

FCCU  
EXPANSION JOINTS  
FOR FLUID CATALYTIC  
CRACKING

**MACOGA**  
ENGINEERED EXPANSION JOINTS



Expansion Joints for  
Fluid Catalytic Cracking - FCCU

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## INTRODUCTION TO FCCU EXPANSION JOINTS

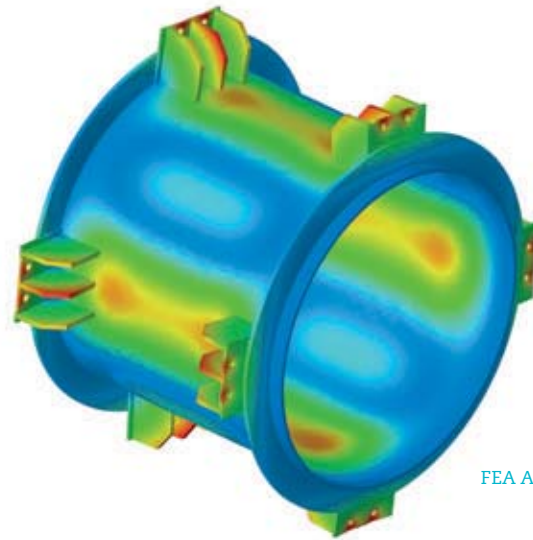
Expansion joints used in FCCU service are exposed to high temperatures, high pressures, large movement conditions and very aggressive media and therefore they are considered highly engineered units and one of the most critical and complex types of expansion joints manufactured.

The design of these expansion joints is complex because:

- They must be suitable to operate at high process temperatures
- They must be resistant to erosion by catalyst
- They must be resistant to corrosion and stress corrosion cracking during operation and shutdown conditions
- They shall ensure an adequate fatigue life
- They must absorb large movements
- They shall ensure a good pressure resistance capacity while having a good flexibility

MACOGA has advanced capabilities to design and analyse FCCU Expansion Joints and all its components and accessories operating at high temperatures. Our analysis tools, e.g. non-linear finite element stress and heat transfer analysis (FEA) make possible to analyse complex components.

With our 3D mechanical CAD software our engineers design FCCU Expansion Joints to the same conditions that they'll experience in the real world before they have been built. This is a design validation tool that helps our engineers to test the designs earlier in the design cycle and against real-world conditions. This lead us to improved design quality and manufacturing efficiency, while reducing time to market, costs and materials waste.



### FEA/CFD

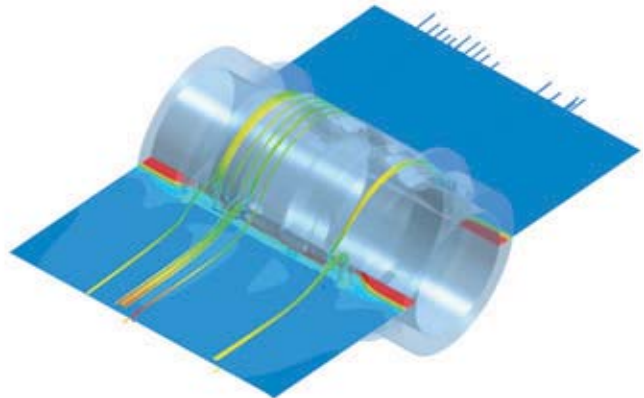
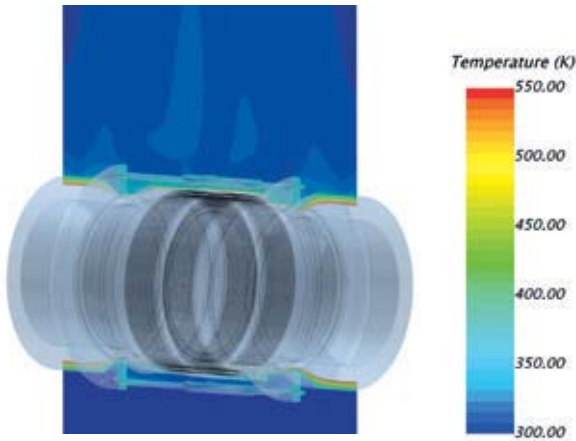
Our engineers are skilled in using Finite Element Analysis (FEA) and Computer Fluids Dynamics (CFD) to analyze the thermal-mechanical performance of different kind of systems.

Finite Element Analysis (FEA) based structural stress analysis is a valuable tool in the evaluation and optimization of product designs for systems including structural stress due to mechanical and thermal loading.

Using FEA/CFD as part of your product design process allows for the rapid and cost effective virtual testing and optimization of your designs. This will reduce overall product development costs, improving design performance and also give your team greater insights into how your design is likely to respond to a range of operating conditions.

Some samples of FEA/CFD studies:

- Design/Analysis to ASME, API, PD and UNE standards
- Stress analysis
- Thermo-mechanical analysis. Heat transfer
- Fatigue
- Vibration Analysis
- Dynamic analysis
- Shock analysis
- Resonance analysis
- Coupled fluid structure interaction
- HVAC analysis



FEA Thermo-mechanical / Heat transfer analysis.

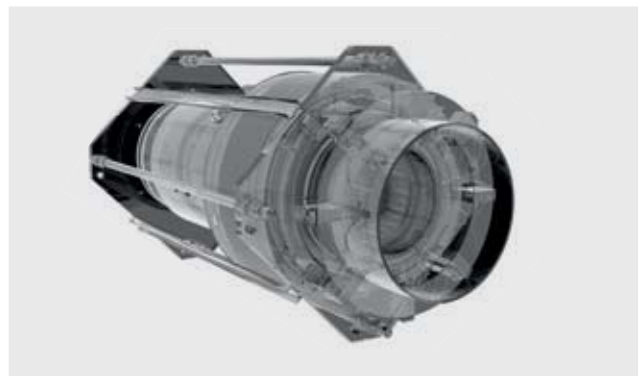
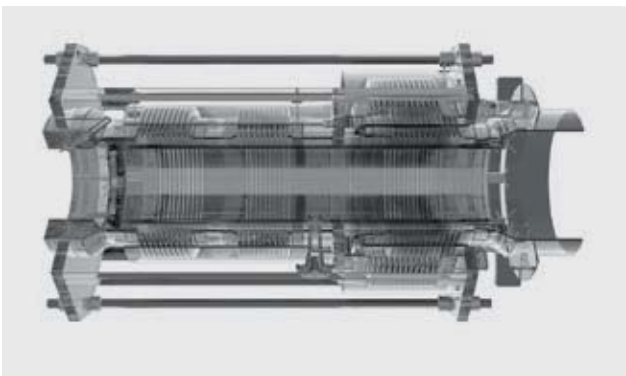
The results obtained in this kind of analysis may be used to assess design safety as well as predict the expected fatigue life of the design.

Fluid Catalytic Cracking (FCC) technology involves high tech Expansion Joints and each technology provider has exclusive designs for these components. MACOGA has worked with all of the major FCC Technology Providers and is familiar with their designs.

FCCU Expansion joints are designed in accordance with:

- ASME B 31.3 Appendix X
- Expansion Joint Manufacturers Association, Inc. (EJMA) Standards

and all applicable codes and specifications from licensors like **UOP, KBR, ExxonMobil, Axens**, etc.



Flexicracking Unit Reactor  
In Line Pressure Balanced Expansion Joint  
Two ply monitored bellows  
Design temperature: 566 °C (media)



## TYPES OF FCCU EXPANSION JOINTS

Typical types of expansion joints used in FCCU applications are: **Restrained Universal, Gimbal, Hinged and Pressure Balanced (in-line and elbow type)** and can be categorized in three major groups:

- Cold Wall
- Hot Wall
- Unlined

The **Cold Wall** units are refractory lined to ensure the shell wall temperature does not exceed the allowed parameters. The lining consists of stainless steel anchors and a high-density vibrocast/self-levelled refractory material. They incorporate internal insulation/packing made of bio-soluble ceramic fibre or silica blankets, a liner seal that keeps in place the internal insulation blankets while keeping fluid particles out of the bellows/liner cavity.

An important advantage of cold wall design Expansion Joints is that the pipe is insulated so it

operates below the media temperature reducing the pipe growth and consequently the expansion joint movement.

An insulation pillow is included to reduce the temperature. An external insulation is incorporated to prevent the bellows element from dropping below the acid dew point, the main reason of premature bellows failure.

The **Hot Wall** units incorporate an abrasion resistant lining, including hex-mesh and castable material or refractory (a multi-purpose abrasion resistant castable which can be hand-packed, vibration cast and gunned) such as RESCO AA-22. The lining is not intended to be used as a thermal fence and requires a specific and controlled drying.

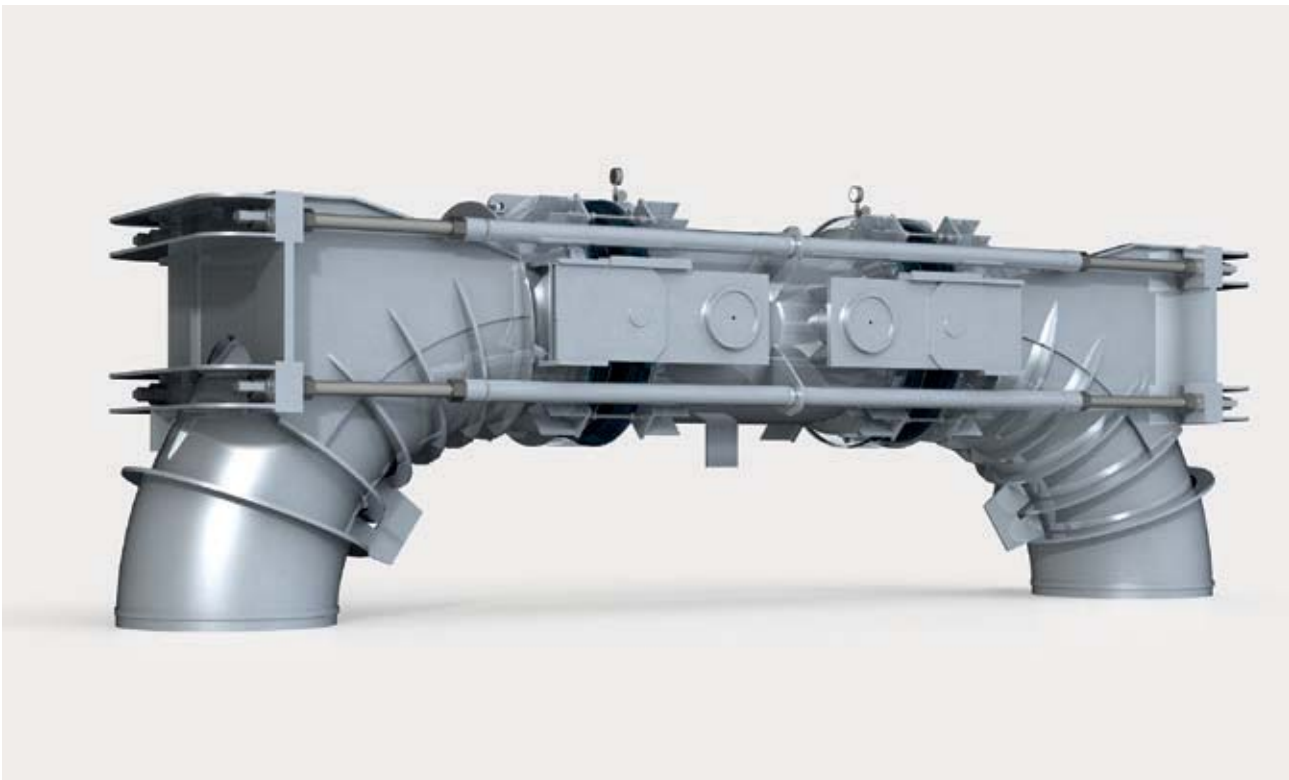
The **Unlined** FCCU Expansion Joints can be exposed to very high temperatures but usually do not convey catalyst so they do not require abrasion resistant lining. This type is generally used for inlet and outlet air and transferring gases from the reactor.

Double Gimbal – Hot Design  
- Floating Ring. Two ply monitored Inconel 625 LCF bellows.  
Design temperature: 760 °C  
(flue gas) 538 °C (bellows)

Universal – Cold wall design  
Two ply testable Inconel 625 LCF bellows. Design temperature: 768 °C (flue gas) 538 °C (bellows)



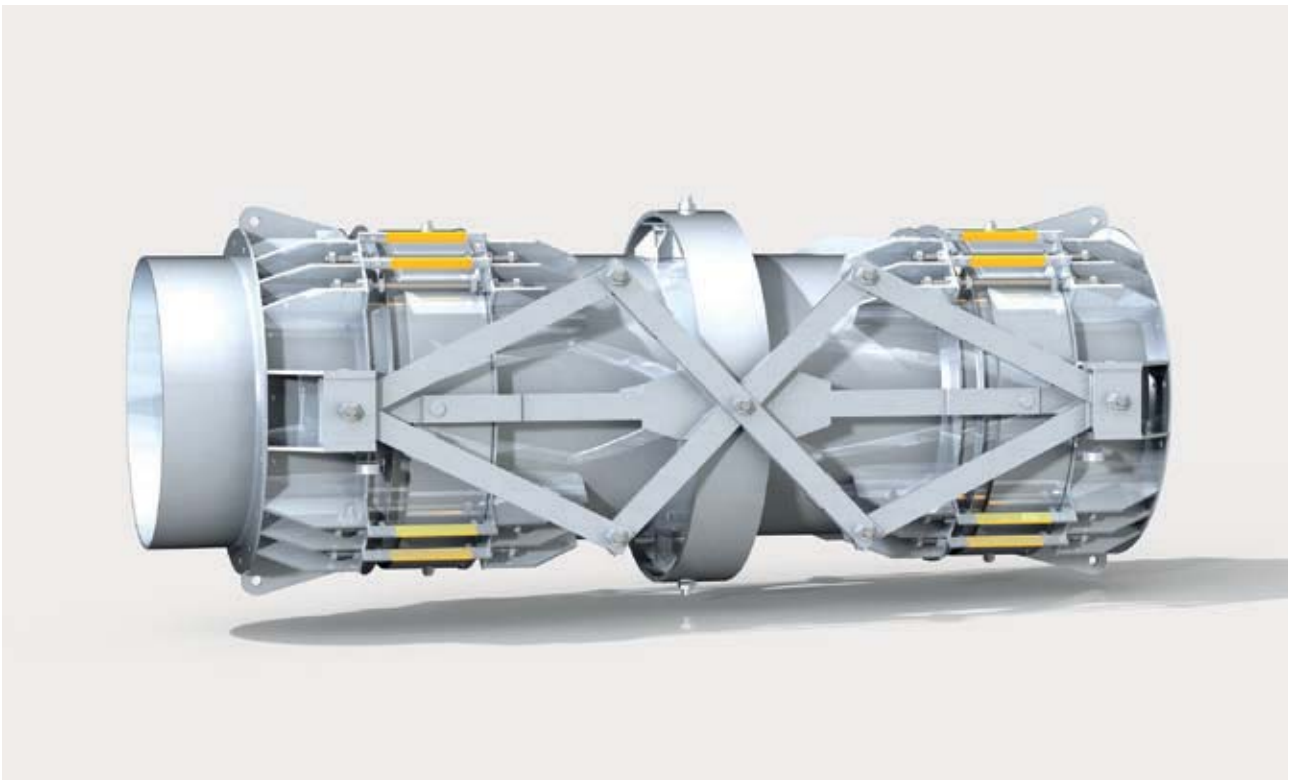




Floating Plate Technology  
Universal - Hot wall design -  
FLUE GAS LINE  
DN1300 - L: 7300 mm

Two ply monitored Inconel 625  
LCF bellows. Design tempera-  
ture: 788 °C (medium) 538 °C  
(bellows). Total weight: 26600 kg





FCCU Regenerator Stand Pipe Expansion Joint – Cold wall design  
Universal with Pantographs. Two ply monitored Inconel 625 LCF  
bellows. Design temperature: 760 °C (medium) 538 °C (bellows)

## THE BELLOWS

The bellows, as the most critical part of the Expansion Joint, can be single ply, multiply, redundant ply or reinforced and generally incorporate an early warning system (active or passive monitoring).

FCCU expansion joints generally incorporate **2-ply testable bellows** where each ply is designed for the full operating conditions. If a hole or stress crack develops in the inner ply during service, the outer ply takes over without exposing operators to increased risk or creating the need for an unscheduled shutdown.

**2 ply testable bellows** system improves reliability and makes the expansion joint more maintenance friendly.

### MONITORED BELLOWS

The annular space between plies can be monitored for leakage to detect a ply failure. This will serve as a warning of an imminent problem. A pressure device in the outer ply alerts about the inner ply failure. The 2-ply testable bellows also allows inspectors to pressure test the inner and outer ply during shutdowns. There are several types of devices used for monitoring the 2 ply testable bellows from simple pressure gauges to electronic devices and can be categorized as Active and Passive Monitors.

Passive monitor: when the inner ply fails the monitor is activated by the pressure between the plies.

Active monitor: the active monitor can detect inner and outer ply failures. A vacuum is created between the inner and outer ply before installing the monitoring device. If the inner ply fails, the pressure between the plies will activate the monitoring device and if the outer ply fails the vacuum will be lost and the monitoring device will be activated.



### **PACKED BELLOWS**

FCCU bellows are generally internally and externally packed with ceramic blankets and the gap between the sleeve and body is filled with a metal braided hose connected to the sleeve by pins. The thickness of the blankets is determined following heat transfer calculations to assure bellows temperature  $200 < T < 500^{\circ}\text{C}$ . The reason to specify the temperature of the bellows at a temperature higher than  $200^{\circ}\text{C}$ , is to prevent dew point corrosion. The upper limit of  $500^{\circ}\text{C}$  was to prevent high temperature embrittlement of Inconel 625.

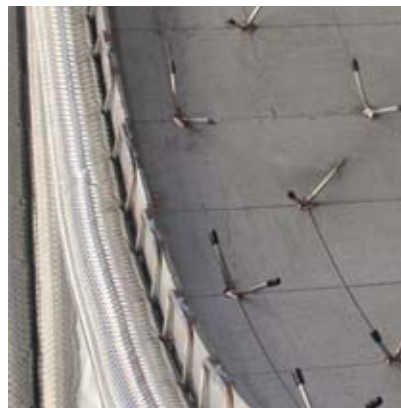
To avoid the dust entering into the bellows cavity as the catalyst can solidify and damage the bellows or restrain the movement capability packed or purged bellows are used. The most frequent is the packed bellows. Purged bellows are not as commonly used today.

### **SELF-EQUALIZING RINGS**

Are commonly used on FCCU Expansion Joints to prevent the convolutions from contacting each other ensuring a uniform compression distribution over the convolutions.

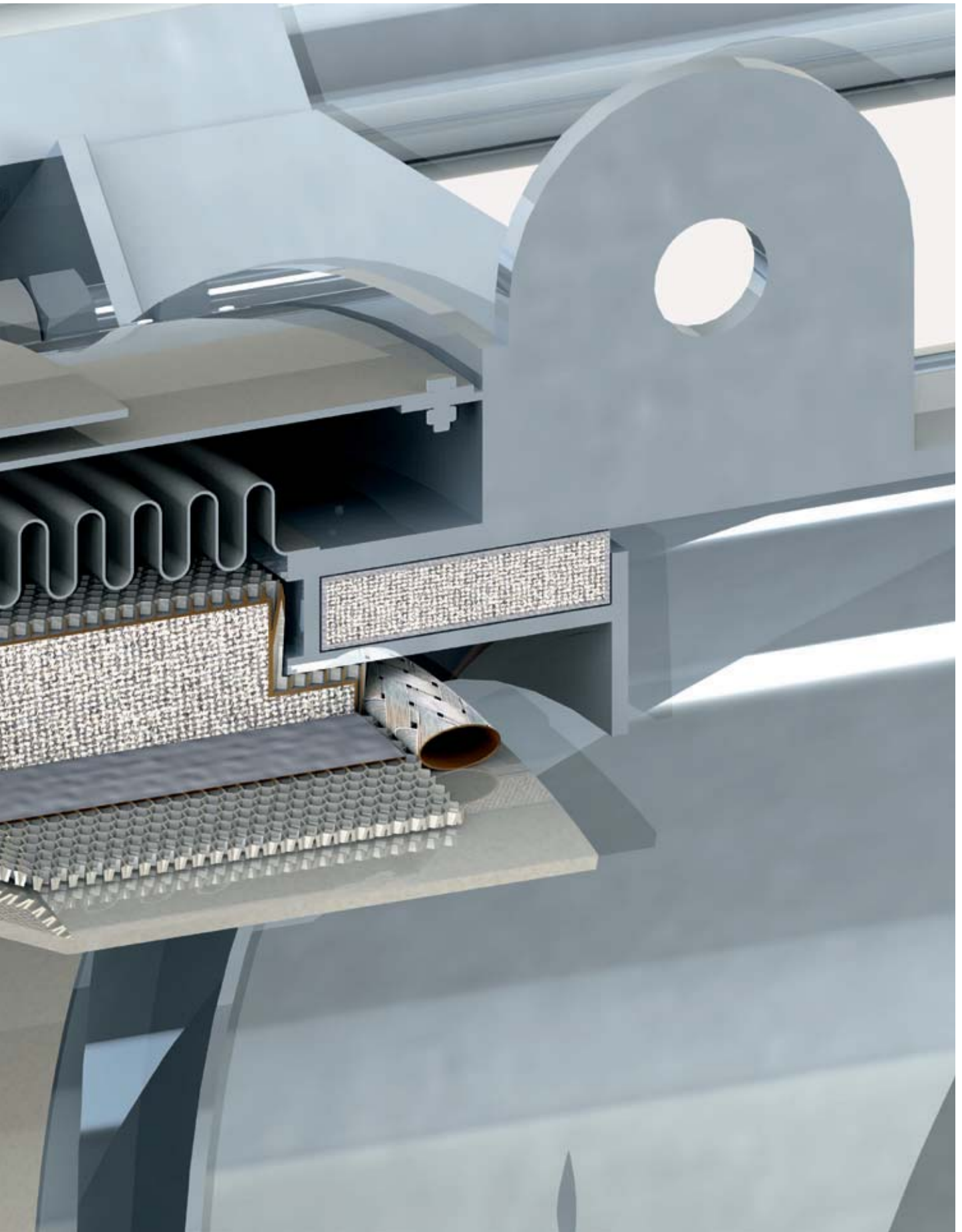
Equalizing rings prevent bellows from an excessive deflection or stress concentration in one or a few convolutions by spreading the movements over all the corrugations.

They also provide a pressure reinforcement capacity when necessary.









## MATERIALS SELECTION

### BELLOWS

The material for bellows for most FCCU applications is Inconel 625LCF. INCONEL® alloy 625LCF (UNS No6626 / W. Nr. 2.4856) developed as a fatigue-resistant, bellows-quality version of INCONEL alloy 625.

The fatigue life of alloy 625LCF can be up to 100 times that of conventional alloy 625. This can result in greatly improved service life over that possible with conventional alloy 625 products.

Inconel 625LCF is the best commercially available material for FCCU bellows in an external expansion joint. This material provides excellent stress corrosion cracking resistance, very good general high and low temperature corrosion resistance and very good mechanical properties including fatigue properties.

Some specifications require for the bellows to be annealed, or solution annealed, after forming.

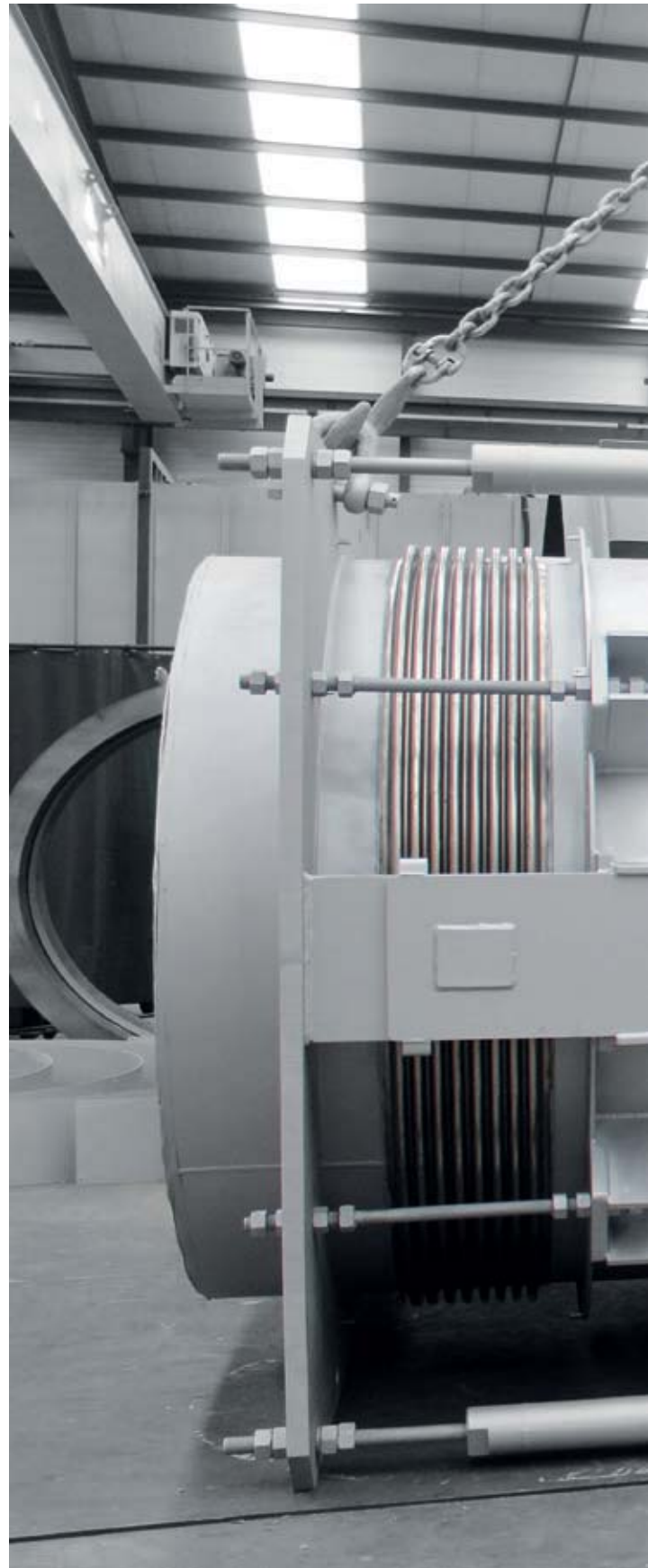
### PIPE BODY

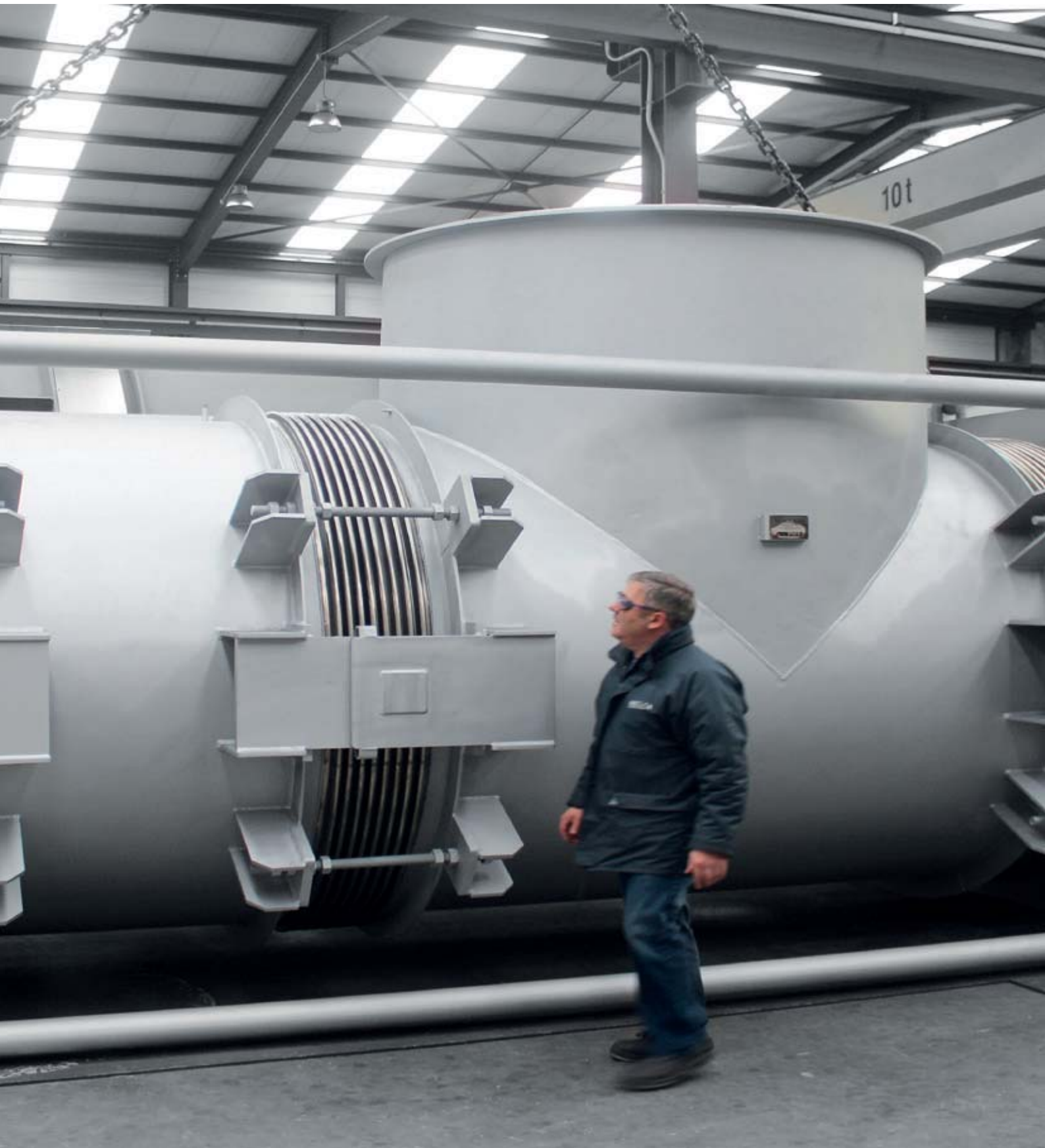
The pipe body for the bellows in hot wall piping systems where operating temperatures are higher than 600 °C, is manufactured from stainless steel Type 304 or 321 H SS. For both materials the carbon content is often restricted to  $0.4 < C < 0.6\%$ .

In hot wall piping systems where the maximum operating temperatures are  $500 < 600^{\circ}\text{C}$ , the low Alloy steels like 1.25 Cr - 0.5 Mo are used.

In cold wall piping systems where the maximum operating temperature is 343 °C, fine grain carbon steel like ASTM A 516 Gr. 70 is used. No special requirements apply.

Universal Tied Pressure  
Balanced – Cold  
Design – ND 2100  
Expansion Joint Length:  
5900 mm. Bellows: two ply  
monitored – Inconel 625 LCF  
Design temperature: 760 °C  
(medium) 538 °C (bellows)







## REFRACTORY MATERIALS AND INSTALLATION

Refractory is a major element of all FCC components. Without proper refractory installation the process unit is risking a costly unscheduled unit shutdown. FCC Expansion Joints are designed with a hot wall (external insulation) or cold wall (internal insulating refractory). The internals that are exposed to catalyst erosion are protected with abrasion resistant refractory even in hot wall designs.

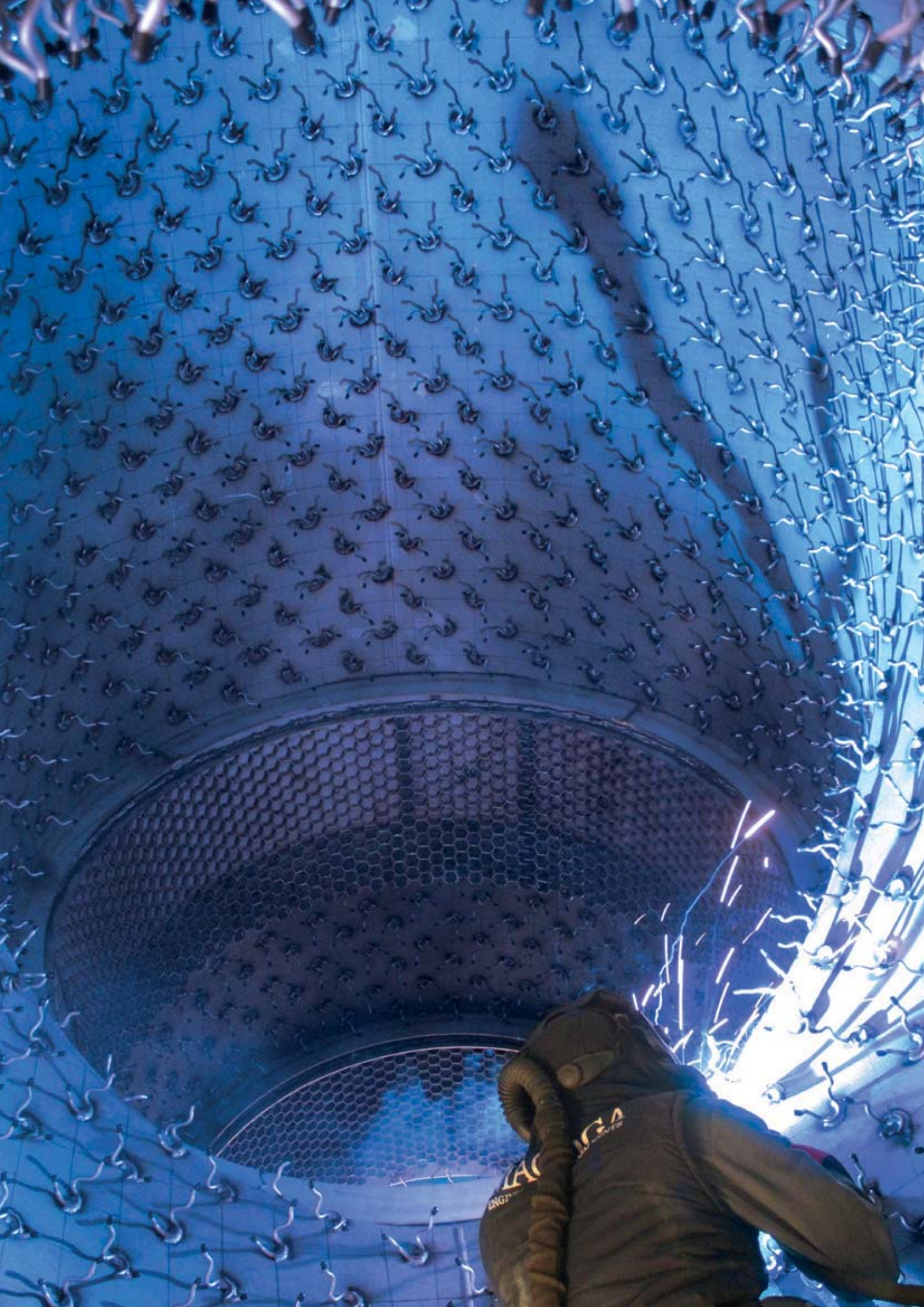
Generally, all these critical linings are designed and installed according to the most up-to-date and demanding refractory licensors specifications as UOP 3-series, ExxonMobil Research and Engineering EMRE Gp, KBR and API 936 or proprietary own specifications.

The insulating or abrasion resistant refractory linings can be installed by casting, gunning (pneumatic application), hand-placing or pneumatic ramming. The abrasion resistant refractory installation involves several critical activities like anchor system (hexmesh or equivalent), QC of materials, prequalification, application and heat dry outs. It is very important that all refractory installation activities are, during all the process, carefully controlled to ensure a good quality control through a good method of statement with drawings, materials selection, testing frequency, installation systems and dry out curve.



MACOGA closely cooperates world leader refractory consultants and engineers, who provide specialized refractory inspection and supervision services.







## EXTERNAL HARDWARE

FCCU joints usually fit in different types of external hardware. The most widely used are:

- Control Rods
- Pantographic linkages
- Slotted Hinges and pantograph central bar
- Central Gimbal

### CONTROL RODS

Used to control and limit the movement of the bellows. Devices, usually in the form of rods ( 30 mm diameter minimum ), attached to the expansion joints assembly whose primary function is to restrain the bellows movements (axial, lateral and angular) during normal operation. Four control rods are normally provided at each bellows element. The rods are equally spaced circumferentially. Control rods are not designed to restrain pressure thrust.

### PANTOGRAPHIC LINKAGES

In universal expansion joints the pantographic linkages ensure that each bellows absorbs exactly half of the total bellows movements.

In case of vertical or inclined installation, the function of the pantograph linkage is also to supporting the weight of the connecting pipe of the two bellows, including refractory and medium weight. Pantograph linkage is not designed to restrain pressure thrust.

### SLOTTED HINGES AND PANTOGRAPH

#### CENTRAL BAR

Slotted hinges installed in a universal expansion joint ensure that each bellows absorbs the same axial movement only. In case of horizontal installation slotted hinges also support the weight of the connecting pipe of the two bellows, including refractory and medium weight.

A pantograph central bar other than the same function of the slotted hinge, in case of vertical or inclined installation, can support one component of the weight of the connecting pipe of the two bellows, including refractory and medium weight. A pantograph central bar is always assembled with the pantograph linkage.

#### CENTRAL GIMBAL

A central gimbal system must be installed in universal untied expansion joints, where a pantograph linkage is mounted and if the required out of plane lateral movement is more than 10 mm.

The primary function of the central gimbal is, in presence of the pantograph linkage, to permit large lateral movements out of plane. The central gimbal is also designed to take the weight of the connecting pipe of the two bellows, including refractory and medium weight.

Slotted hinges with pantographic linkage  
Two ply monitored Inconel 625 LCF bellows  
Design temperature: 552 °C

Each type is used to execute precise and different functions on FCCU Expansion Joints.





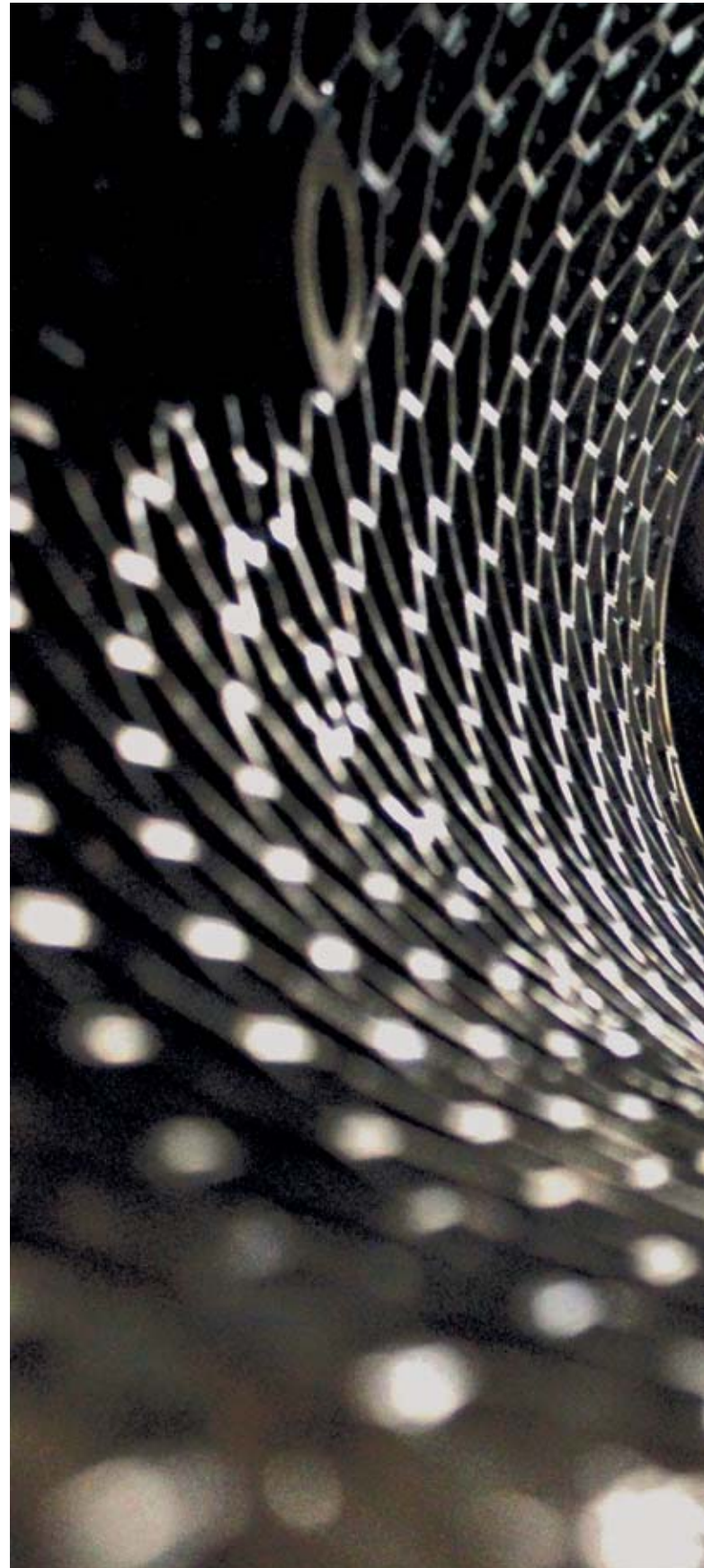
## QUALITY ASSURANCE & TESTING



All MACOGA FCCU Expansion Joints undergo a comprehensive quality control and testing programme including:

- Review Drawings
- Advanced Review of Calculations
- Check Material and welding consumables certificates
- Review and update WPS, PQR and WQR
- Review NDE Procedures & Operator Qualification
- RT- Radiographic Examination
- PT - Liquid Penetrant Examination
- MT - Magnetic Particle Examination
- Hardness Testing of Welds
- Pressure & Leak Detection Test
- PMI - Positive Material Identification
- Inspection of Refractory Lining
- Surface Preparation & Paint System
- Check Packing & Marking
- Etc.

An exhaustive Inspection Plan is issued for every expansion joint for customer's review and approval.







## FCCU EXPANSION JOINT ON-SITE SERVICES

We help you get them properly installed. In any refining facility the FCCU Expansion Joints are critical units that require a high level of expertise during installation and maintenance to ensure that the refining process is not disrupted and optimal production can be achieved.

MACOGA offers its customers in the oil and gas, refinery and petrochemical industries a complete field service package.

We provide a professional variety of site services including assembly, supervision of installation and inspection that minimize risks of unplanned shut-downs and help to avoid failures and breakdowns.

### **ASSEMBLY OF THE EXPANSION JOINTS**

Our site team is trained and consists of qualified welders, technicians and engineers who worked in plants and refineries worldwide. Thanks to our many years of experience in manufacturing and installing FCCU Expansion Joints we know what matters.

A site-specific erection plan is developed during one or more pre-construction conferences and site inspections involving the customer, the contractor, and others such as the project engineer.

MACOGA manages all aspects of site work for the Expansion Joints supplied. From initial delivery of the equipment to site, installation to agreed standards, and final commissioning, MACOGA will manage the project.

### **ASSEMBLY SUPERVISION**

Qualified and trained engineers are available for guidance and instruction during assembly and/or erection process (by others) of our Expansion Joints. We offer pre-instruction and guidance for starting assembly and periodical inspections that guarantee the correct procedures are being carried out and unquestionably a Final Inspection after completion the assembly and/or erection works.

Additional services available include Nondestructive Examination.





## **FCCU EXPANSION JOINTS ON-SITE INSPECTION SERVICE**

Whether your operations follow predictive maintenance or corrective maintenance procedures, detecting early signs of Expansion Joint fatigue or failure can save you on costly repairs and extend your asset lifecycle for optimal refining operations.

### **Why FCCU Expansion Joints On-Site Inspection?**

The life of the expansion joints varies with the design, storage conditions, installation practices, application, and service.

Appropriately timed inspections, repairs, and/or replacement of critical joints will ensure the reliable operation of the associated equipment and of the whole refinery.

Premature or unexpected failure of the expansion joints and emergencies can be avoided carrying on-site scheduled inspections. On-site Inspections will provide valuable information about the conditions of the Expansion Joints and will allow the refinery to take appropriate actions in due time.

### **What is Site Inspection?**

Site visits typically include in-depth analysis and visual review of the Expansion Joints (in hot and cold conditions) identified by the customer. Our staff will collect any monitoring data and operating schedules available from the facility to aid in the analysis. We collect equipment specifications and operating information on specific forms and checklists. Using checklists ensures that the engineers collect consistent and critical information. In addition, we take photographs of the Expansion Joints, equipment, and controls for accurate documentation while on site.



On-Site Inspection at BPOil Refinery



### **What are the key benefits?**

MACOGA can offer on-site inspection of FCC Expansion Joints well in advance your next planned outage, during the beginning stages of a turnaround to aid in planning and expediting the turnaround, during installation of new Expansion Joints, during start-up and periodical inspections.

After every site inspection, MACOGA will issue a report that will assist plant personnel in understanding the types and functions of expansion joints, operation and failure mechanisms of expansion joints, condition monitoring and troubleshooting techniques. Maintenance, repair, and replacement issues are also discussed. This document will assist plant personnel in determining if new expansion joints or revamping

are required, the design features of new or replacement expansion joints as well as provide guidance in the handling, storage, installation, and inspection of these types of joints in the refinery.

### **MACOGA on-site staff can provide you:**

- Installation guidance for new FCCU Expansion Joints
- Inspection in cold conditions (plant shutdown)
- Inspection in hot conditions (plant in operation)
- Periodical Inspections
- Maintenance and refurbishment
- Problem resolution
- Immediate response to site inspections needs
- Quick-turn expansion joint replacement during shutdowns and turnarounds



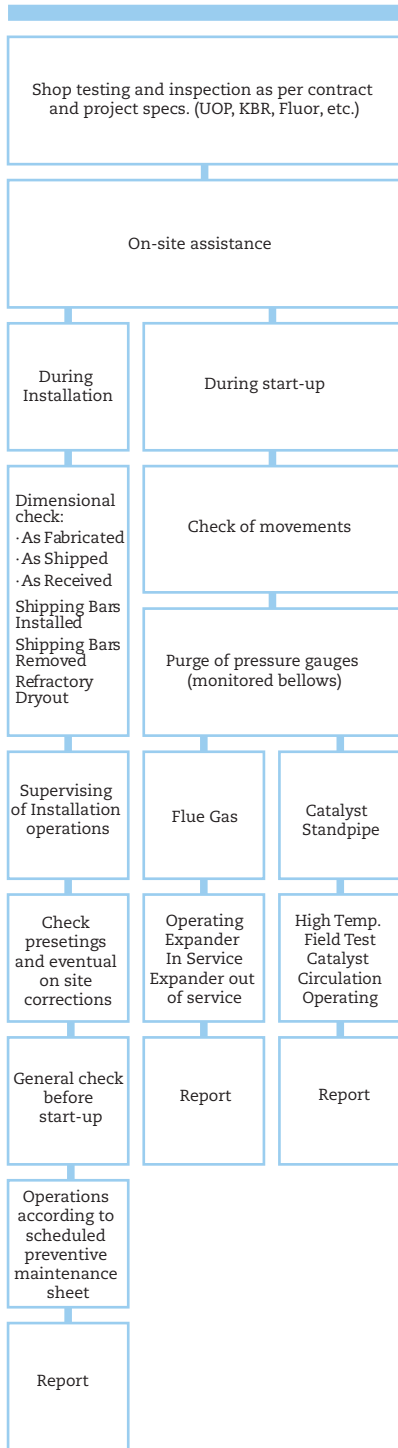
Type of failure	Causes / Things to do	Risk level
Evidence of cracks in the external structures	Perform an accurate cleaning of the area around the cracks. Grind to bottom the defective zone. Proceed with weld repair.	Medium / high
Leakage of the expansion joints due to cracks in the circumferential weld of bellows to pipes	Perform an accurate cleaning of the area around the cracks. Grind to bottom the defective zone. Proceed with weld repair. Repair can be done in Hot conditions only, Check with Dye Penetrant Test.	High
Leakage in the bellows due to the breakup of the longitudinal welding due to the yielding of the base material.	Such breakup is not repairable. It is necessary to foresee an external box that can be rigid or flexible (clamshell). The clam shell installation can be carried out in hot conditions if the temperature at the bellows is less than 400 °C and can be performed without shutting down the plant. This repair must be done by specialized welder.	High
Increase of temperature in the bellows	Probably due to yielding of the inside braid house (sealing) and/or likely damage of the internal insulation. Periodically check the increase of temperature. In hot conditions a box must be installed. In cold condition the damaged items must be replaced.	Medium / high
Bellows convolutions with non constant geometry, swollen convolutions, convolutions distortion.	Such anomaly has to be evaluated by a specialist. It can be a symptom of the beginning of bellows local instability or of bellows column instability probably due to collapse of the base material. Not repairable. Foresee future bellows replacement	Medium
Increase of temperature in the pipes and external attachments	Probable due crack or yielding of the internal refractory lining. Breakup repairable in cold conditions only. In hot conditions externally cool with compressed air.	Medium
Deterioration of blanket insulation installed between bellows and external cover	A substitution is recommended every 4-5 years maximum.	Medium
Control rods with nuts in contact with the external attachment.	Verify that after installation the nuts have been loosened as per drawings. Check if the expansion joint movements are over the foreseen design limits. It is necessary to analyze the problem in detail to take the necessary countermeasures and before proceeding with further actions like unscrew the nuts in contact.	Low/medium
Bellows or the expansion joint under vibration effect	Extremely dangerous situation for the bellows. It is necessary to analyze the problem in detail to take the necessary countermeasures to eliminate this problem.	High
Bending of the external structures	Probably due to excessive external loads. Not repairable.	Low / medium

#### Risk legend

- LOW = No problem to continue in operation. No action must be taken.
- LOW / MEDIUM = No problem to continue in operation. Problem must be properly evaluated.
- MEDIUM = No problem to continue in operation. Problem must be properly evaluated and future replacement must be considered.
- MEDIUM / HIGH = Problem must be properly evaluated. The problem must be constantly monitored and reported. Problem must be properly evaluated and future replacement must be considered.
- HIGH = Appropriate action must be taken immediately. Expansion joint or bellows must be replaced as soon as possible

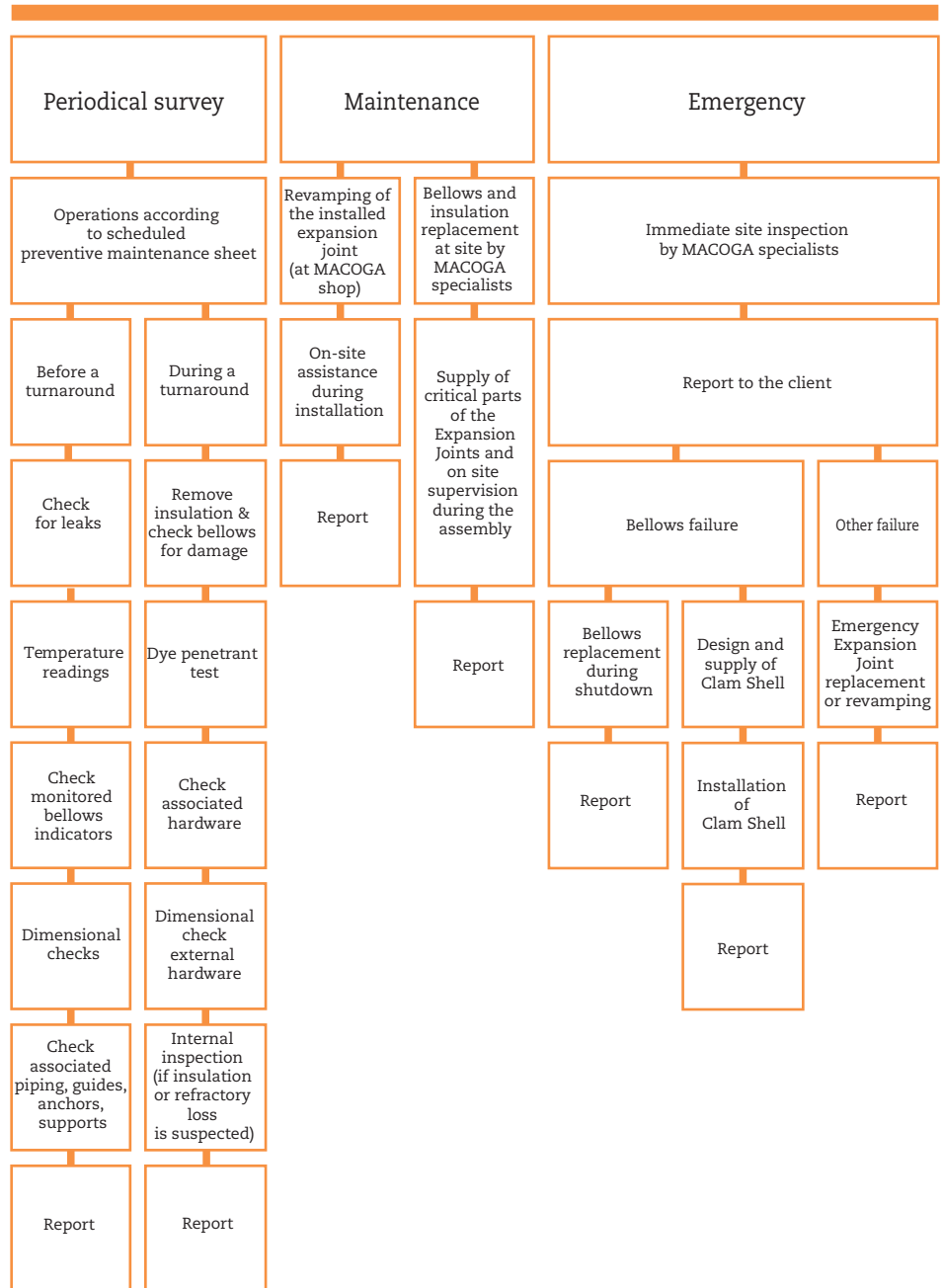
## New

### FCCU Expansion Joint



## Installed

### FCCU Expansion Joint





## **CLAMSHELL BELLOWS**

A clamshell bellows is a temporary repair solution for damaged expansion joints.

MACOGA Clamshell bellows is a good option where an existing expansion joint is to be repaired without cutting or opening the pipe.

Clamshell bellows is a two-piece bellow which is welded around the existing unit. The bellows is split in half longitudinally in our works. The halves are match-marked to ensure the bellows halves are aligned correctly. The clamshell is fitted accurately in position. A purge gas is set up to minimize oxidizing of the weld to ensure a good quality weld. The clamshell halves are then welded back together.

MACOGA provides skilled clamshell bellows welders to perform this welds at site. Field welds are 100 % dye penetrant tested by our qualified staff.



Your next FCCU turnaround or plant outage can benefit from the revealing information that MACOGA On-Site staff can provide. MACOGA offers a unique means to evaluate your FCCU Expansion Joints condition and equipment reliability.

Our technicians are experienced, knowledgeable engineers who have worked throughout the world in innumerable refineries.



## OUR CUSTOMERS

Our expansion joints are present in more than 80 countries across all continents performing demanding tasks and we build this global experience into every expansion joint and support service that bears our name. We listen and learn about the challenges our customers face, and strive to help meet them.

MACOGA is always ready to provide support exceeding customer expectations.

We strongly believe in developing long-term partnerships with our customers, in order to provide them with long lasting, strategic benefits. We believe that our first-class customer reference list below reflects our commitment to value delivery.

This is a sample of some of our significant customers for FCCU Expansion Joints and Refineries:

- UOP
- BPOil
- Saudi Aramco
- ExxonMobil
- Technip
- GASCO
- Saras
- Kuwait Petroleum Corporation
- ISAB Lukoil
- Preem
- ADNOC
- Petrobras
- PDVSA
- National Iranian Oil
- Gazprom
- Petronas
- Sonatrach
- Pertamina
- Repsol
- OMV Group
- Hellenic Petroleum
- CEPSA
- Ceska
- Tecnicas Reunidas
- Petronor
- Petrobras
- Takreer
- MAN Diesel & Turbo
- GALP
- JGC
- Orlen
- Petroperu



## EMERGENCY SERVICE

During an emergency situation (Refinery unscheduled shut-down, parts failure, etc.) you can't afford to wait in line for a standard delivery to get your Expansion Joints.

MACOGA Premium Service tool is the most reliable and efficient solution for those customers who require Expansion Joints in a record time.

### Features & Benefits

- Immediate reply to your inquiry
- Immediate availability of drawings
- High priority production
- Delivery 100% guaranteed anywhere in the world in a record time.
- Express Transport
- Tracking of your shipment





MACOGA is a full-service manufacturing company dedicated to quality products and superior customer service with more than 40 years of experience in Expansion Joints.

MACOGA has established a global reputation for quality engineering design, manufacturing and on-site services with a unique approach that builds close relationships with our clients.

We are known for our success and capability in getting things done. We have the expertise and experience to manage, mobilize and optimize large complex expansion joints, safely and on-time.



**MACOGA**  
ENGINEERED EXPANSION JOINTS

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