MEGA FLEXON

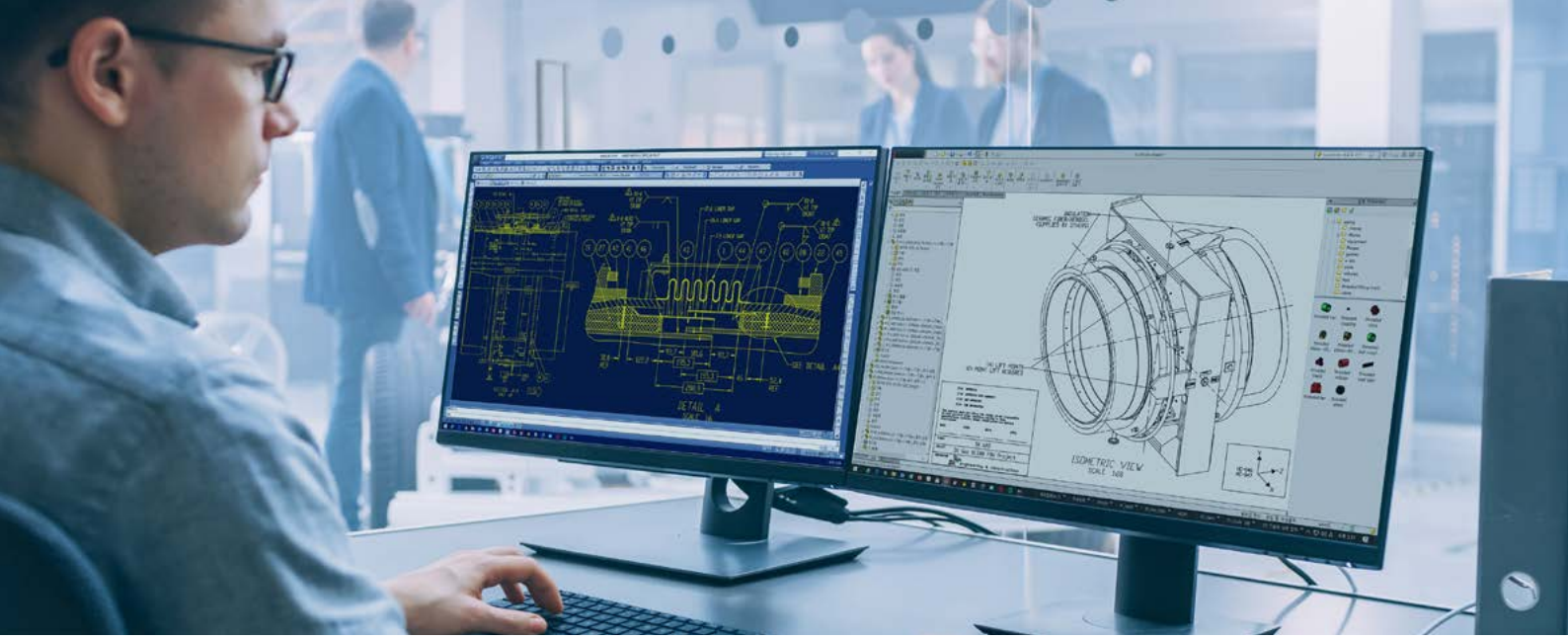
EXPANSION JOINT & FLEXIBLE PRODUCTS

ISO 9001
ISO 14001
ISO 45001

High-Temperature

EXPANSION JOINTS

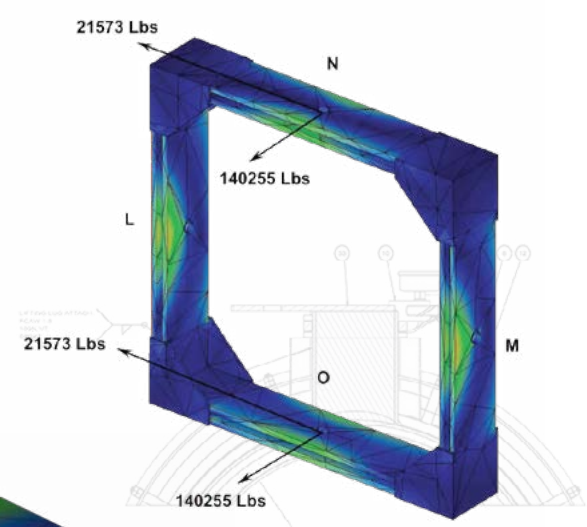
For Propane De-Hydrogenation (PDH)

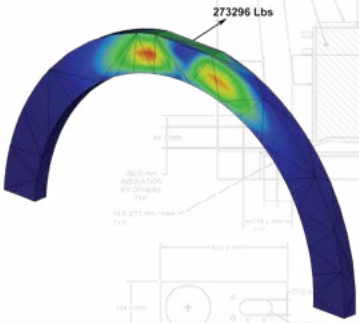


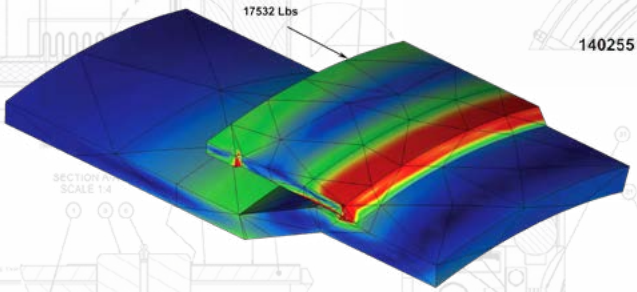
Engineering Approach

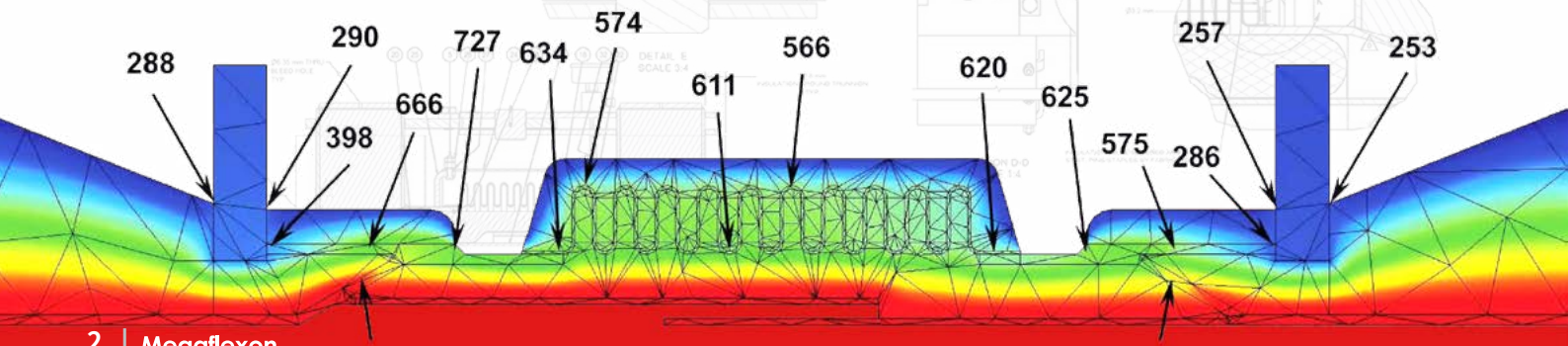
The designs of metallic expansion joint, rubber expansion joint and non-metallic expansion joint are based on and complies with the following:

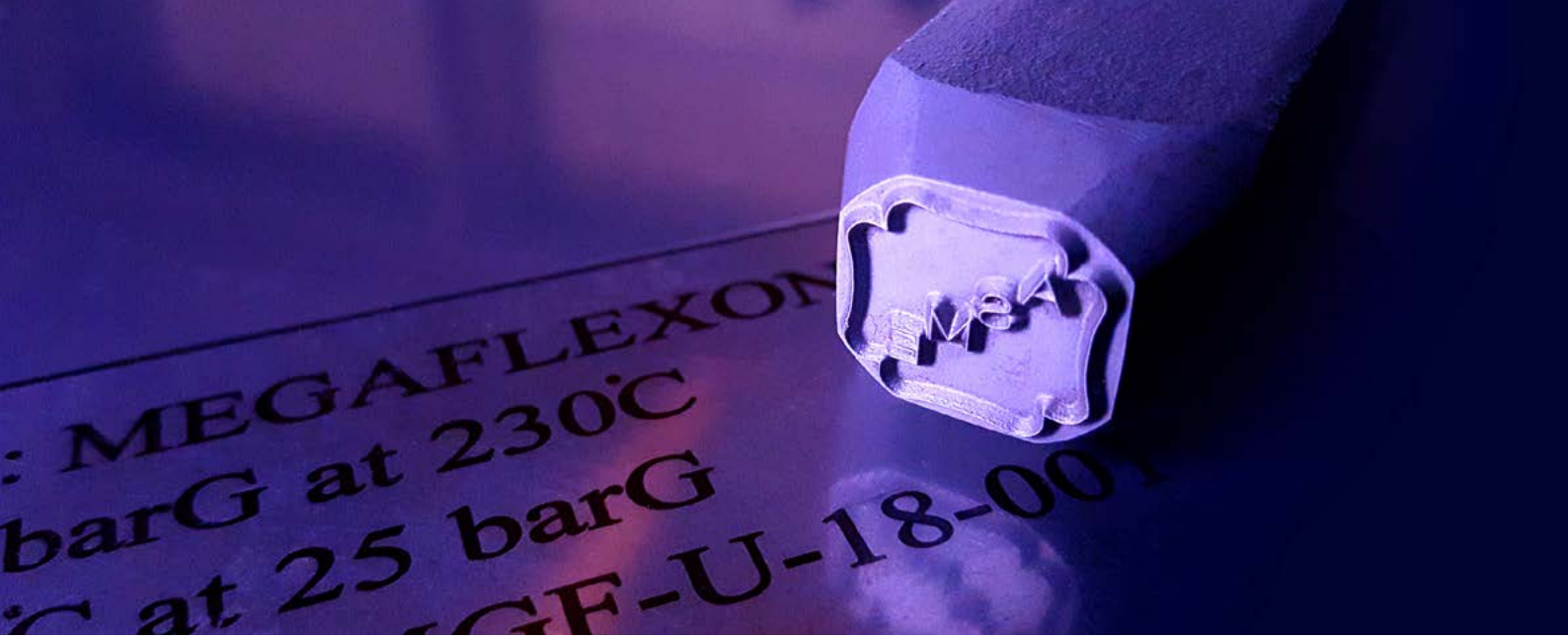
- **EJMA latest edition**
- **ASME Section VIII**
- **ASME Section IX**
- **ASME B31.1 (Power Piping)**
- **ASME B31.3 (Process Piping)**
- **TEMA latest edition**
- **FEA Finite Element Analysis**











Certifications

Megaflexon declares that Quality and Service are our most TOP priority. We always put quality and service on our most top priority and will make sure to deliver zero-defect products and service on time to our customers.
In order to ensure our quality commitment, our degreed quality specialists do strictly carry out all required activities for quality assurance.

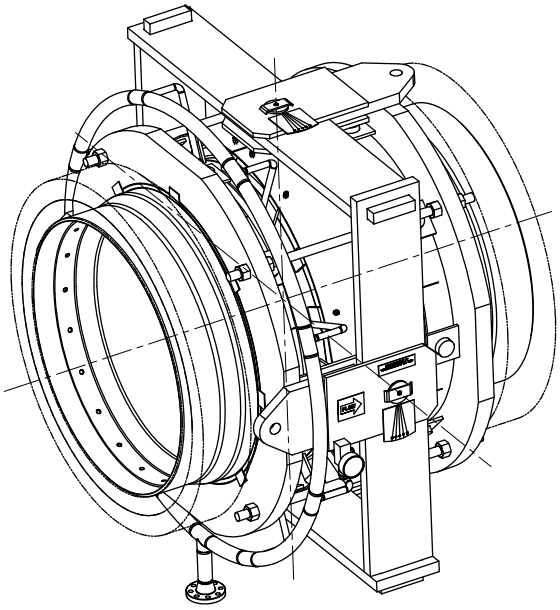
- The National Board
- ASME "U" Stamp
- ASME "S" Stamp
- ASME "PP" Stamp
- CE PED
- ISO 9001
- ISO 14001
- ISO 45001

▲ *Propane De-Hydrogenation(PDH) Plant View*

An overview of THE CATOFIN® PROCESS and an Engineering details on optimized expansion joint design.

The CATOFIN® technology is a unique licensed process for the production of olefins, such as propylene (from propane) and iso-butylene (from iso-butane). Propylene is produced in a catalyst process by means of dehydrogenation and the process is an alternative to the traditional production method, which involves cracking crude oil in refineries. One of the advantages of it lies in the purity of the process with proportions of propylene in excess of 85%, which means it achieves the highest yield of all methods. CB&I Lummus is the license holder company for CATOFIN® process technology.

Engineering of expansion joint for CATOFIN® is in accordance with specifications HJ-270 and H-270 from CB&I Lummus. One of the most challenging things to engineer expansion joints for CATOFIN® process in accordance with HJ-270 and H-270 specification is that we must be thoroughly analyzed for thermal stresses resulting from high temperature use to avoid any of failure.



For this purpose, we focused on the following points for our engineering.

1. Material 321H is stipulated for the bellows material by specification provided by Lummus Technologies. Other than the bellows, also pipe, liner and hardware components are applied as the material 321H.
2. Full penetration welds and plug welds are applied on liner attachment welds to avoid insufficient liner thickness or poor liner attachment. The liner is of the telescopic type and is attached by both of full penetration welds and plug welds in this way.
3. Applying insulation for inside of the bellows to avoid the thermal stress of high temperature application.
4. Two ply testable bellows.
5. Purging provides additional assurance that the bellows will operate at a non-critical temperature.
6. Double expanded pipe with hot-forming which without circumferential welding seams.
7. Floating anchor which minimized heat introduction to the fixing components.

▲ *Hot Wall Expansion Joints for PDH Installation View / SK GAS ULSAN PDH PLANT, KOREA*

For this purpose,
we focused on the following points for our engineering.

1. Material 321H is stipulated for the bellows material by specification provided by Lummus Technologies. Other than the bellows, also pipe, liner and hardware components are applied as the material 321H.

Because 321H has lower strength values at high temperature application, Lummus set out detailed specifications for the bellows temperature and connection of components under the condition of hot service medium. By compliance this significantly detailed specification, it is able to apply 321H instead of extremely expensive material.

2. Full penetration welds and plug welds are applied on liner attachment welds

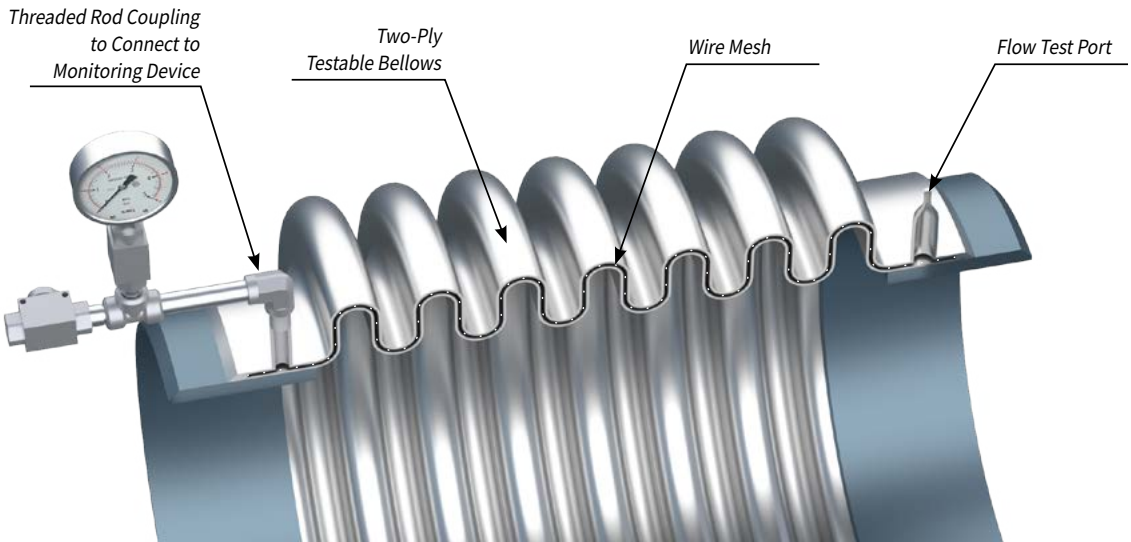
As specified in Lummus specification, closely developed liner design of fabrication with full penetration welds and plug welds is applied to avoid insufficient liner thickness and poor liner attachment. The liner attachment fabrication is more affirming to lead successful operation under severe condition of high temperature application.

3. Applying insulation for inside of the bellows to avoid the thermal stress of high temperature application

The Bellows elements are highly stressed parts of the expansion joint and is well recognized that it should be operate at a temperature below critical points. By adding insulation between bellows and internal sleeve, it can be protected from high temperature service fluids and to enable this, bellows is designed as raised type. Furthermore, added fixing pins works to prevent the insulation from being sag or jagged and is always evenly fixed.

4. Two ply testable bellows

In order to provide maximum assurance of risk free operation, it requires to be ply testable. Each bellows is made from 2 plies of material such that each ply is fully capable of operation under given design conditions. A pressure tab is included on the outer bellows ply in order to sense any pressure build up between the plies that could result from a leak through the inner ply.



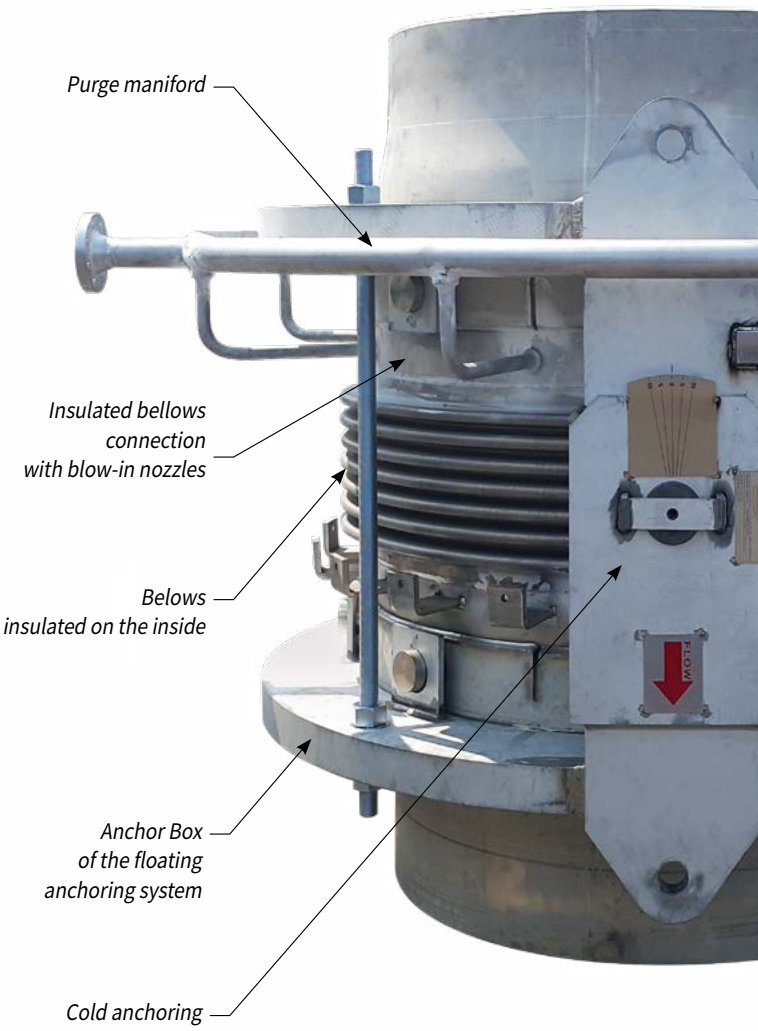
▲ *Hot Wall Type Expansion Joints for PDH Installation View / SK GAS ULSAN PDH PLANT, KOREA*

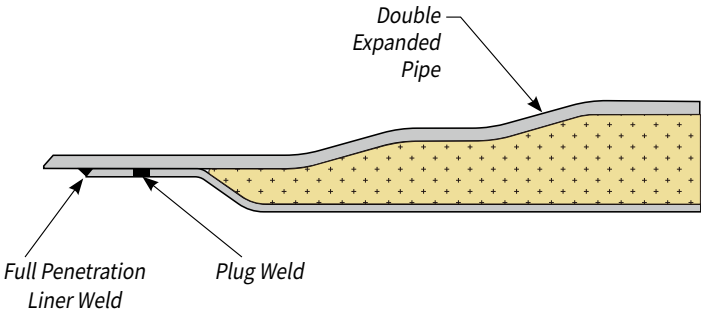
5. Purging provides assurance that the bellows will operate at a non-critical temperature

Propane is injected from outside into the bellows cavity and it can create the barrier flow for the service medium. This reliably keeps the bellows cavity away from the hot service medium and ensures that no carbonization, which could lead to clogging of the intermediate area, occurs in the line as well as accelerate the flow rate.

6. Double expanded pipe with hot-forming which without circumferential welding seams

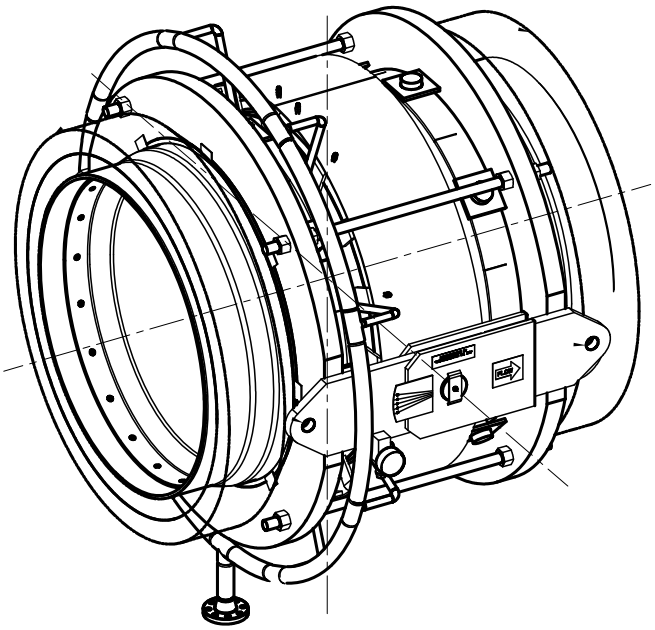
Process technology with hot-formed expanded pipe connections which enable less thermal stress on the pipes. The combination of low allowable stress limits and significantly different thermal growth between attached components results differential thermal stress at root of transition or welded seams.
To avoid this, it is adopted to use hot-form expand of pipe rather than weld seam. The knuckle radius at transition points is generous and the stress intensification factor is held to the minimum.





7. Floating hardware which minimized heat introduction to the fixing components

When designing expansion joints for high temperature application, areas with bellows are reinforced by applying sufficient insulation to lower the temperature because it is critical, but thermal stresses transferred directly to fixed parts welded to external pipe sockets were not fully considered before. When the service medium temperature is transferred to the fixing parts nearly unreduced, the load capacity will dramatically get lowered. Therefore, we adopted floating type of fixing parts which lead to minimized heat transfer. The main points of this floating type fixing parts are design the anchor box to reduce thermal stress peak by allowing only 4 designated contact points to connect to the pipe socket. The reaction force of fixing parts will be uniformly distributed over 4 contact points thus transfer much less thermal stress to the pipes.



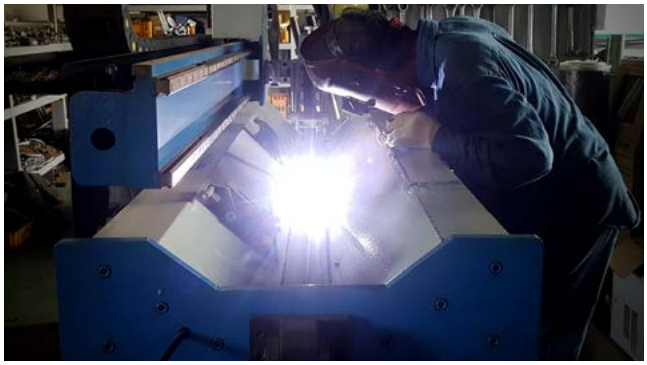
▲ *Hot Wall Type Hinged Expansion Joints*

▲ *Hot Wall Floating Type Gimbal Expansion Joints*

Bellows Manufacturing

Megaflexon manufactures bellows using an expanding mandrel (punch forming) method followed by a finish rolling. A rectangular sheet is sheared and rolled into a tube. The tube is welded using an auto flat-bed welder with no filler metal added.
The longitudinal seam weld is then planished back down to the base material thickness. Dye penetrant, X-ray, or air testing is performed at this stage.
After testing, the convolutions are punched individually drawing material from the top and bottom of the tube. The drawing process eliminates any possible thinning in the bellows material. Then, the re-rolling process and then trimming process will follow.
In addition to this, Megaflexon manufactures bellows using a variety of machines, including hydraulic forming machines and automatic hydraulic forming machines.

▲ *Hydraulic Forming Machine (Max. : 2,200mm)*



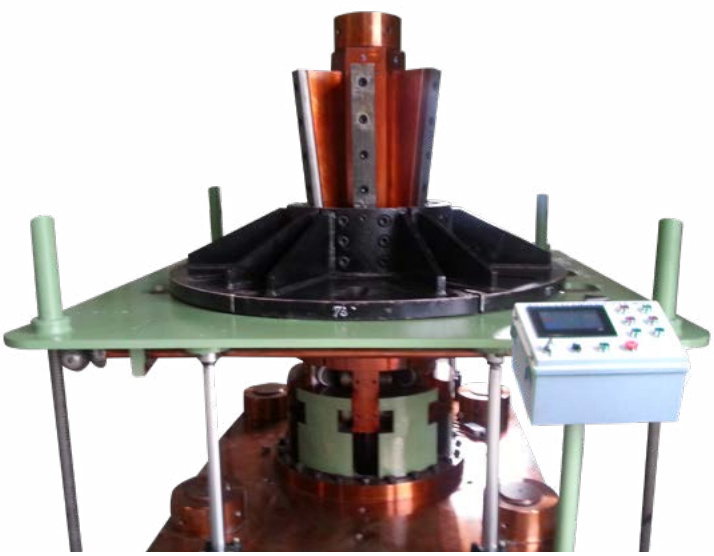
▲ *Automatic Longitudinal Seam Welding Machine*

▲ *Automatic Hydraulic Forming Machine (Max. 750mm)*

▲ *Hydraulic Mandrel Punch Forming Machine (Max. : 4,500mm)*

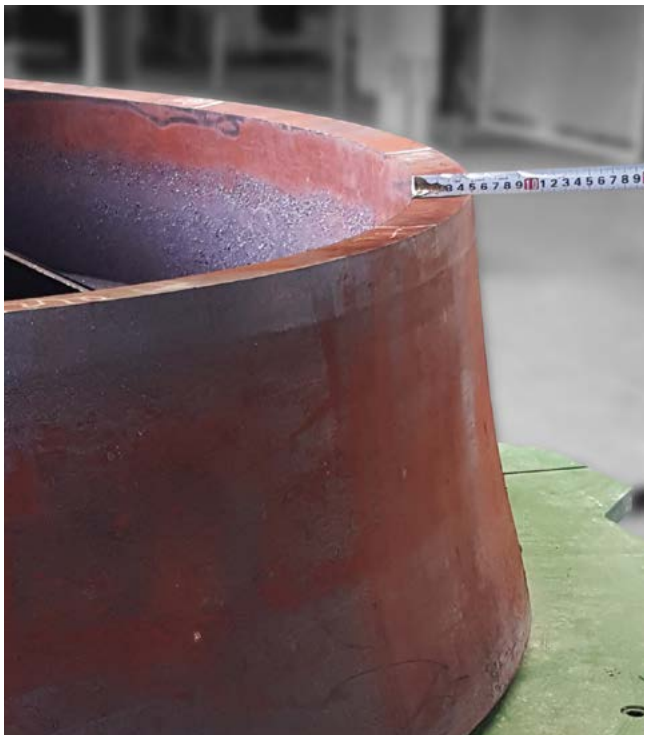
Pipe Expanding Machine

- ***1000 tons***
- ***MAX. 3500 mm / Thickness 50 t***



▲ *Expanding Machine*

▲ *Expanded Single Hinge Type Expansion Joints*



▲ *Thickness Measurement (52mm) / ASTM A516 Gr70*
50mm expanded from original diameter 1800mm

▲ *Expanded Pipe View / ASTM A240 TP 321H / 20T*
75mm expanded from original diameter 2400mm

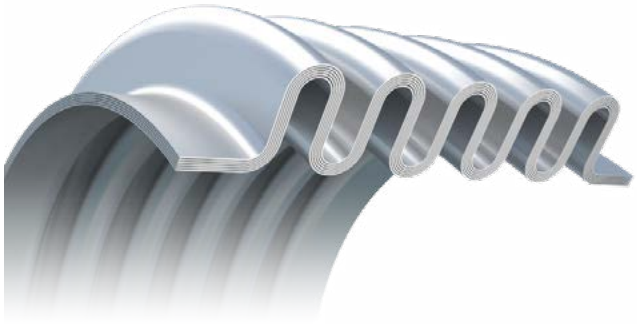
Various Type Of Bellows

Bellows may be either U-shaped or toroidal (Ω-shaped) in cross-section. The U-shaped bellows is superior for great deflection but has a lower pressure capacity for the same material thickness. Conversely, toroidal (Ω-shaped) bellows is limited to small deflection but has a higher pressure capacity. The use of external reinforcement of the U-shaped can provide a combination of great deflection and high internal pressure capacity, and the pressure capacity can also be increased by the use of multi-ply construction or by increasing the material thickness of the bellows. The U-shaped bellows is mostly manufactured and used in industries, and the Ω-shaped bellows has limited application in case of high pressure and small deflection requirements.
Megaflexon manufactures bellows using a variety of methods, such as hydroforming and hydraulic mandrel punch forming etc. Hydroform process is used for relatively small bellows forming, and hydraulic mandrel punch forming process is used for relatively large bellows forming (up to 4500mm). Although the forming method is different, both ways are providing efficient ways of uniform structure with adequate dimensional accuracy.

▲ *HIGH CORRUGATION BELLOWS*

▲ *MIDDLE CORRUGATION BELLOWS*

▲ *OMEGA BELLOWS*



▲ *MULTI-PLY BELLOWS*

▲ *TOROIDAL BELLOWS*

High Corrugation Bellows

Nominal Dia	300A - 4500A
Materials	• Stainless Steel-Type 300 Austenitic Series • Super Duplex Stainless Steel • Nickel Alloys • Hastelloy • Titanium • Zirconium • Hayness 230 & etc.

Features

- Excellent flexibility comes from the high convolution and long fatigue life.
- Bellows forming method : Hydraulic forming & hydraulic mandrel punch forming

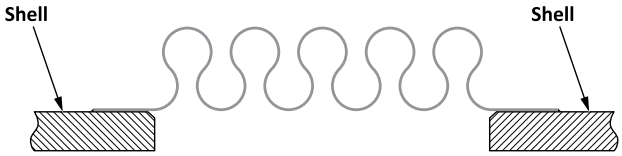
Middle Corrugation Bellows

Nominal Dia	1000A - 4500A
Materials	• Stainless Steel-Type 300 Austenitic Series • Super Duplex Stainless Steel • Nickel Alloys • Hastelloy • Titanium • Zirconium • Hayness 230 & etc.

Features

- Flexible & bellows in large size formed with 2ply of 0.3t ~ 1.2t plates.
- Bellows Forming Method : Hydraulic forming & Hydraulic Mandrel Punch Forming

Omega Bellows

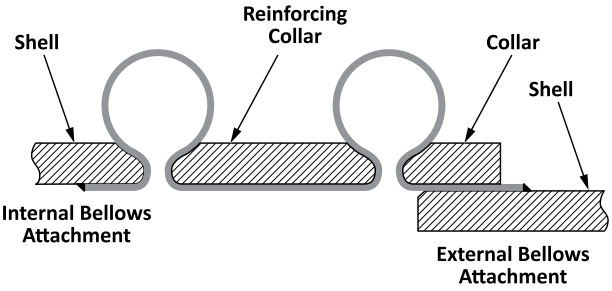


Nominal Dia	25A - 1800A
Materials	• Stainless Steel-Type 300 Austenitic Series • Super Duplex Stainless Steel • Nickel Alloys • Hastelloy • Titanium • Zirconium • Hayness 230 & etc.

Features

- The convolution configuration is Omega shape which is circles connected continuously and has superior fatigue life.
- Bellows Forming Method : Hydraulic forming

Toroidal Bellows

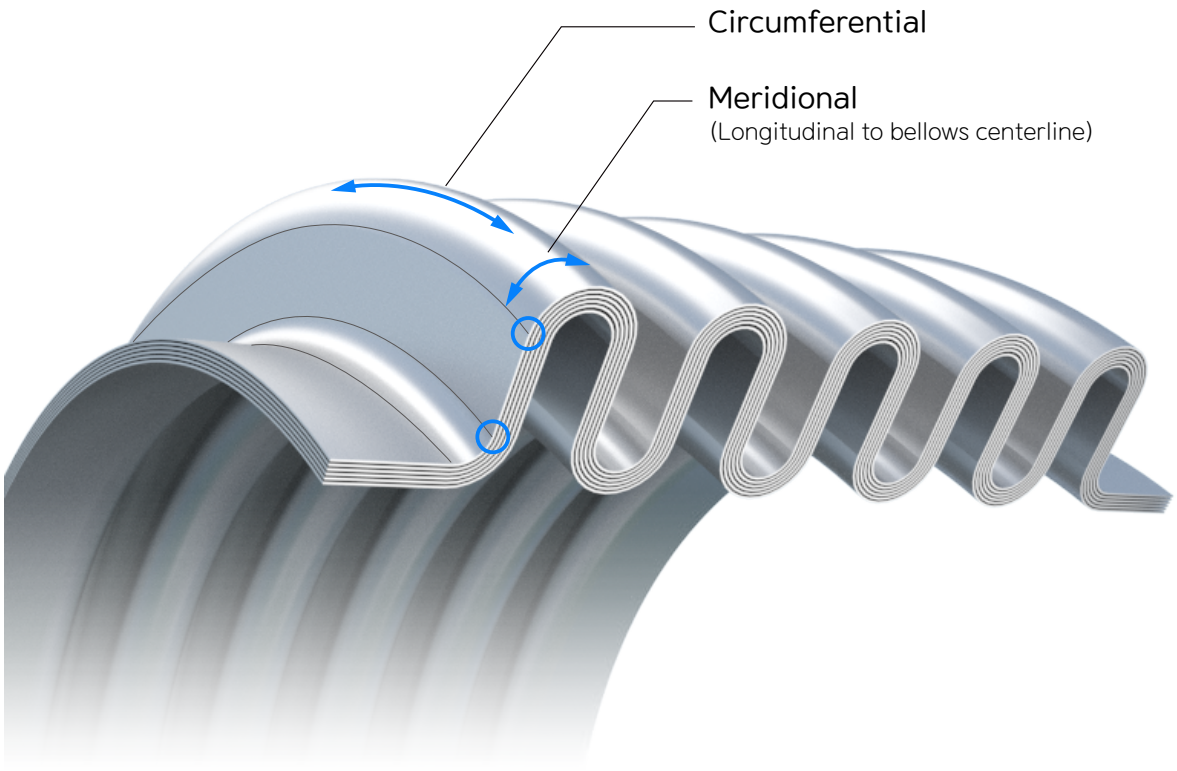


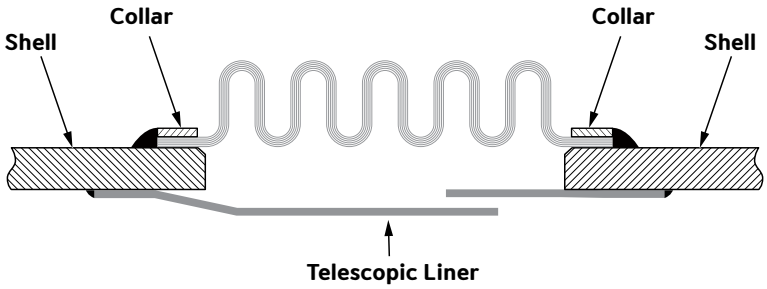
Features

The Toroidal Bellows are mainly designed for high-pressure application where needs small amounts of movement. The majority of these joints are designed for Heat Exchanger in accordance with ASME Sec VIII, Div-1, Appendix 26, and also as per EJMA for other applications. The natural stability of a circle under internal pressure allows the thin-walled toroid element to withstand pressures that an apparently more stable multi-ply, reinforced bellows could not. The advantage of this design is its easy to manufacture with a low material cost of bellows element and the stability of the expansion joint even at pressures well beyond the design conditions. The only drawback is the small amount of movement the joints can absorb, which when dealing with heat exchanger designs, is all that is required.

- Bellows Forming Method : Hydroforming

Multi-Ply Bellows





Nominal Dia	50A - 4500A
Materials	• Stainless Steel-Type 300 Austenitic Series • Super Duplex Stainless Steel • Nickel Alloys • Hastelloy • Titanium • Zirconium • Hayness 230 & etc.

Features

- Form up to 6 layers of thin stainless sheets layerd & laminated flexible ultrahigh pressure bellows.
- Bellows Forming Method : Hydraulic forming & Hydraulic Mandrel Punch Forming

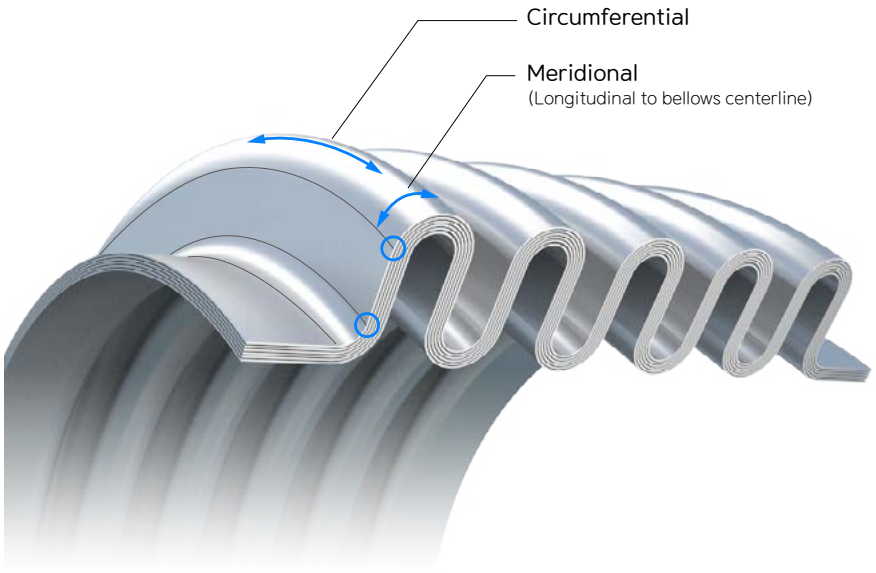
Bellows Monitoring

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.



▲ *Multi-Ply Bellows*

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 outage.

Two-ply Testable Bellows Monitoring Solution

The two-ply testable bellows (also referred to as a redundant ply design) can, in the majority of cases, provide early warning about bellows failure. Alt-hough a representative sample performs in a statistically predictable way, any single expansion joint's exact fatigue life is unpredictable. Installation of two-ply testable bellows can, in a majority of cases, provide early warning about bellows failure.

Many refineries use two-ply testable bellows especially in critical process equipment such as the FCC unit, but they are also used in the spent catalyst standpipe, regenerated catalyst stand-pipe, recirculation cooled catalyst flue gas piping and the turbo expander. Gas and steam turbine applications also find these bellows ideal in the exhaust, crossover and flue gas piping.

What is a two-ply testable bellows?

A two-ply testable bellows consists of two plies of identical thickness, with a small cavity between the plies.
The two-ply design is used when it is necessary to monitor the integrity of the bellows inner or outer ply. Both plies are designed for the full pressure and temperature cycles required. If one ply fails, the second will ensure pressure integrity and take over until a scheduled repair or replacement can be facilitated. This allows maintenance personnel to take action and plan solutions accordingly to minimize downtime.

Active and passive monitors

There are various methods to monitor a two-ply testable bellows, from simple pressure gauges to electronic sensing devices. Overall they are cat-egorized as active and passive monitors. Passive monitors utilize the line pressure to indicate an inner ply failure. When the inner ply fails, the inter-nal pressure between the plies activate the moni-toring device. Passive monitors will only sense an inner ply failure. Active monitors will detect both inner and outer ply failures. A vacuum is created between the plies before the monitoring device is installed. In case the inner ply fails, the pres-sure between the plies will increase to the line pressure. If the outer ply fails, the vacuum will be lost. In both cases the monitoring device will be activated.

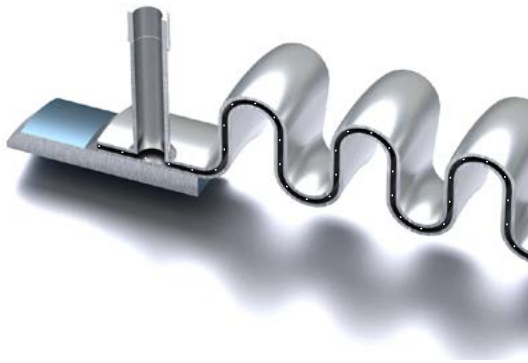
Monitoring devices used are most commonly pres-sure gauges, pressure transducers and pop up detectors. Direct monitoring to the control room is also an option and can be attached directly to the test ports.
In case the monitoring device indicates pressure between the plies, our recommendation is (1) dur-ing operation, use the bleeder valve to evacuate the pressure and close valve immediately. Then check for pressure build up. (2) If pressure builds up again, the inner ply may have cracks that allow the system pressure to fill the space between the two plies. A replacement bellows should then be considered.

Technical characteristics

Two cylindrical tubes are formed with thin wire mesh between, to generate a cavity between the plies in the two-ply testable bellows. The purpose of the mesh is to ensure that there is a flow path between the plies.
The test ports are placed at each end of the bel-lows, 180° apart; a test port tube is welded to the outer bellows ply. Typically, one test port will be blinded off with a pipe cap and the other con-nected to the desired monitoring device.
Note: When installing an expansion joint with two-ply testable bellows, test ports/ valves must be kept open the first 24 hours to release any moisture or condensate that may have collected between the plies during storage or manufacturing.

Benefits of Two-Ply Testable Bellows

- Bellows monitoring (deterioration & leakage)
- Early warning of leak detection
- Two (2) plies designed for the full system design conditions
- Minimizing the risk of unplanned shutdowns
- The system can maintain operation while a suitable repair or replacement can be arranged
- Reduced downtime in services where the bellows failure could cause a forced outage



To monitor the integrity of the bellows, pressure gauges and pressure transducers are most commonly used for measuring the pressure between the plies. A test tube connects the pressure gauge, valve and pipe cap as illustrated above.

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.

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.

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 to be taken if this is performed.

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.

Yellow shipping bars and setting bars After installation these bars must be removed.

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

The gimbal restraint is designed to absorb system pressure thrust and torsional twist while allowing angulation in any plane. Gimbal Assemblies, when used in pairs or with a Single Hinged unit, have the advantage of absorbing movements in multi-planer piping systems. The gimbal works the same as an automobile's universal drive shaft.

Slotted Hinges

The slotted hinges can also be seen in the photograph above. The main purpose of the hinges 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.

▲ *Pantograph Type*

▲ *Gimbal Floating Type*

▲ *Slotted Hinge Type*

Floating Type Dual Gimbal Expansion Joint

(HOT WALL CONDITION) FOR CPC RFCC, TAIWAN

CPC now operates two refineries in Taiwan - at Taoyuan in the north and Dalin in the south - with a combined daily refining capacity of 600,000 barrels.

Megaflexon has successfully designed, manufactured and tested a FCCU expansion joint universal double gimbal cold wall design for CPC RFCC in TAIWAN.

The expansion joint, designed for 3.4 kg/cm² and a temperature of 538 °C(PIPE), and 777°C (bellows).

- ***Year*** *: 2015*
- ***Owner*** *: CPC Corporation, TAIWAN*
- ***Total Q'ty*** *: 6sets*
- ***Size*** *: 98"(DN2450) x 13800mmL*
- ***Design Pressure*** *: 3.4 kg/cm²*
- ***Design Temp.*** *: Bellows (777°C) / Pipe (538 °C)*
  Hot Wall Floating Type

Floating Pantograph Type (Hot Wall Condition) Installation View

Expansion Joint for PDH Project

for SK GAS ULSAN PDH PLANT, KOREA

Megaflexon has successfully manufactured and supplied a total of 138 high-temperature Expansion Joints such as Pantograph type, Gimbal type, Hinge type, etc. to SK GAS Ulsan PDH plant, the one of the largest world's PDH plant.

- ***Year*** *: 2014*
- ***Owner*** *: SK GAS, KOREA*
- ***Total Q'ty*** *: 138sets*

- ***Single Slotted Hinge Type*** *78"(DN1950) x 1850mmL*
- ***Single Gimbal Type*** *96"(DN2400) x 1950mmL*
- ***Universal Pantograph Type*** *96"(DN2400) x 4400mmL*

& others

SK GAS ULSAN PDH PLANT facility is projected to produce 600,000 tons of propylene annually.

- ***Design Code & Standard***
  - *EJMA 10th Edition*
  - *ASME B31.3 2018 Edition Process Piping*

All bellows meet the requirement of min. 10,000 Cycles.
All the designs are satisfied with the concurrent movements according to the data sheet.
Our expansion joint are produced by hydraulic mandrel punch forming.

- **PROJECT** : SK GAS ULSAN PDH PROJECT
- **OWENER** : SK GAS
- **TYPE** : DUAL GIMBAL FLOATING TYPE
- **SIZE (ID x L mm)** : 96”(DN2400) x 6500mmL
- **DESIGN CONDITION** : 2.81 kg/cm^2, 649°C

- **PROJECT** : SK GAS ULSAN PDH PROJECT
- **OWENER** : SK GAS
- **TYPE** : SINGLE SLOTTED HINGE TYPE
- **SIZE (ID x L mm)** : 48”(DN1200) x 1700mmL
- **DESIGN CONDITION** : 649°C / 2.81 kg / cm^2g

- **PROJECT** : SK GAS ULSAN PDH PROJECT
- **OWENER** : SK GAS
- **TYPE** : SINGLE GIMBAL TYPE
- **SIZE (ID x L mm)** : 96”(DN2400) x 1950mmL
- **DESIGN CONDITION** : 2.81 kg/cm^2, 649°C

MEGA FLEXON

EXPANSION JOINT & FLEXIBLE PRODUCTS

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