

Cold Wall, Hot Wall and Unlined Expansion Joints

EagleBurgmann[®]
expansion joint solutions

Expansion Joints for Fluid Catalytic Cracking Units (FCCU)



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expansion joint solutions

Value Engineering raised on global experience

Over 50 years of challenges in the expansion joint industry proves that EagleBurgmann Expansion Joint Solutions is one of the worlds most experienced and innovative expansion joint manufacturers.

Experience is sourced from all continents and various market sectors to provide our customers with the latest technologies and solutions.

Metal and fabric expansion joints are flexible connections, installed in piping and ducting systems to accommodate expansion and vibration caused by changes in temperature, pressure and media comprise.

EagleBurgmann Expansion Joint Solutions major focuses:

- Value engineering to decrease operational downtime
- Lean manufacturing to reduce costs
- 3D smart design to maximize overall service life

EagleBurgmann Expansion Joint Solutions comprehensive service:

- Evaluations and troubleshooting
- Initial dimensional measurements
- Installation and refurbishment
- Supervision and training
- Plant surveys
- Emergency services
- Final inspection by experienced Service Engineers

EagleBurgmann Expansion Joint Solutions is approved to:

- European Pressure Equipment Directive (PED) 97/23/EC
- ISO 3834-2
- ISO 9001
- ISO 14001
- OHSAS 18001
- ASME U Stamp
- ASME R Stamp
- Other approvals is available upon customer request

EagleBurgmann Expansion Joint Solutions is a respected member of:

- The European Sealing Association (ESA)
- Fluid Sealing Association (FSA)
- Expansion Joint Manufacturers Association (EJMA)
- Euro-Qualiflex

EagleBurgmann Expansion Joint Solutions is proud of the appreciation given from hundreds of customers around the world.

EagleBurgmann Expansion Joint Solutions has global production in:

- Europe
- Americas
- Asia Pacific

We have a worldwide sales network supported by EagleBurgmann and Freudenberg offices.

www.eagleburgmann-ej.com



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**Critical Application
High Temperature
High Pressure**

Introduction to Expansion Joints for FCC

Fluid catalytic cracking units (FCCU)

operate at very high pressures and temperatures (+1400 °F), consequently resulting in large thermal movements that must be absorbed by the expansion joint. Furthermore, the introduction of abrasive media (catalyst) requires additional protection to avoid gradual deterioration and premature failure of the expansion joint. The bellows membrane is the most critical element of the expansion joint assembly. Its relatively thin wall construction is designed for maximum flexibility, but must be protected

against erosive catalyst and other corrosive media. Failure of FCCU expansion joints during operation can be extremely hazardous to personnel and very expensive to the refiner.

Types of Expansion Joints

There are various types of expansion joints used in FCCU applications: Tied Universals, Hinge, Gimbal and Pressure Balanced.

All of these fall into one of three major categories: Cold Wall, Hot Wall, and Unlined FCCU joints that will be discussed in more detail. The bellows membrane design for all three categories is basically the same; although the bellows membrane can be single ply, multi-ply, redundant ply or reinforced.



46" inside diameter FCCU universal regenerated catalyst standpipe expansion.



42" inside diameter FCCU Cold Wall Gimbal Expansion Joint.



48" diameter single hinged Hot Wall Expansion Joints for Installation in the Reactor Overhead Line.



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The Bellows Membrane

Bellows Material
Forming Process
Annealed Bellows

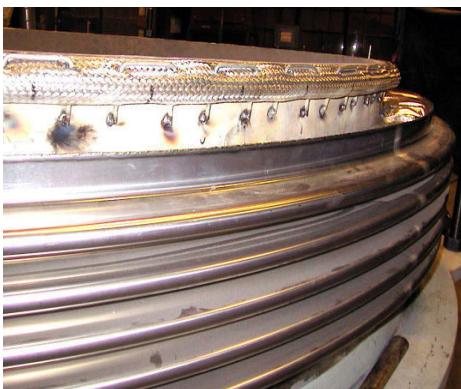
The Bellows Membrane

For many FCCU applications Inconel 625LCF (low cycle fatigue) is typically the material of choice. Almost identical to the original Inconel 625, this special bellows grade of Inconel 625 is used for its high strength, excellent fabricability (including joining), and outstanding corrosion resistance. Service temperatures range from cryogenic to (1800 °F) and this material provides tighter controls over the carbon, silicon and nitrogen contents. This produces a microstructure that enhances low-cycle fatigue.

Bellows are subject to high bending stress well into the plastic range to achieve the movements required by the thermal expansion of the system. The finished bellows should be uniform in shape and pitch with no forming scratches or heavy tooling marks.

The bellows forming process introduces work hardening into the bellows that for the majority of applications is acceptable. This work hardening increases the bellows's ability to withstand pressure however; it reduces the cycle life of the bellows.

(EJMA cycle life formula is based on as formed bellows). If the bellows is annealed after forming, the reduced pressure capability needs to be taken into account. FCCU bellows are often designed to work at elevated temperatures well into the creep fatigue range of the material. To reduce the creep fatigue effect, some specifications call for the bellows to be annealed, or solution annealed, after forming. As most FCCU bellows are designed to absorb large movements, beginning with a completely annealed bellows is usually advantageous.



Inconel 625LCF (low cycle fatigue) is typically the material of choice for bellows used in FCC service.



Bellows are subject to high bending stress well into the plastic range to achieve the movements required in FCC service.



The finished bellows should be uniform in shape and pitch with no forming scratches or heavy tooling marks.



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**Abrasion Resistant Lining
High Shell Temperature
Oversized Bellows**

Types of FCCU Expansion Joints - Hot Wall

Types of FCCU Expansion Joints

There are three major types of FCCU expansion joints: hot wall, cold wall, and unlined.

Hot Wall Expansion Joints

These joints usually have some form of abrasion resistant lining, comprised of hexmesh and castable material or refractory such as Resco AA-22, a

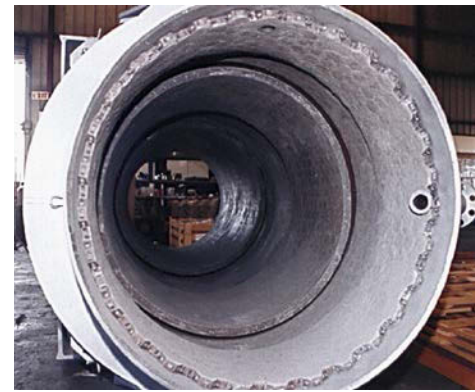
common abrasion resistant material. The lining is designed to withstand the abrasion from the catalyst flowing through the unit in service. The lining requires a thermal dry out after installation.

The lining is not intended to be used as a thermal barrier; therefore the shell temperatures of the expansion joint rise above the allowable tempera-

tures for normal carbon steels. The joint shells are normally manufactured from various Chrome Moly alloys and stainless steels. Due to their trademark conical sections near the bellows area, hot wall expansion joints are easily visible. The oversize bellows allows for a smooth flow across the bellows area using a straight through liner arrangement.



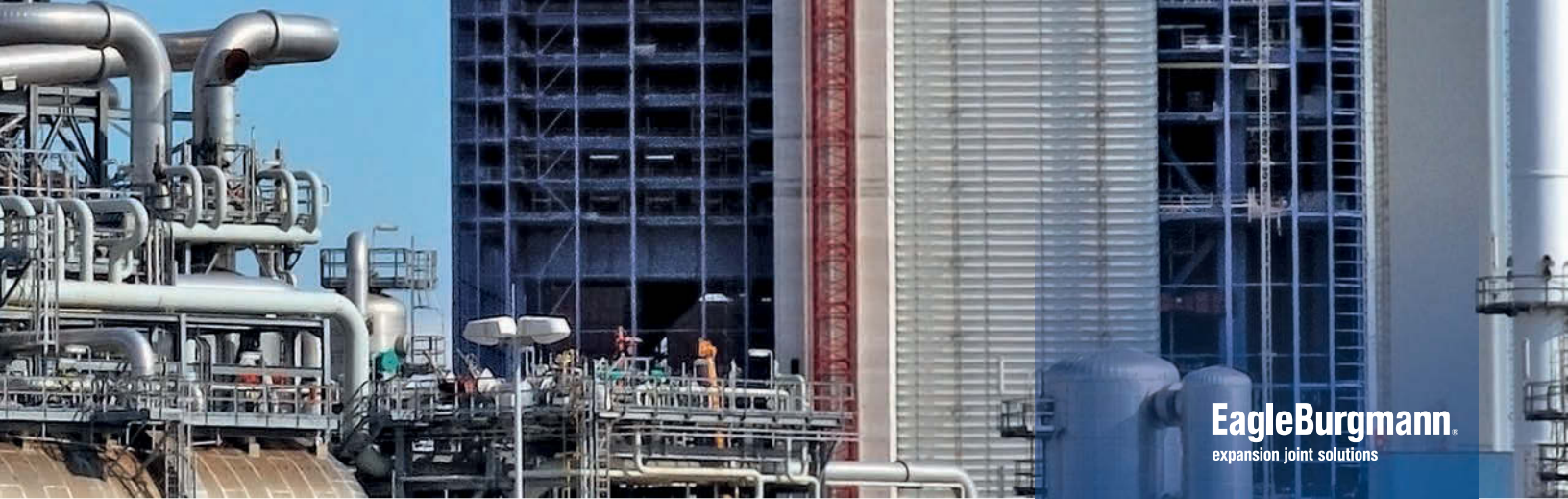
Hexmesh before castable material has been installed.



After castable material has been installed.



36" inside diameter universal hinged hot wall expansion joint for a reactor vapor line.



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Types of FCCU Expansion Joints - Cold Wall

Refractory Lined
Lower Shell Temperature

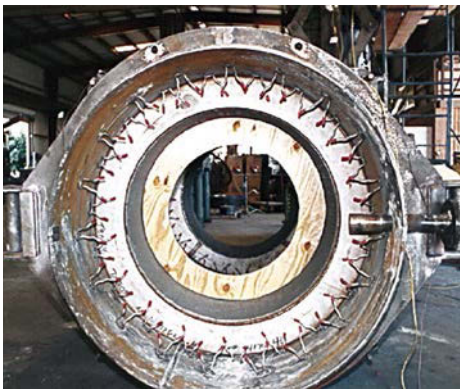
Cold Wall Expansion Joint

As their name suggests, cold wall joints are refractory lined to ensure the shell wall temperatures does not exceed 650 °F. The shell may be constructed from low alloy or carbon steel materials.

The lining consists of stainless steel anchors and a high-density vibrocast refractory material. Depending on service condition, the thickness ranges from 4" to 8". Again, the final process involves a thermal dry out before operational service.

The internal surface will be blasted to near white and casting forms fitted internally to hold the wet refractory in place until it cures.

After the expansion joint has been thermally dried the lining process is now complete. After the unit is installed the remaining refractory will be added onsite.



Stainless steel anchors prior to vibrocasting the refractory.



Expansion joint after being thermally dried.



14" ID Single Hinged Cold Wall Expansion Joint for service temperatures of 1450 °F and 635 psig of pressure.



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Increase efficiency
Reduce maintenance cost
Minimal gas and heat loss

Types of FCCU Expansion Joints - Unlined

Unlined FCCU Expansion Joints

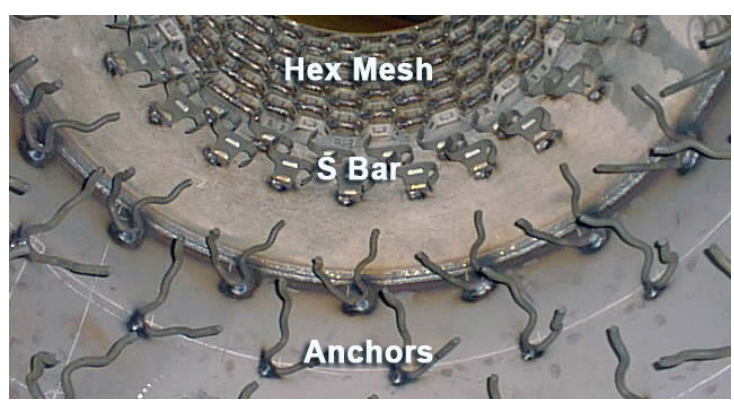
normally do not carry catalyst in the media, although the temperatures can be extremely high. Unlined joints are used for inlet air, outlet air, and transferring gases from the reactor, etc. These joints are still required to accept large movements and are designed with the same hardware as lined expansion joints.

Unlined joints are manufactured from various shell materials dependent upon the service temperature and media conditions. Lower temperature and less severe service applications utilize the higher-grade carbon steels. In more severe conditions, stainless steel, and occasionally, high nickel alloys are used. The unit shown here is a 66" diameter unlined tied universal incorporating equalizing hinges for

the high lateral movement. The shell material is A51 6-70 fabricated to ASTM specification 672.



Unlined tied universal expansion joint incorporating equalizing hinges for the high lateral movement.



Hexmesh, S bar and anchors are used to secure the refractory inside lined expansion joints.



Design Considerations

Packed & Purged Bellows Typical Seal Arrangement

Packed and Purged Bellows

When the expansion joint is carrying catalyst, the fines and dust can collect under the bellows. The catalyst can solidify and destroy the bellows membrane or inhibit the joint movement capability. The problem exists irrespective of installation position, however the more the joint moves towards a vertical flow up position, the easier it is for the catalyst to fill the void between the bellows and liner (bellows annulus). There have been various methods used to stop catalyst ingress into the annulus. The two predominant methods used today are:

- Packed bellows
- Purged bellows

By far the most common is the packed bellows. A packed design incorporates a ceramic insulation pillow filling the annulus and a catalyst seal between the liner faces.

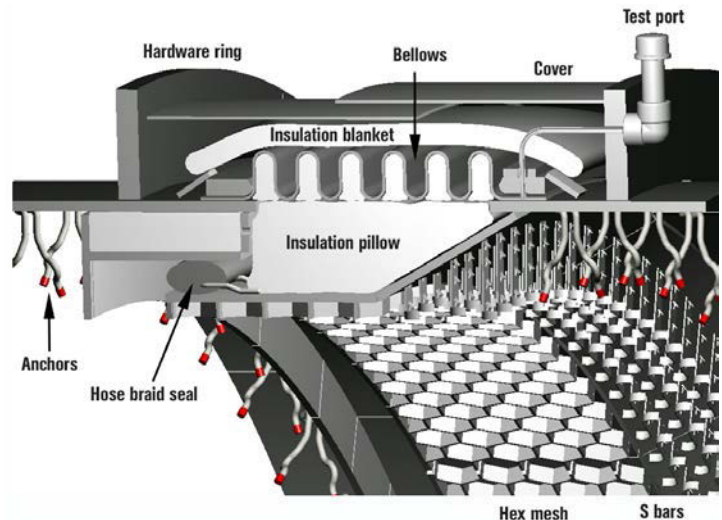
Packing the annulus of the bellows creates various design considerations to be examined carefully. This cross section shows that the liner is connected to the shell wall by a conical section. The thermal gradient between the hot liner and cooler shell would cause severe thermal stress if the liner were attached with a simple ring. For this same reason, the downstream liner is not welded directly to the shell.

The joint is internally packed with ceramic insulation to protect the shell from becoming hot where refractory cannot be installed due to the liner arrangement.

The surface of the liner has an abrasion resistant lining. The hexmesh is transformed into full refractory by suspending the hexmesh from bars that are attached to the shell wall. The seal itself is usually made in two parts, both stainless steel.

The outer cover is braided hose that is filled with wire mesh rope. The seal is attached to the liner with stainless clips that are secured into the seal itself. Because the liner gap changes during lateral and angular movement, the diameter of the seal has to be calculated in order to maintain a seal when the liner gap opens and closes in service.

When a packed design is used, the inner insulation pillow can reduce the bellows temperature below the media's dew point. If the media contains chlorides, acids or other elements that will attack the bellows membrane as they condense, it is important to maintain a minimum bellows temperature during operation. The outer pillow is used to ensure a minimum bellows temperature above the media's dew point. It is also important to maintain the gap between the shell and liner end ring allows the end ring to grow thermally. The growth is absorbed along the liner seal tube. The opposite end of the liner seal tube is connected to the shell with a smaller ring that is protected from the full media temperature.



This is a typical liner seal arrangement. Usually the type and placement of the seal is indicated on the individual specification for the expansion joint.

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From major gas pipelines spanning the high desert to specially designed pressure balanced assemblies for a water cooling system, EagleBurgmann Expansion Joint Solutions are installed in thousands of applications, plants and refineries worldwide. Whether it's air, gas, petrochemicals or water, our expansion joints are designed to provide maximum reliability and safety anywhere they are installed. Our technical expertise and progressive manufacturing capabilities enable us to offer our customers solutions that increase overall service life, reduce costs and decrease operational downtime.

**EagleBurgmann Expansion Joint Solutions -
Innovative Solutions for Long-term Reliability, Safety and Operational Success.**







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**Purged Bellows
Air or Steam
Equally Around Annulus**

Design Considerations

Purged Bellows

Purged bellows are not as commonly used today, but they are still installed successfully on some FCCU units when required.

The purge is applied to the bellows annulus in the form of air or steam. The continuous flow under the bellows introduces a high-pressure area and

a flow going back into the gas stream. The purges stop the catalyst from entering the bellows annulus.

Caution should be taken so that the media used to purge the bellows is compatible with the process conditions and does not cause corrosion problems within the bellows element.

Typically numerous nozzles are used to introduce the purge equally around the annulus. The nozzles are connected to a circular pipe manifold that surrounds the bellows on the outside of the joint.

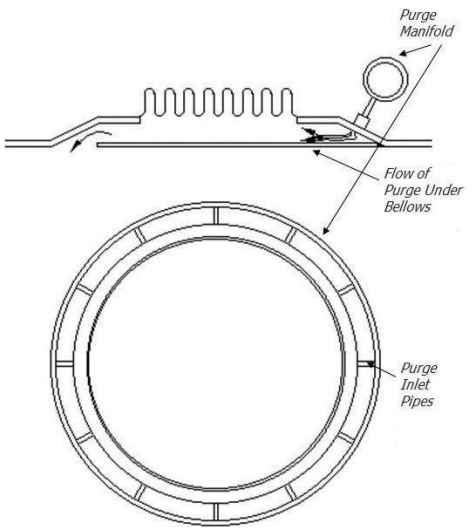
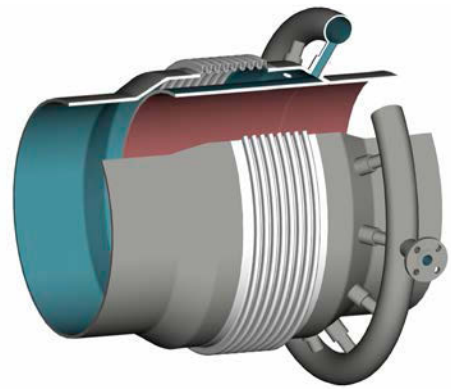


Illustration showing a purged bellows.



3D cross section model of a purged bellows.



Typically numerous nozzles are used to introduce the purge equally around the annulus.



Self Equalized and Non-Equalized Bellows

**Absorb High Deflections
Distribute Movement**

Self Equalized and Non-Equalized Bellows

As previously mentioned, bellows for FCC units are subject to large movement deflections in the axial and lateral planes. Due to these large movements, the individual convolutions absorb high deflections. To prevent the convolutions from contacting each other, self-equalizing rings are commonly used. The individual convolution deflection is determined by the resultant total deflection for the sum of the movements divided by the number of convolutions in the bellows. If a 10 convolution bellows is compressed 2" the individual convolution movement is 0.2" Theoretically each convolution will share equally in the total movement.

This is true in reality if several important conditions are achieved.

- The convolutions are uniform
- The induced work hardening is uniform
- The material grain structure is uniform

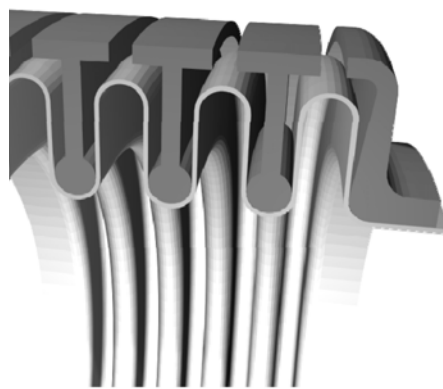
When one of the above is not achieved the result is non-uniform movement in the individual convolutions. If one or two of the convolutions in the bellows are geometrically different to the rest of the convolutions, this will result in a non-uniform movement distribution over the convolutions making up the bellows. The non-uniform convolutions will absorb more movement than others. This may result in the convolutions touching (bottoming out) and rubbing in service consequently leading to premature failure. Increasing the movement for this bellows to 4" will distribute 0.4" of movement to each individual convolution. This allows for a much smaller error.

Utilizing self-equalizing rings ensures that non-uniformity does occur even if the convolutions move slightly differently. Self-equalizing rings have no effect on extension movements. The drawback of using self-equalizing rings is that the root ring in each convolution that supports the equalizing ring reduces the amount of movement each convolution can absorb as the bending stress caused by the deflection is increased.

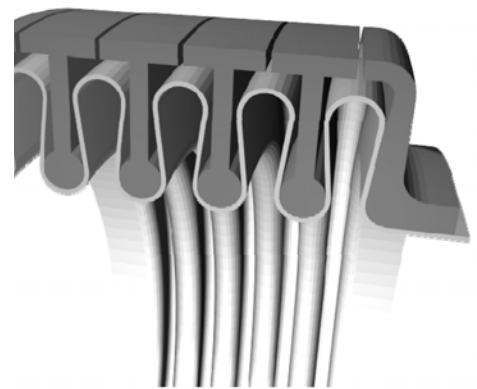
Equalizing rings will increase the cost of the bellows portion of the expansion joint. Most FCCU applications do not need self-equalizing rings and should only be considered in cases when the movement conditions cause severe compression. Seek the advice of a professional before specifying equalizing rings.



Expansion joint with self-equalizing rings.



Simple equalizing (root) rings.



Ring gap closes before convolutions touch.



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Multi-Ply Bellows
Normal Two-Ply Monitoring
Redundant Ply

Bellows Monitoring

Bellows Monitoring

The use of multi-ply bellows on FCCU expansion joints is widespread today. Various reasons exist for the use of multi-ply bellows, ranging from redundant ply design to simple monitoring for early warning of failure.

Multi-ply Bellows

Multi-ply bellows in themselves allow the bellows designer to design for higher movements combined with high pressure and still achieve good cycle life. In laymen's terms the thicker the bellows wall thickness the lower the cycle life for a given movement. By using two plies of a thinner

material the cycle life will increase for the same movement without a dramatic drop in pressure capability. A simple two ply bellows is designed to use the strength of both plies to ensure pressure capability. Redundant ply bellows are designed so that each ply is strong enough to withstand the operating conditions even after one ply fails. These types of multi-ply designs are usually monitored to alert the user when one ply fails.

Normal Two-ply monitoring

Monitoring a normal two-ply design still offers great advantages for the operator. A very small leak through the inner ply will normally not cause

a catastrophic failure. The indicator will show the leak and the unit can be shut down for repairs without a total failure of the unit.

Redundant Ply

Redundant ply designs offer safety and outage scheduling benefits. The intent is to enable the unit to continue to operate until the next scheduled outage even after one ply has failed. The inner ply typically fails before the outer ply. The operators can see the failure and plan for changing the unit at the next scheduled turnaround.



Redundant ply design enables the expansion joint to continue operation until the next scheduled turnaround.



Two-ply testable bellows.



Redundant ply bellows are designed so that each ply is strong enough to withstand the operating conditions even after one ply fails.



Monitor Types

Passive Monitors
Active Monitors

Monitor Types

Various monitoring devices can be used from connecting a simple pressure gauge to electronic sensing devices.

Our monitors can provide a visual indicator that will reveal a ply failure that connects directly to the port and is installed before shipment.

Passive monitors

Passive monitors utilize the line pressure to indicate an inner ply failure. When the inner ply fails the line pressure between the plies will activate the monitoring device. Passive monitors will only sense an inner ply failure.

Active monitors

The active monitor will detect both inner and outer ply failures. A vacuum is pulled between the plies before the monitoring device is installed. If the inner ply fails, the pressure between the plies will increase to the line pressure. If the outer ply fails the vacuum will be lost.



This is a typical monitoring port as it protrudes through the cover and plate.



Active monitors use a pressure gauge that can detect both inner and outer ply failure.



Two-ply dry nitrogen pressure thrust test ports installed between plies.



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Pressure Retaining Covers
Control Rods
Sampling Pipes

Exterior Hardware

Exterior Hardware

Many different types of hardware are used to perform various functions on FCCU joints. This brochure covers the most widely used hardware.

Pressure retaining covers

Pressure retaining covers are typically telescopic and have rings at each end. The covers are designed to retain the pressure in case of bellows failure. The cover can be welded at the end rings

and in the middle to seal the bellows. Since the bellows will no longer absorb any thermal movement, care should be taken if this is performed.

Control Rods

Control rods, as their name suggests, are used to control and limit the movement of the bellows.

By definition, control rods are not designed to withstand pressure thrust.

Sampling pipes

Pipes which penetrate the shell wall are used for various reasons and are specified by the end user.

The pipes can often interfere with other hardware on the joint. When specifying these pipes, it is important to be flexible with their position if possible.



Pressure retaining cover.



Sampling pipes.



Control rods and telescopic covers can be seen on this FCCU expansion joints.



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Exterior Hardware

Pantographic Linkages
Single Plane Pantograph
Gimbal Pantograph
Slotted Hinges

Pantographic Linkages

Pantographic linkages are devices that equalize the amount of axial compression each bellows absorbs. They ensure that each bellows takes exactly half of the axial movement imposed on the unit.

Single plane pantographs

Joints that absorb lateral deflection in only one plane can utilize simple pantographic linkages.

Gimbal Pantographs

Joints that need to absorb lateral deflection in two planes should be fitted with a gimbal type pantograph. The center gimbal ring allows the joint to offset in the opposite plane to the pantograph without the linkage binding.

This picture below shows the pantograph center pins connected through the gimbal. The end pins on the gimbal are hinged to allow lateral movement in the opposite plane.

Slotted Hinges

The main purpose of slotted hinges on an expansion joint is to fix the center of rotation for the bellows while at the same time ensuring each bellows shares the angulation caused by lateral deflection equally.

Slotted hinges are also used to take the dead load of the center spool off the bellows. This is only effective when an expansion joint is close to a horizontal position.



Gimbal pantograph expansion joint.



Slotted hinge expansion joint.



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Improve reliability
Increase service life
Worldwide service teams

Installation, Service and Preventive Maintenance

Servicing our customers is vital

Operational reliability and long service life of expansion joints is crucial. Unplanned shut downs are not only troublesome, but expensive. The right installation can save hundreds of manhours with a proper and safe installation.

EagleBurgmann Expansion Joint Solutions offers field service 7 days a week, within 24 to 48 hours.

The key to long-term and reliable expansion joints is dependent on a professional installation team. EagleBurgmann Expansion Joint Solutions' service team has extensive installation experience and supervision on projects worldwide.

Safety is the highest priority

Not only for our production and field service personnel, but for our customers and users of our products. The safety of all employees and personnel working on your plant or refinery is our greatest concern.

Our service teams complete routine safety training and certification to ensure each member observes current industry safety practices as well as site specific policies and procedures.

Our Comprehensive Service includes:

- Evaluations and troubleshooting
- Initial dimensional measurements
- Installation & refurbishment
- Supervision and training
- Plant surveys
- Emergency services
- Final inspection and experienced service engineers.

Emergency contacts:

Fabric & Metal Expansion Joints:

Tel. +45 2124 6632

Fabric Expansion Joints (USA):

Tel. +1 (859) 746 0091

Metal Expansion Joints (USA):

Tel. +1 (619) 562 6083



KE Fabric Expansion Joint installed over the manifold.



KE Fabric Expansion Joints are installed in gas turbines.



Installation of KE Fabric Expansion Joint.



Complete Line of Expansion Joint Solutions

Fabric
Rubber
Metal

Fabric Expansion Joints

are installed as flexible connections in air and flue gas pipe and duct systems to take up or compensate for thermal expansion, vibrations and misalignments. Our Fabric Expansion Joints take up movements in several directions simultaneously, have almost no reactive forces, need little space for installation, are easy to adapt to existing physical conditions, and they are easy to transport and install.

Metal Expansion Joints

EagleBurgmann Expansion Joint Solutions offers a full range of metal expansion joints from round and rectangular ducting expansion joints to highly engineered expansion joints to serve customers in the power generation, oil and petrochemical, pulp and paper, industrial and heavy equipment suppliers and a variety of OEM markets.



Fabric Expansion Joints



Highly engineered Metal Expansion Joints



Metal Expansion Joints

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EagleBurgmann Expansion Joint Solutions is a leading global organization in the development of expansion joint technology; working to meet the challenges of today's ever-changing environmental, quality and productivity demands. Our flexible products are installed in thousands of plants, refineries and on equipment worldwide where reliability and safety are key factors for operating success. As part of the international organization EagleBurgmann Group, more than 5000 employees contribute their ideas, solutions and commitment to ensure our customers worldwide can rely on our products and services. **For more information – visit eagleburgmann-ej.com and eagleburgmann.com.**

EagleBurgmann KE, Inc.
10038 Marathon Parkway
Lakeside CA 92040 - USA
Tel: +1 (619) 562 6083
Fax: +1 (619) 562 0636
EJsales@us.eagleburgmann.com
www.eagleburgmann-ej.com

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