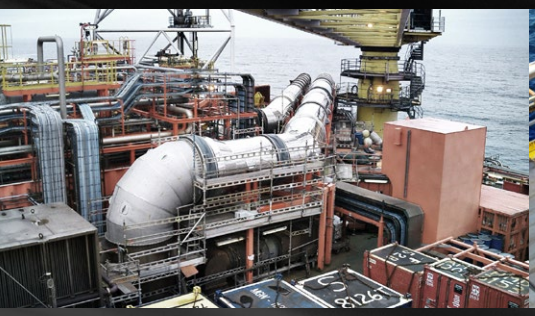


GTX™ EXPANSION JOINTS

FOR GAS TURBINE EXHAUST SYSTEMS

LBH

INVOLVED IN EXPANSION

INTRODUCTION

During 1995 LBH International A/S replaced six Gas Turbine Expansion Joint units for a major Florida power company. Supported by our US Representative we also had the opportunity to install extensive thermal monitors on all the units which enabled us to observe the progress of these retrofit units that comprised turbine exhaust joints (turbine hot flange to diffuser hot flange) and HRSG inlet joints between the diffuser and the HRSG (hot flange to cold flange).

The operating temperature of the Westinghouse 501F Turbine was 620°C with a rapid ramp cycle. Both the original frames and the fabric had been failing. Within three months of start up, the frames began cracking and after just six months of operation the fabric began failing. FEA was used to develop a solution to the frame cracking problems.

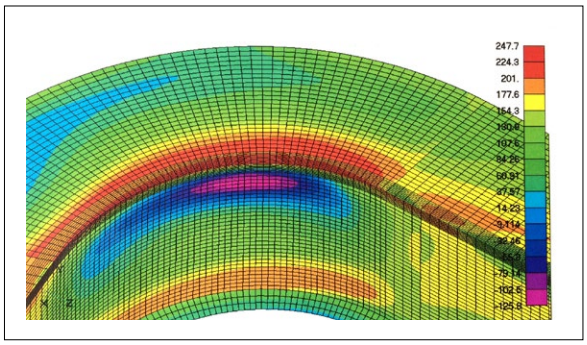
Special pillows were designed and the newest materials of modern technology were used in new composition of Fabric Expansion Joint Bellows. These units were continually monitored by the power company and the initial data was used to evaluate the accuracy of the FEA predictions.

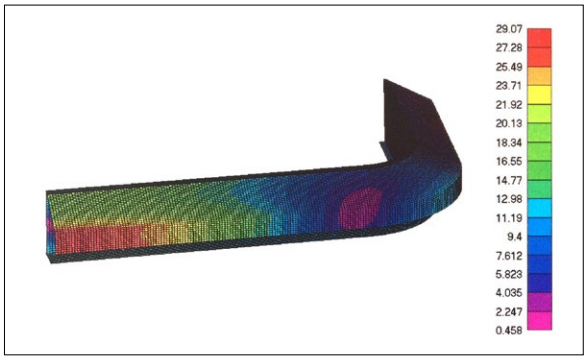
The analysis proved to be extremely accurate, and the project was used as a solid platform for a new family of LBH Products: **GTX™ Expansion Joints**.

This product line has constantly been developed in cooperation with our customers, and a remarkable consolidation happened in 2005, where LBH was selected to deliver rectangular and circular GTX™ Fabric Expansion Joints to form part of replacement of a gas exhaust system on the offshore platform Gullfaks A-M24C owned by Statoil Norway.

LBH scope of supply comprised analytical verification of the requirements of:

- Computation of expected compensator maximum outside surface temperature
- Structural integrity of the compensator main steel parts under temperature and pressure loading





The positive analytic results are confirmed by at least 10 years in operation and no reported damages. Next culmination was reached in 2010 with the revolutionary type INCO-FLEX (patent pending), where LBH as a consequence of its superior proven design and high included safety factor grants a product guarantee of four years.

In 2015 LBH complemented the GTX™ product range with type GTX™-D dedicated for short shut-down, easy service and replacement of all wear parts incl. Bellows, Bolster and WMS. This gives the user the choice between:

GTX™-A, -B, -C
Bellows with superior quality, proven design since more than 20 years. Possible to build in LBH standard unit designs.

GTX™-D
Unit design for short shut down and easy and quick replacement of Bellows and Bolsters.

GTX™-INCO-FLEX
Unit design for superior high safety and long working life with four years of guarantee.

APPLICATION

GTX™ Expansion Joints is the LBH brand name of Fabric Expansion Joints for **G**as **T**urbine E**X**haust systems, and is a narrow range dedicated to solve the severe conditions related to gas turbine applications in diffusers, exhaust plenum, dampers inlet and outlet, by-pass stacks and boiler inlet (HRSG), where increasing demands are being made to working life and more specifically:

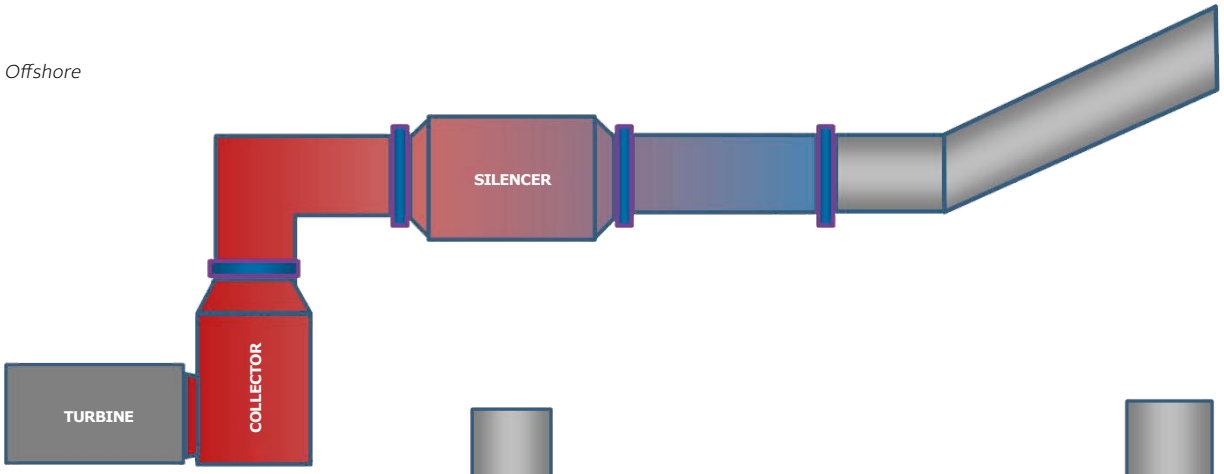
- **Movements compensation**
- **Acoustic features- sound reduction**
- **Temperature reduction and max surface temperature**
- **Increasing ramp conditions**

LBH Expansion Joints Type GTX™ are used in all types of gas turbine plants onshore and offshore.

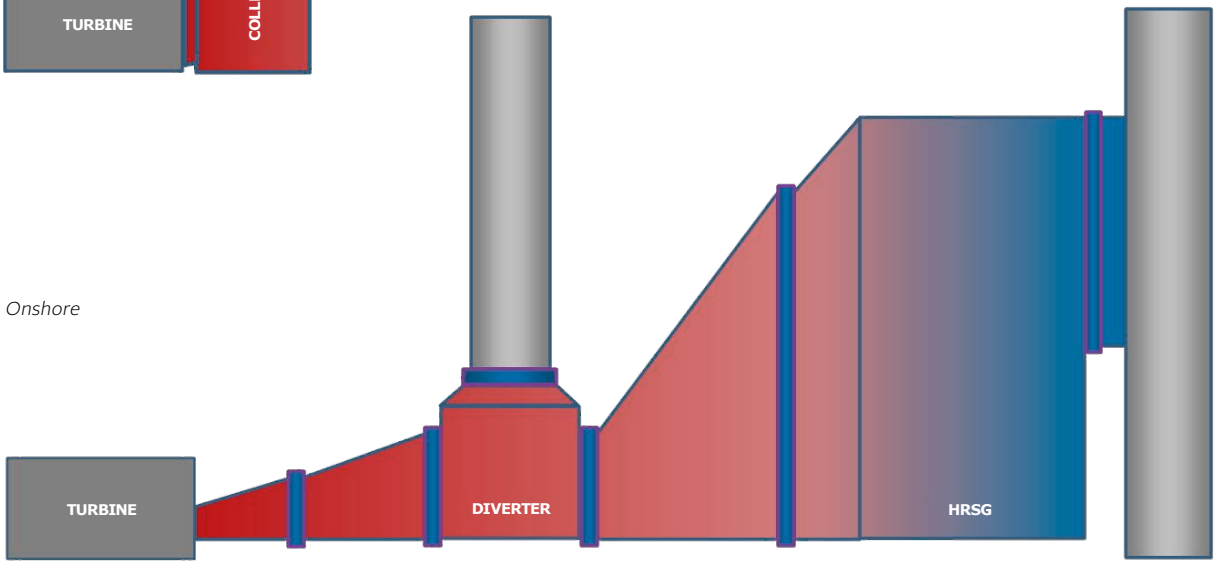
Illustration shows typical onshore Combined Cycle Gas Turbine Plant with by-pass installation and HRSG inlet and outlet, where temperatures with todays technology ranges from 550°C-650°C (gas turbine outlet) to 200°C-300°C (HRSG outlet). On the inlet side of the gas turbine is installed LBH Elastomeric Expansion Joints with good acoustic characteristics. This product is presented in separate leaflet for LBH Elastomer Expansion Joints.

Offshore application is "system wise" in general more simple than onshore, as installation typically limits to turbine- and generator enclosure, vent system and exhaust system from exhaust collector to stack.
Illustration shows typical offshore gas turbine plant.

Offshore

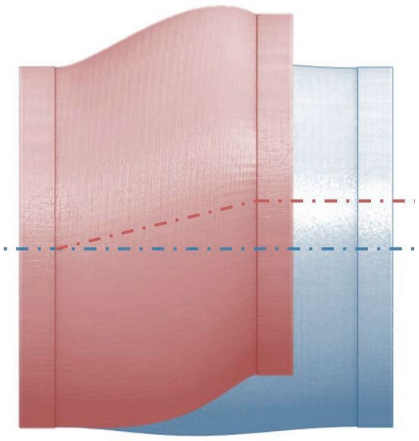


Onshore



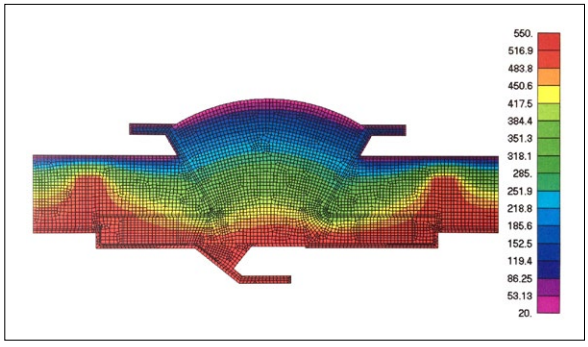
CONDITIONS

Modern gas turbines gives a power option that delivers nearly "instant-on" electricity. Where it can take a traditional coal fired power plant several hours starting up, ramp conditions for a modern gas turbine unit can be counted in minutes.



There are examples of new turbines (2015), which can add 60 MW per minute. These increasing characteristics of the gas turbine of course transfer high requests and demands to the suppliers of components of which expansion joints are focus products.

GTX™ Expansion Joints with usual high included safety margin are designed for today's request of subsequent *typical* design conditions:



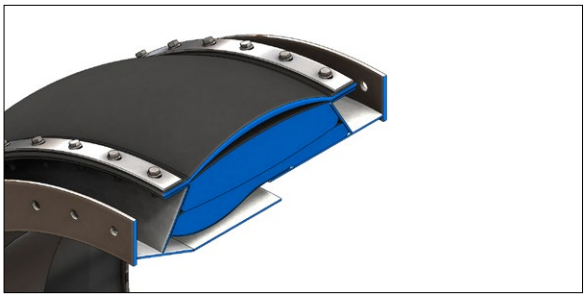
Medium:	Exhaust gas from burning of gas, oil, coal
Temperature:	550°C-650°C
Pressure:	5-10 kPa
Gas velocity:	50-100 m/sec
Movements:	Axially: 60-120 mm (30% of F/F) Laterally: +/-10 to +/-60 mm (+/-15% of F/F)
Ambient temp.:	60°C

Pressure – pulsation and flutter:
cf. ESA Engineering Guide Article 5.9 page 25

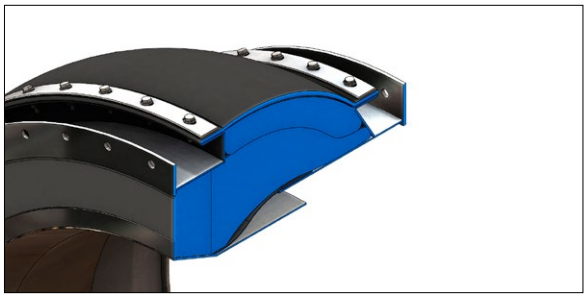
CONFIGURATIONS

LBH GTX™ Expansion Joints are available in various frame designs and fabric materials ("Bellows"). All standard designs can be modified to suit customer requirements; however LBH will not compromise our basic design philosophy to accommodate a design, which may reduce the life or safety of the units. Frame design – configuration – is selected based on the application and the initial frame design on site, which can be based on a hot or a cold mating flange. Our hot frames are designed to withstand the high thermal stress, that is caused by the temperature variation in the flange at start up and ramp conditions. In the following is shown the principle LBH solution for four typical frame designs.

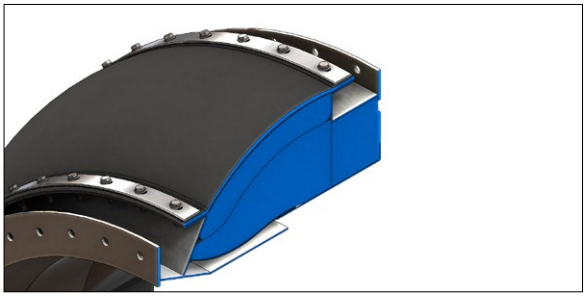
Hot-Hot
Unit design for severe service in gas turbine systems, where both of the mating flanges are to operate at the exhaust gas temperature. The special design is superior in compensating for thermal stress influence (see illustration below).



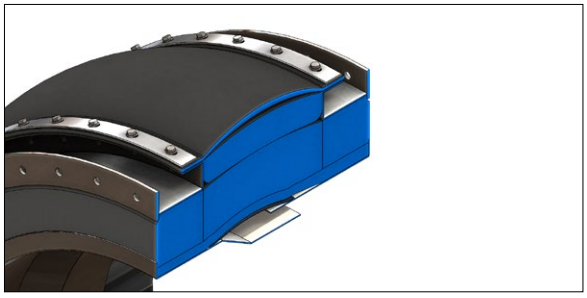
Cold-Hot
Unit design for severe service in gas turbine systems, where the inlet flange is internally insulated and attached to an internally insulated ducting or diffuser flange and the outlet flange operates at the exhaust gas temperature (see illustration below).



Hot-Cold
Unit design for severe service in gas turbine systems, where the inlet flange operates at the exhaust gas temperature and the outlet flange is internally insulated and attached to an internally insulated ducting (see illustration below).



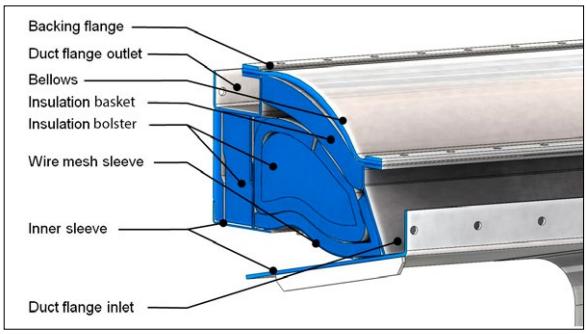
Cold-Cold
Unit design for severe service in gas turbine systems, where both flanges are attached to an internally insulated ducting arrangement (see illustration below).



LBH always offers tailor made designs according to customer flanges whether it's conical, round or rectangular.

SELECTION

LBH Expansion Joint is the designation for the complete Expansion Joint consisting of Metal Parts; (cf. section "Configuration"), Bolsters, Wire Mesh Sleeves and Expansion Bellows. The complete Expansion Joint is designed for the conditions as mentioned in previous section, and even if insulation Bolsters and Baskets will reduce effect of e.g. temperature on the Expansion Bellows itself, this flexible element is designed for the full design temperature and -pressure.



As a guide type selection can be done between following standard Bellows mentioned with increasing complexity; typical application area is mentioned as an example (CCGT)

- **GTX™-A:** HRSG Inlet
- **GTX™-B:** Diverter inlet and outlet
- **GTX™-C:** Gas turbine outlet
- **GTX™-D:** Same features as GTX™ -A, -B, or -C with special designed assembly parts - optimized for requirements for decreased shut down
- **GTX™-INCO-FLEX:** Gas turbine outlet or any place where superior safety is requested

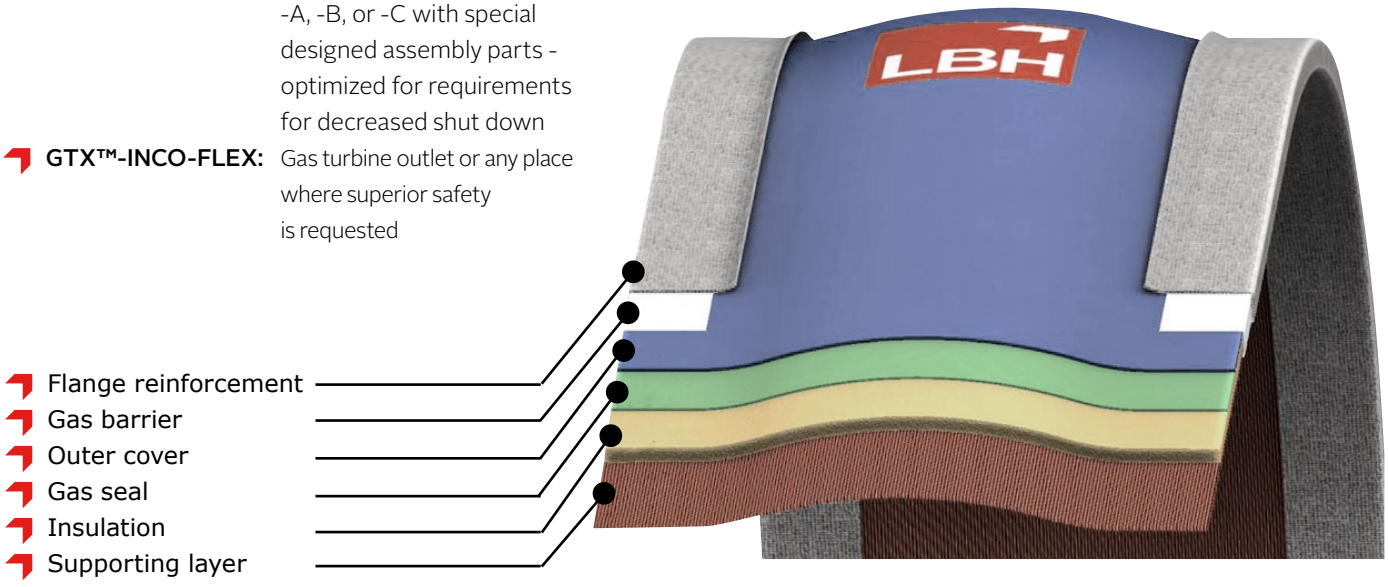
Supporting layer (inner layer, gas side) of the Expansion Bellows is a supporting layer for insulation material and is an acid resistant high temperature stainless steel wire mesh shaped to fit application.

Insulation provides a thermal barrier to ensure low outside skin temperature and to ensure, that temperature of the gas seal does not exceed its maximum service temperature. As insulation is being used a combination of woven, knitted and needled fabrics in a quality considering the extreme conditions occurring in gas turbine applications. In evaluation and selection of these materials are special care taken to health and safety, and LBH was the first manufacturer to exclude ceramic fiber content in insulation materials.

Gas seal is the specific ply in the Expansion Bellows, which is designed to prevent gas penetration through the Expansion Joint body. It is designed to cope with the internal pressure and resist chemical attack.

Outer cover is exposed to, and must provide protection from, the external environment. It is normally designed as a gastight barrier and may act as single or secondary gas seal.

Flange reinforcement is additional sheets of fabric to protect the Expansion Bellows from thermal and/or mechanical degradation.



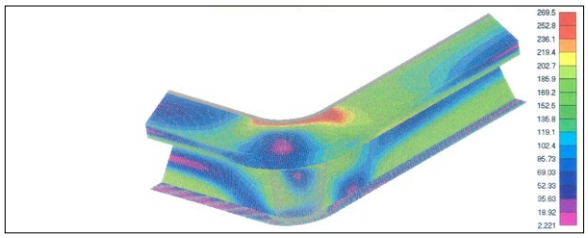
FOCUS AREAS & SOLUTIONS

The main focus areas by Gas Turbine Expansion Joints are rapid temperature increase and high gas velocity. These conditions will often cause failures to steel parts and insulation materials if the design does not take these focus areas into consideration.

RAPID TEMPERATURE INCREASE

Tension

The rapid temperature increase will especially by hot side duct flanges cause great temperature differences and severe tension to the steel parts. This is mainly the

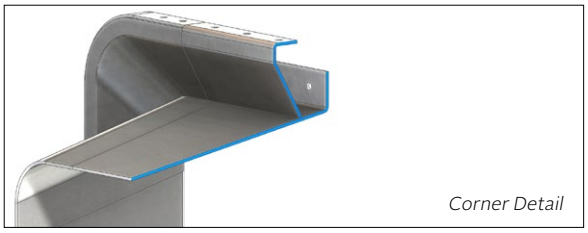


case by rectangular expansion joints where the tensions will concentrate in the corners. However, also round expansion joints may suffer with buckling steel parts if the right design is not chosen.

This challenge can be handled in two ways:

One way is to use special profiled duct flanges to limit the temperature differences in the frames, which will decrease the maximum tension. However, allowing the outer areas a temperature increase will cause other disadvantages like severe temperatures at the Bellows and Bellows´ frames and so not meeting requests of maximum surface temperature, which of safety reasons often are requested to be below 200°C. Other disadvantages are design of flow plates and turbulence.

LBH solution is to design the duct flanges, so that tension and stresses are minimized. Further to configu-

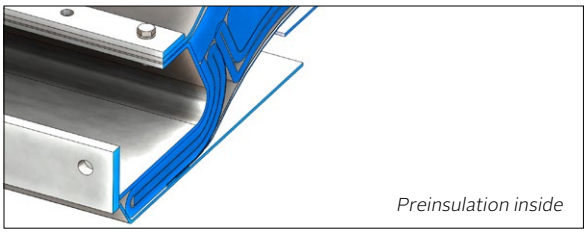


Corner Detail

ration of flange sides, corner design is a high valued focus area. LBH obtain in this way a satisfactory level of surface temperature, which ensures a long proven life time. The design of LBH has proven its value during many years of operation.

Outside temperature

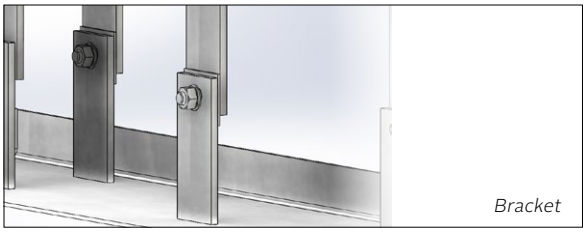
If a satisfactory (low) level of surface temperature cannot be obtained by natural air circulation around the special designed flanges, LBH recommends a pre-insulation inside the hot flange as an effective solution.



Preinsulation inside

This will lower the general steel temperature and have positive impact on the stresses in the metal flanges.

Cold side inner sleeves and their supports need to be designed in such a way that they can absorb extension when heated up. Therefore LBH designs and produces these inner sleeves and supports in sections and

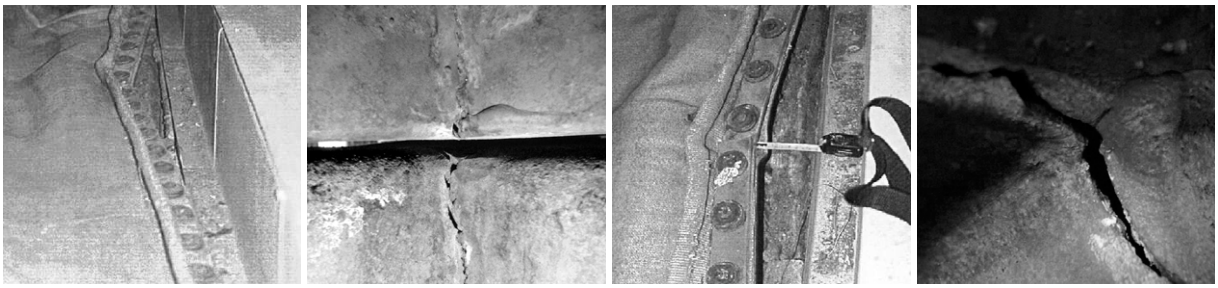


Bracket

fixed with brackets which can slide. To avoid hot spots on the outer surfaces we have designed special brackets, which effectively eliminate this problem.

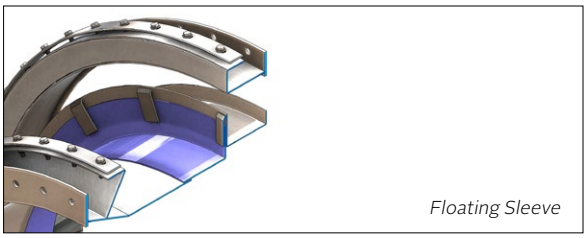
HIGH GAS VELOCITY

Another focus area is the high gas velocity, which locally can exceed 100 m/s. The inner sleeves must be shaped to get the best possible smooth flow, and max. lateral movement must be considered. Furthermore the sleeves have to be rigid enough to avoid vibrations and turbulence, as well as acoustic challenges have to be considered by designing the inner sleeve.

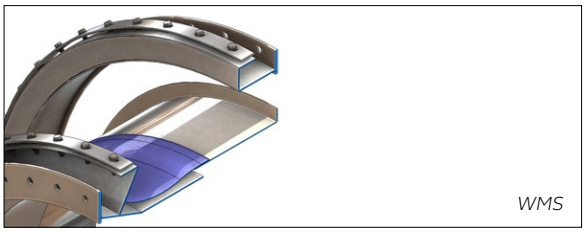


Insulation protection

The insulation materials must be well protected from the high speed gas flow. A traditional way to protect the soft parts is to use a floating sleeve; cf. illustration. This protects well by smaller dimensions, but at bigger dimensions problems with buckling along the sides and friction in corners have to be faced and considered. LBH has therefore developed a 'soft' sleeve with the designation "WMS" (Wire Mesh Sleeve), which consists of multiple layers of wire mesh with careful selected mesh openings. WMS is fixed to the inlet and outlet flange but flexibility remains and movements in all directions are possible. In this way LBH achieves a very good insulation protection with no gaps and possible fiber escapes to flowing medium. At the same time avoiding the problems, the floating sleeve might cause as mentioned previous in this section and in section describing "one way" to solve tension challenges



Floating Sleeve



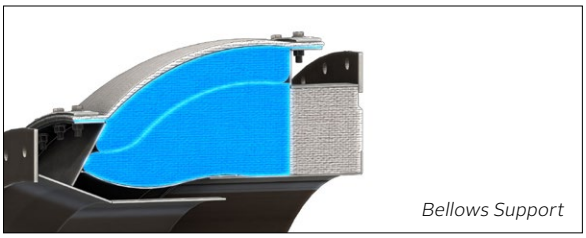
WMS

Bellows support

As GTX™ Bellows are designed for the max. gas turbine design temperature, the main purpose of the Bolsters, the Baskets and potential additional Insulation is to:

- Decrease surface temperature
- Improve acoustic characteristics
- Protect, support and stabilize the Bellows in case of pressure fluctuations and vibrations

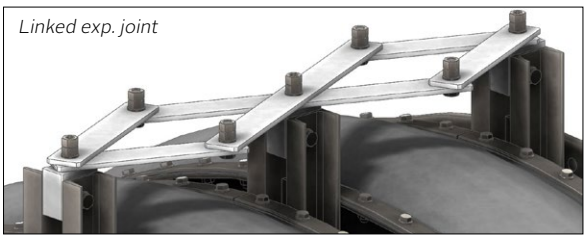
The severe pulsations will have a great impact on the insulation. Therefore LBH offers a solution using insulation with high thermal and mechanical stability.
Stone-wool and other insulation materials with added chemical binders are not used, as they will not keep sufficient stability at actual temperatures. Cancer classified materials like "ceramic felt" are of course not considered in LBH solutions since many years.



Bellows Support

DESIGNED TO THE REQUIREMENTS

The different design measures can be used in different combinations depending on requirements, conditions and limits. The final design will always be tailor-made to meet the expectations of our customers in the best possible way.



Linked exp. joint

Special requirements like e.g. drainage or linked expansion joints are also possible. During the years our skilled and challenged design team has made many individual trouble shooting and solutions to meet specific requirements and demands.

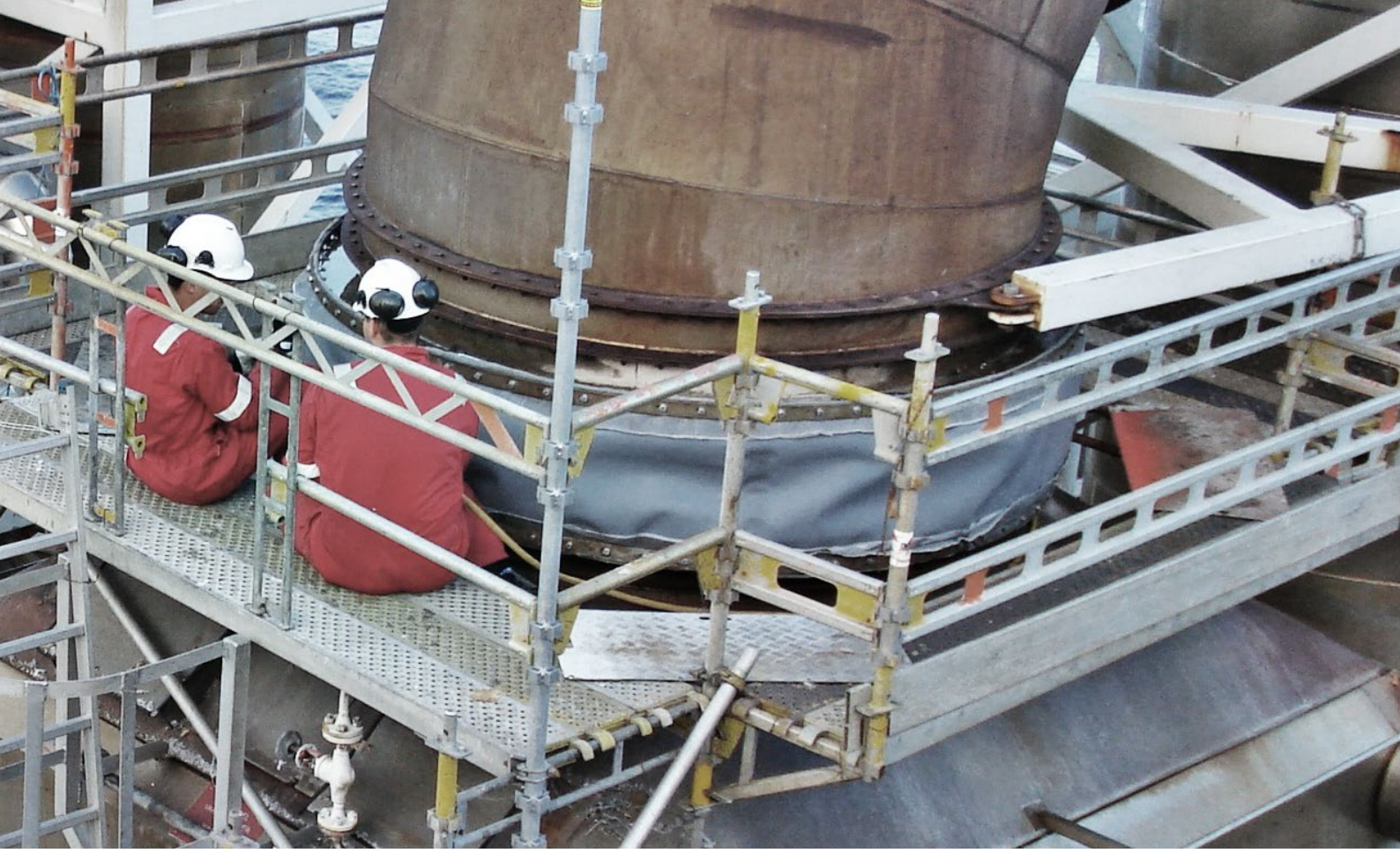
INSTALLATION, SERVICE & MAINTENANCE

For safe installation is referred to either installation manual of LBH or similar from ESA. These will give detailed instructions of correct precautions from the moment of unloading the goods on site until the product is finally installed, checked and approved for operation.

GTX™ Expansion Joints are wear parts and must be inspected regularly and minimum once a year acc. to LBH maintenance chart.

LBH supervisor team is available both for new installation, repair and replacements, and is also at disposal for maintenance check. LBH supervisors stand out as utmost experienced, flexible and capable of solving the most unforeseen (as well as foreseen) challenges on site. The supervisor team have undergone many hours of training, seminars and education for several different on site situations. For offshore applications exactly these skills are requested, as great experience and special training is required. In retrieving permission to enter offshore rigs following certificates are necessary; Basic Offshore Safety Course and additional Basic Safety Training for The North Sea Area / HUET (Helicopter Underwater Evacuation Training). Further to these basic education courses, the individual oil companies have their own requests for e.g. work permit and safe job analysis training. We strive always to have minimum two of our supervisors with updated certificates according to above.

Our team of supervisors are available on a 24 hour hotline on phone number +45 6532 4611

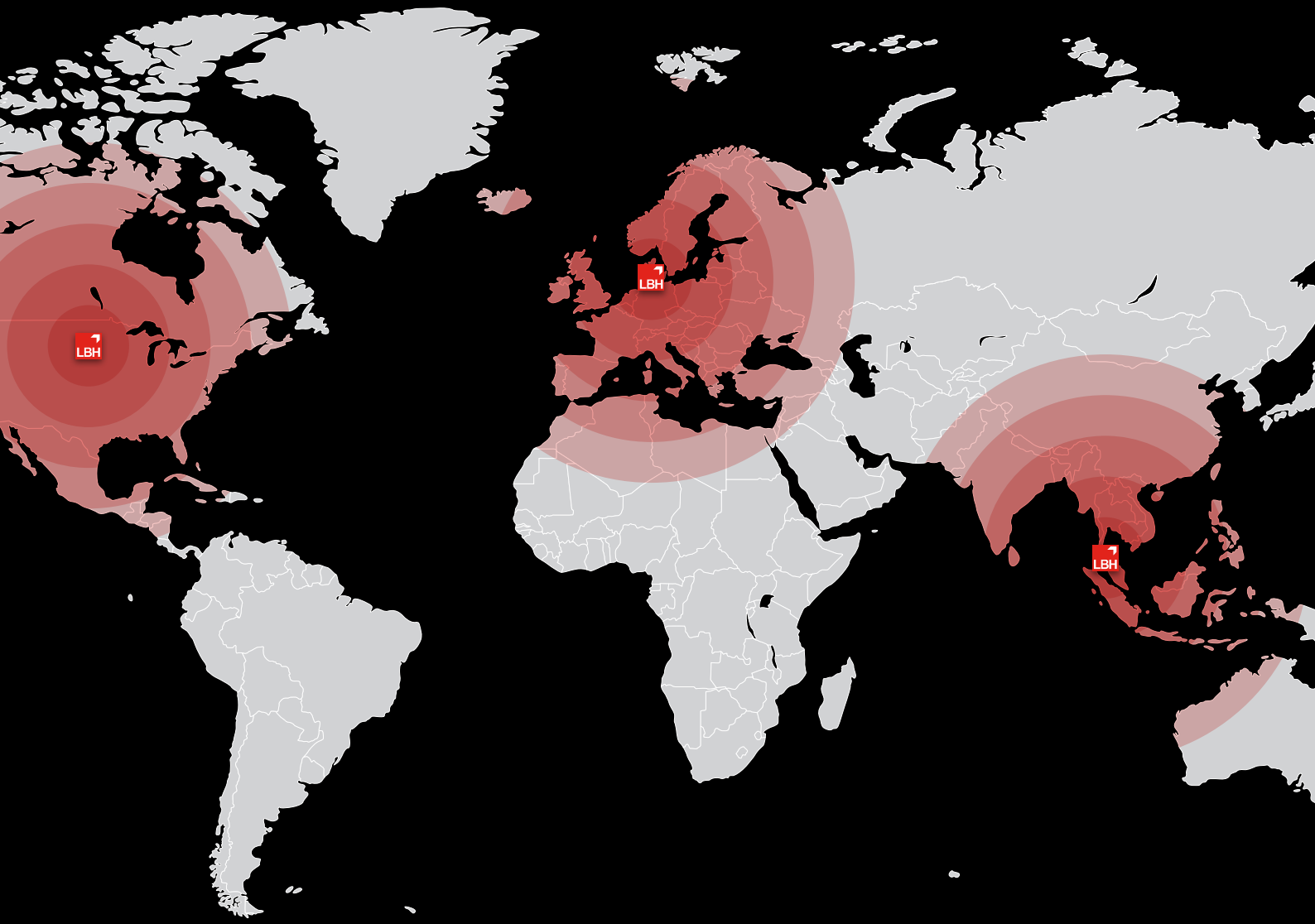


ESA

In this brochure is referred to "ESA Engineering Guide" and "ESA Installation manual".
European Sealing Association (ESA) was founded in 1992 and in Year 2000 LBH International A/S together with other reputable manufacturers founded ESA Expansion Joint Division. The objective of the Division is to serve as a focal point for all efforts to improve the manufacture, understanding and application of expansion joint technology. Both ESA Engineering Guide and Installation manual contributes to support customers in a serious way with background in empiric conclusions and many years of common experience.

European Sealing Association e.V.

LBH WORLDWIDE



For information on your local representative,
please contact LBH regional headquarters or visit our website:

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