maximum temperature for which the expansion joint is proposed.

Cold face flexible element thermal testing

The data should include as a minimum, gas temperature at the inside surface of the internal liner, temperature of the inside surface of the fabric, temperature at the inside surface of the innermost elastomer coated layer, both outside and under the back-up bar, and the ambient external air temperature. Time at temperature should be a minimum of four (4) hours after the steady state condition is achieved. The manufacturer shall maintain written procedures to control, calibrate and maintain inspection, measuring and test equipment used to demonstrate product conformance to the specified customer requirements.

E. Final Inspection And Identification

E-1. Prior to shipment, the following items of an expansion joint should be checked to ensure maximum integrity of the product:



Hot side flexible element thermal testing

a) Dimensional compliance with manufacturing drawings, including flange bolt pattern (if applicable).

b) Integrity of splices in the fabric element (if applicable).

c) Security of nuts and bolts on back-up bars, flange assemblies, and shipping bars or restraining hardware.

d) Adequate size, number, and placement of shipping bars, lugs, or installation aids (painted yellow if removal is required after installing).

e) Expansion joint assemblies with baffles (flow liners) should be shipped and stored with up-stream end uppermost to help prevent accumulation of rainwater.

f) Identification markings, flow direction arrows, and instruction should be clearly stenciled or permanently affixed.

g) Installation instructions should be included with each assembly.

h) General condition of fabric element, frame fit-up and paint shall be in accordance with customer requirements and good manufacturing practices.

APPENDIX 5 - Expansion Joint Specification Sheet

Download electronic worksheet for data entry at www.fluidsealing.com/ejspecsheet.html

Customer	Customer's Name:			Date:		Page:
Customer	Address:			Project Name:		Delivery Req'd By:
Customer	City, State/Prov., Postal Code:			Specification #		Inquiry #
Customer	Name of Person Submitting Data:	Tel: Fax:		Item# / Tag #	Item# / Tag #	Item# / Tag #
Customer	Quantity Per Item:					
Customer	New or Replacement:					
Service	Type of Plant/Service (Precipitator, Scrubber, etc) :					
Service	Type of Fuel & Percent Sulfur:					
Service	Peak Load or Base Load:					
Service	Number of Startups & Shutdowns Per Year:					
Service	Location of Expansion Joint (Inside Diameter Fan Outlet, Stack, etc) :					
Size	Duct Size (Inside Dimensions or Diameter) :			FT IN	FT IN	FT IN
Size	Face-to-Face Dimension (If Replacement Required) :			IN	IN	IN
Gas	Flowing Medium (Air, Flue, Gas, etc) :					
Gas	Dust Load:			PSF	PSF	PSF
Gas	Flow Velocity:			FPS	FPS	FPS
Gas	Flow Direction (Up, Down, Horizontal, Angular Up, Angular Down, etc) :					
Press	Design Pressure	Maximum		IN $H_2$0	IN $H_2$0	IN $H_2$0
Press	Design Pressure	Normal		IN $H_2$0	IN $H_2$0	IN $H_2$0
Temperature	Gas Temperature	Normal Continuous		°F	°F	°F
Temperature	Gas Temperature	Maximum (Upset)	Temperature	°F	°F	°F
Temperature	Gas Temperature	Maximum (Upset)	Duration Per Event	HR	HR	HR
Temperature	Gas Temperature	Maximum (Upset)	Cumulative Duration	HR	HR	HR
Temperature	Ambient Temperature	Maximum		°F	°F	°F
Temperature	Ambient Temperature	Minimum		°F	°F	°F
Movement	Axial Compression:			IN	IN	IN
Movement	Axial Extension:			IN	IN	IN
Movement	Lateral:			IN	IN	IN
Movement	Angular :			°	°	°
Movement	Torsional:			°	°	°
Duct	Duct Material:					
Duct	Duct Thickness:			IN	IN	IN
Duct	Duct Corner (Radius or Square):					
Duct	Baffle (Flow Liner)					

APPENDIX 6 - Thermal Expansion Chart

Temperature ºF	Temperature ºC	Carbon Steel	Austenitic Stainless Steel	12CR/17CR/27CR	25CR/20NI
-325ºF	-198ºC	-2.37	-3.85	-2.04	-3.00
-300ºF	-184ºC	-2.24	-3.63	-1.92	-2.83
-275ºF	-171ºC	-2.11	-3.41	-1.80	-2.66
-250ºF	-157ºC	-1.98	-3.19	-1.68	-2.49
-225ºF	-143ºC	-1.85	-2.96	-1.57	-2.32
-200ºF	-129ºC	-1.71	-2.73	-1.46	-2.15
-175ºF	-115ºC	-1.58	-2.50	-1.35	-1.98
-150ºF	-101ºC	-1.45	-2.27	-1.24	-1.81
-125ºF	-87ºC	-1.30	-2.01	-1.11	-1.60
-100ºF	-73ºC	-1.15	-1.75	-0.98	-1.39
-75ºF	-59ºC	-1.00	-1.50	-0.85	-1.18
-50ºF	-46ºC	-0.84	-1.24	-0.72	-0.98
-25ºF	-32ºC	-0.68	-0.98	-0.57	-0.78
0ºF	-18ºC	-0.49	-0.72	-0.42	-0.57
25ºF	-4ºC	-0.32	-0.46	-0.27	-0.37
50ºF	10ºC	-0.14	-0.21	-0.12	-0.16
70ºF	21ºC	0.00	0.00	0.00	0.00
100ºF	38ºC	0.23	0.34	0.20	0.28
125ºF	52ºC	0.42	0.62	0.36	0.51
150ºF	66ºC	0.61	0.90	0.53	0.74
175ºF	79ºC	0.80	1.18	0.69	0.98
200ºF	93ºC	0.99	1.46	0.86	1.21
225ºF	107ºC	1.21	1.75	1.03	1.45
250ºF	121ºC	1.40	2.03	1.21	1.70
275ºF	135ºC	1.61	2.32	1.38	1.94
300ºF	149ºC	1.82	2.61	1.56	2.18
325ºF	163ºC	2.04	2.90	1.74	2.43
350ºF	177ºC	2.26	3.20	1.93	2.69
375ºF	190ºC	2.48	3.50	2.11	2.94
400ºF	204ºC	2.70	3.80	2.30	3.20
425ºF	218ºC	2.93	4.10	2.50	3.46
450ºF	232ºC	3.16	4.41	2.69	3.72
475ºF	246ºC	3.39	4.71	2.89	3.98
500ºF	260ºC	3.62	5.01	3.08	4.24
525ºF	274ºC	3.86	5.31	3.28	4.51
550ºF	288ºC	4.11	5.62	3.49	4.79
575ºF	302ºC	4.35	5.93	3.69	5.06
600ºF	316ºC	4.60	6.24	3.90	5.33
625ºF	330ºC	4.86	6.55	4.10	5.60
650ºF	343ºC	5.11	6.87	4.31	5.88
675ºF	357ºC	5.37	7.18	4.52	6.16
700ºF	371ºC	5.63	7.50	4.73	6.44
725ºF	385ºC	5.90	7.82	4.94	6.73
750ºF	399ºC	6.16	8.15	5.16	7.02
775ºF	413ºC	6.43	8.47	5.38	7.31
800ºF	427ºC	6.70	8.80	5.60	7.60
825ºF	441ºC	6.97	9.13	5.82	7.89
850ºF	454ºC	7.25	9.46	6.05	8.19
875ºF	469ºC	7.53	9.79	6.27	8.48
900ºF	482ºC	7.81	10.12	6.49	8.78
925ºF	496ºC	8.08	10.46	6.71	9.07
950ºF	510ºC	8.35	10.80	6.94	9.37
975ºF	524ºC	8.62	11.14	7.17	9.66
1000ºF	538ºC	8.89	11.48	7.40	9.95
1025ºF	552ºC	9.17	11.82	7.62	10.24
1050ºF	566ºC	9.46	12.16	7.95	10.54
1075ºF	580ºC	9.75	12.50	8.18	10.83
1100ºF	593ºC	10.04	12.84	8.31	11.13
1125ºF	607ºC	10.31	13.18	8.53	11.41
1150ºF	621ºC	10.57	13.52	8.76	11.71
1175ºF	635ºC	10.83	13.86	8.98	12.01
1200ºF	649ºC	11.10	14.20	9.20	12.31
1225ºF	663ºC	11.38	14.54	9.42	12.59
1250ºF	677ºC	11.66	14.88	9.65	12.88
1275ºF	690ºC	11.94	15.22	9.88	13.17
1300ºF	704ºC	12.22	15.56	10.11	13.46
1325ºF	718ºC	12.50	15.90	10.33	13.75
1350ºF	732ºC	12.78	16.24	10.56	14.05
1375ºF	746ºC	13.06	16.58	10.78	14.35
1400ºF	760ºC	13.34	16.92	11.01	14.65

Movement is inches per 100 feet between 70ºF and indicated temperature.

APPENDIX 7 - Conversion Charts

PRESSURE CONVERSION CHARTS

To Convert To	Pounds Per Square Inch	Inches Of Water (32ºF)	Inches Of Mercury (32ºF)	Kilograms Per Square Centimeter	Bars	Atmospheres
Pounds Per Square Inch		27.680	2.036	0.070	0.069	0.068
Inches Of Water (32ºF)	0.036		0.074	0.003	0.002	0.002
Inches Of Mercury (32ºF)	0.491	13.590		0.035	0.034	0.033
Kilograms Per Square Centimeter	14.220	394.100	28.960		0.981	0.968
Bars	14.500	401.800	29.530	1.020		0.987
Atmospheres	14.700	406.900	29.921	1.033	1.013	

kP	Pounds Per Square Inch									
	0	1	2	3	4	5	6	7	8	9
0	- -	0.145	0.290	0.435	0.580	0.725	0.870	1.015	1.160	1.305
10	1.450	1.595	1.740	1.885	2.031	2.176	2.321	2.466	2.611	2.756
20	2.901	3.046	3.191	3.336	3.481	3.626	3.771	3.916	4.061	4.206
30	4.351	4.496	4.641	4.786	4.931	5.076	5.221	5.366	5.511	5.656
40	5.802	5.947	6.092	6.237	6.382	6.527	6.672	6.817	6.962	7.107
50	7.252	7.397	7.542	7.687	7.832	7.977	8.122	8.267	8.412	8.557
60	8.702	8.847	8.992	9.137	9.282	9.427	9.572	9.718	9.863	10.008
70	10.153	10.298	10.443	10.588	10.733	10.878	11.023	11.168	11.313	11.458
80	11.603	11.748	11.893	12.038	12.183	12.328	12.473	12.618	12.763	12.908
90	13.053	13.198	13.343	13.489	13.634	13.779	13.924	14.069	14.214	14.359
100	14.504	14.649	14.794	14.939	15.084	15.229	15.374	15.519	15.664	15.809

• Kilopascals to Pounds Per Square Inch (1kP = 0.1450377 lb/in.^{2})

TEMPERATURE CONVERSION CHART

Fahrenheit	Celsius	Fahrenheit	Celsius	Fahrenheit	Celsius
-688	-400	-7.6	-22	69.8	21
-508	-300	-5.8	-21	71.6	22
-418	-250	-4	-20	73.4	23
-328	-200	-2.2	-19	75.2	24
-238	-150	-0.4	-18	77	25
-148	-100	1.4	-17	78.8	26
-139	-95	3.2	-16	80.6	27
-130	-90	5	-15	82.4	28
-121	-85	6.8	-14	84.2	29
-112	-80	8.6	-13	86	30
-103	-75	10.4	-12	87.8	31
-94	-70	12.2	-11	89.6	32
-85	-65	14	-10	91.4	33
-76	-60	15.8	-9	93.2	34
-67	-55	17.6	-8	95	35
-58	-50	19.4	-7	96.8	36
-56.2	-49	21.2	-6	98.6	37
-54.4	-48	23	-5	100.4	38
-52.6	-47	24.8	-4	102.2	39
-50.8	-46	26.6	-3	104	40
-49	-45	28.4	-2	105.8	41
-47.2	-44	30.2	-1	107.6	42
-45.4	-43	32	0	109.4	43
-43.6	-42	33.8	1	111.2	44
-41.8	-41	35.6	2	113	45
-40	-40	37.4	3	114.8	46
-38.2	-39	39.2	4	116.6	47
-36.4	-38	41	5	118.4	48
-34.6	-37	42.8	6	120.2	49
-32.8	-36	44.6	7	122	50
-31	-35	46.4	8	167	75
-29.2	-34	48.2	9	212	100
-27.4	-33	50	10	302	150
-25.6	-32	51.8	11	392	200
-23.8	-31	53.6	12	482	250
-22	-30	55.4	13	572	300
-20.2	-29	57.2	14	752	400
-18.4	-28	59	15	932	500
-16.6	-27	60.8	16	1112	600
-14.8	-26	62.6	17	1292	700
-13	-25	64.4	18	1472	800
-11.2	-24	66.2	19	1652	900
-9.4	-23	68	20	1832	1000

- Fahrenheit to Celsius - ((°F-32)x(5/9))=°C
- Celsius to Fahrenheit - (°C x (9/5))+32=°F

APPENDIX 8 - GLOSSARY OF TERMS AS THEY ARE USED IN THIS HANDBOOK

Active Length (Flex Length): The portion of the flexible part of the joint that is free to move.

Ambient Temperature: The external environment temperature adjacent to the external face of the expansion joint.

Anchor: Terminal point or fixed point from which directional movement occurs.

Angles: L-shaped steel member used either as a duct flange or as the fastening member of an expansion joint used for bolting or welding the joint to the mating flange surfaces of the ductwork or adjacent equipment.

Angular Movement: The movement which occurs when one flange of the expansion joint is moved to an out of parallel position with the other flange. Such movement is measured in degrees.

Angular Deflection: *See Angular Movement.*

Angular Offset: *See Angular Movement.*

Assembled Splice: A splice that is constructed of multi-layers of materials and connected by mechanical means such as adhesives, stitching, or lacing hooks.

Axial Compression: The dimensional shortening of an expansion joint parallel to its longitudinal axis. Such movement is measured in inches or millimeters and usually caused by thermal expansion of the ducting system.

Axial Elongation: *See Axial Extension.*

Axial Extension: The dimensional lengthening of an expansion joint parallel to its longitudinal axis. Such movement is measured in inches or millimeters.

Backing Bars: *See Back-Up Bars.*

Back-Up Bars: Metal bars used for the purpose of clamping the expansion joint to mating ductwork flanges or clamping the fabric portion of a belted type of joint to the metal adapter flanges.

Baffle (Flow Liner): A shield that is designed to protect the expansion joint from the abrasive particles in the gas stream and/or to reduce the flutter caused by the air turbulence in the gas stream and in some cases may be part of the overall thermal protection system.

Bearing Point: *See Fixed Point.*

Belt: The flexible element of an expansion joint.

Belt Type Expansion Joint: An expansion joint in which the flexible element of the joint is made like a flat belt and is bolted or clamped to metal adapter flanges or frame.

Bolster: Also know as a cavity pillow . The cavity pillow fills the cavity between the flexible element and the flow liner or baffle and helps minimize the accumulation of particulate matter, and in some applications unburned fuel, from becoming trapped in the expansion joint cavity.

Bolt Hole Pattern or Drill Pattern: The systematic location of bolt holes in the duct flanges and expansion joint flanges where the joint is to be bolted to ducting flanges.

Bolt-in Baffle (Flow liner): A baffle that is designed to be bolted to the breach flange. This design can be either single or double acting and requires the use of a seal gasket.

Bolt Torque: The torque with which bolts must be fastened. This varies according to bolt dimensions, bolt lubrication, flange pressure etc.

Boot or Belt: The flexible element of an expansion joint.

Breach Flange or Duct Flange: The portion of the duct system, usually an angle or a channel that interfaces with the flange of the expansion joint.

Breach Opening or Duct Face-to-Face Distance: The distance between the mating duct flanges in which the joint is to be installed.

Cavity Pillow: The cavity pillow fills the cavity between the flexible element and the baffle (flow liner) and helps minimize the accumulation of particulate matter, and in some applications unburned fuel, from becoming trapped in the expansion joint cavity.

Chimney Joint: A special type of seal or expansion joint used in chimneys or flues.

Clamp Bars: *See Back-Up Bars.*

Clamping Area: That part of the expansion joint which is covered by the back-up bar.

Cold Pre-Set: *See Pre-set.*

Combination Type Expansion Joint: An expansion joint which utilizes both belt type and flanged expansion joint clamping configurations.

Compensator: *See Expansion Joint.*

Composite Type Expansion Joint: An expansion joint in which the various plies are of different materials that are not integrally bonded together. It is normally made up of an inside liner, thermal insulating barrier and an outer cover. Other special plies can be included.

Concurrent Movements: Combination of two or more types (axial or lateral) of movements.

Continuous Temperature Rating: Temperature at which an expansion joint may be operated continuously with safety.

Corners: Molded, formed, or radiused belt corners of rectangular expansion joint.

Cuff: The flange reinforcement that is an additional sheath of fabric to protect the expansion joint from thermal and/or mechanical degradation.

Design Temperature: The maximum or most severe temperature expected during normal operation, not including periods of abnormal operation caused by equipment failure. (See excursion temperature).

Design Pressure/Vacuum: The maximum or most severe pressure/vacuum expected during normal operation, not including periods of abnormal operation caused by equipment failure. During cyclic phases in the system, both pressure and vacuum conditions may occur.

Dew Point: The temperature at which gasses condense to form a liquid. Acid dew point varies with gas composition and is a higher temperature than the moisture dew point.

Double-Acting Flow Liner: A shield constructed so that the liner is formed of two pieces, each providing protection against fly ash or media flow. One piece is attached to each side of the frame or ductwork, joined by the expansion joint (see also Internal flow liner).

Drain: A fitting to drain the expansion joint of condensate or other liquids that collect at the lowest point.

Drill Pattern: The systematic location of bolt holes on the breach flange to which the expansion joint will be attached.

Duct Flange: *See Breach Flange.*

Duct Face-To-Face Distance: *see Breach Opening.*

Duct I.D.: The inside dimension of the ductwork measured from the duct walls.

Effective Length: *See Active Length.*

Elastomer: Designation for rubber and synthetic polymers.

Excursion Temperature: The temperature the system could reach during an equipment failure, such as an air heater failure. Excursion temperature should be defined by maximum temperatures and time duration of excursion.

Expansion Joint: Non-metallic expansion joints are flexible connectors designed to provide stress relief and seal in gaseous media in ducting systems. They are fabricated from a wide variety of non-metallic materials, including synthetic elastomers, fabrics, insulation materials and fluoroplastics, depending on the designs.

Expansion Joint Assembly: The complete expansion joint, including, where applicable, the flexible element, the frame and any flow liners or ancillary components.

Expansion Joint Frame: A metal frame on which the expansion joint is attached . The frame may incorporate flow liners.

External Arch Corner: An expansion joint comer with the arch formed outwardly that is designed primarily for pressure service, generally used in conjunction with a molded joint.

External Influences: Forces or environment acting on the expansion joint assembly from outside of the process.

External Insulation: Insulation materials applied to the outside of either the duct or expansion joint.

Fabric Expansion Joint: *See Expansion Joint.*

Fabric Flanged Type Expansion Joint: *See Flanged Expansion Joint.*

Fastening Elements: Bolts, nuts, studs, washers and other items for securing a connection.

Fatigue: Condition which sets in when joint components have been subjected to stress. It is depends on the severity and frequency of operating cycles.

Field Assembly: A joint that is assembled at the jobsite.

Finite Element Analysis (FEA)**:** Study of a structure and its components to ensure that the design meets the required performance criteria for thermal, vibration, shock and structural integrity.

Fixed Point: The point at which the ducting system is anchored.

Fixings: The mechanical system for holding the expansion joint in position and creating a seal between the joint and the duct system.

Flanged Expansion Joint: An expansion joint when installed takes the "U" shaped configuration.

Flange Gasket: A gasket which is inserted between two adjacent flanges to form a gas-tight connection.

Flange Reinforcement: *See Cuff.*

Flexible Element: *See Expansion Joint.*

Flexible Length: *See Active Length.*

Fly Ash Seal: A flexible element that is attached between the baffle plates and/or duct wall to restrict the buildup of fly ash between the baffle and joint body. This element is not gas tight.

APPENDIX 8 - GLOSSARY OF TERMS AS THEY ARE USED IN THIS HANDBOOK

Fly Ash Shield: *See Flow Liner.*

Floating Liner: A specific type of baffle arrangement.

Flow Direction: The direction of gas flow through the system.

Flow Liner (Baffle): A shield that is designed to protect the expansion joint from the abrasive particles in the gas stream and/or to reduce the flutter caused by the air turbulence in the gas stream and in some cases may be part of the overall thermal protection system.

Flow Velocity: The rate of flow through the expansion joint system.

Flue Gas Duct: Duct which conveys the flue gas through the system.

Fluoroelastomer: *See DSJ-401-09 Appendix 1.*

Fluoroplastic: *See DSJ-403-07 Appendix 3.*

Flutter: The action that occurs on the flexible element caused by the turbulence of the system gases or vibration set up in ducting system.

Frame: The complete angle iron or plate frame to which flexible element portion of the expansion joint is attached.

Free Length: *See Active Length.*

Gas Flow Velocity: *See Flow Velocity.*

Gas Seal: The specific ply in the flexible element that is designed to stop gas penetration.

Inner Ply: The gas side ply of the flexible element.

Installed Face-to-Face Distance: The distance between the expansion joint frames after installation when the system is in the cold position.

Insulation: Materials used to protect the outer cover in composite constructions from thermal degradation. Also used in cavity pillows. (*See also Cavity Pillow*).

Internal Arch Corner: An expansion joint corner with the arch formed inwardly (concave), designed primarily for vacuum service. Used generally in conjunction with a molded joint.

Joint Cuff: *See Cuff.*

Lateral Movement: The relating displacement of the two ends of the expansion joint perpendicular to its longitudinal axis.

Lateral Offset: The offset distance between two adjacent duct flanges or faces.

Leakage Rate: The rate of leaking through the flexible elements bolt holes and mounting interface areas.

Life Cycles: The cumulative number of times the flexible element moves from the cold to hot position and then back to cold again until failure.

Lifting Lugs: A lifting device that is attached to the metal portion of the expansion joint frame for field handling and erection.

Limiting Stress: The load which, when applied, does nor exceed the elastic limits of the material and provides a safe operating level.

Manufactured Face-to-Face of Expansion Joint: The manufactured width of the flexible element measured from joint flange face to flange face.

Maximum Design Temperature: The maximum temperature that the system may reach during normal operating conditions. This is not to be confused with excursion temperature.

Membrane: A ply of material.

Misalignment: The out-of-line condition that exists between the adjacent faces of the breach or duct flanges during ductwork assembly.

Molded Type Expansion Joint: An expansion joint in which the entire wall of the joint is molded into a "U" or a convoluted configuration. The joint is manufactured by a molding process.

Movements: The dimensional changes which the expansion joint assembly is required to absorb, such as those resulting from thermal expansion or contraction.

Multi-Layer Expansion Joint (Composite): An expansion joint in which the various plies are of different materials which are not integrally bonded together.

Needle-Mat: *See Insulation.*

Noise Attenuation: The reduction of noise transmitted through the expansion joint systems construction.

Nominal Thickness: The nominal thickness is not to be less than 85% of the stated normal value.

Non-Metallic Expansion Joint: *See Expansion Joint.*

Operating Pressure/Vacuum: The pressure or vacuum condition which occurs during normal performance.

Operating Temperature: The gas temperature at which the system generally will operate during normal conditions.

Outer Cover: The external side of the flexible element.

Pantograph Control Mechanism: *See Scissors Control Guide.*

Pre-Assembled Joint: The combination of the metal framework and a flexible element, factory assembled into a single assembly.

Pre-Compression: Compressing the flexible element (shortening the installed F/F).

Pre-Set: Dimension that flexible elements are deflected to ensure that desired movements will take place. See Lateral Offset and Manufactured F/F.

Primary Seal: The component designed as the main means of preventing leakage through the expansion joint (*See also Secondary Seal*).

Protective Shipping Cover: Material used to protect the flexible element during shipment and installation.

Protective Strip or Rub Tape: Fabric material or tadpole tape sometimes used between flexible element and metal member of expansion joint assembly to protect flexible element from heat transfer or abrasion.

Pulsation: *See Flutter.*

Resultant Movement: The net effect of concurrent movements.

Scissors Control Guide: A special metal construction using a "scissors" principle that is used to distribute large movements uniformly between two or more flexible elements in line and combined.

Secondary Seal: The component designed as a back up to the primary seal for preventing leakage through the flexible element (*See also Primary Seal*).

Service Life: Estimated time the expansion joint will operate without the need of replacement.

Set Back (Stand Off Height): The distance the expansion joint is set back from gas stream to allow for lateral movements and to prevent the joint from protruding into the gas stream or rubbing on the baffle when operating under negative pressure.

Shipping Straps or Bars: Braces that are located between the two expansion joint flanges to prevent over-compression or distortion during shipment and joint assembly.

Simultaneous Movements: *See Concurrent Movements.*

Single-Layer Expansion Joint: Expansion joint formed of one consolidated layer, often constructed from elastomers and reinforcement materials or fluoroplastics and reinforcement materials.

Site Assembly: A joint which is assembled at the job site.

Sleeve Type Expansion Joint: *See Belt Type Expansion Joint.*

Splices: Procedure for making endless flexible elements from open ended material. Splicing may be accomplished by one or more of the following; cementing, heat sealing, stitching, vulcanizing or mechanical fasteners.

Splicing Kit: A collection of all materials and appropriate specialist tools required to join or splice a flexible element during site assembly.

Splicing Material: Material used for affecting a splice in a flexible element.

Spring Rate: The force (lb/in) required to move the flexible element in compression, extension and laterally.

Stand Off Height: *See Set Back.*

Support Layer: Keeps the insulation in place and provides protection during handling and operation.

Telescopic Flow Liner: *See Double-Acting Flow Liner.*

Tensile Strength: Ability of a material to resist or accommodate loads until the breakage point.

Thermal Barrier: A layer of insulating material designed to reduce the surface temperature at the gas sealing layer to a level compatible with its heat resistance capability.

Thermal Movements: Movements created within the duct system by thermal expansion. Can be axial, lateral or torsional.

Torsional Movement: The twisting of one end of an expansion joint with respect to the other end along its longitudinal axis. Such movement being measured in degrees same as angular movement.

Transit Bars: *See Shipping Straps.*

Vulcanized Splice: A splice of elastomeric materials that are bonded with heat and pressure.

Wear Resistance: The ability of a material to withstand abrasive particles without decomposition.

Welding Blanket: A fire resistant blanket that is placed over the expansion joint to protect it from weld splatter during field welding operations.

Weld In Baffle: A flow liner that is designed to be welded to the duct wall or expansion joint frame. This design can be either single or double acting type.

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