HIGH-TEMPERATURE APPLICATIONS
THE CATOFIN® PROCESS

CATOFIN® is a licensed process for producing propylene from propane gas. Here, propylene is produced in a catalyst process by means of dehydrogenation, i.e. by reducing the amount of hydrogen in the propane. The process is an alternative to the traditional production method, which involves cracking crude oil in refineries. The advantages of the CATOFIN® method lies in the purity of the process. With proportions of propylene in excess of 85 %, the CATOFIN® process achieves the highest yield of all methods. A further positive side-effect: It functions with gas, i.e. without the scarce raw material crude oil. The global rights to the CATOFIN® process are held by the American company CB & I Lummus.

ENGINEERING TO CB & I HJ-270 & H-270

PURCHASER: BOREALIS GROUP
Specific: Engineering of expansion joints with material 321H / 1.4878 in accordance with CATOFIN® specifications HJ-270 and H-270 from CB & I Lummus, as well as specific customer requirements.

In reference to the operating efficiency of the planned facility, the specification was worded to the effect that compliance requires all engineering disciplines at Witzenmann to be pushed to the limit.

This modernisation is one of the first plants to be refurbished according to the more stringent CATOFIN® specification. Therefore, it was not possible to draw on current empirical values. In an extensive exchange with both the Belgian customer and the US-based licensor, high-precisions solutions were developed in order to meet the challenging demands.

The demands
The main demand was a complex, interdependent package comprising:
- Process-technology challenge with hot-formed, expanded pipe connections without circumferential weld seams
- Expansion joints at high process temperatures with “cold” bellows (insulation between bellows and internal sleeve) within an existing plant
- Maximal permitted length tolerances of 1 mm for all components and welded assemblies with up to 14,500 mm component lengths
- Short project time
According to detailed FE calculations, the engineers at Witzenmann determined that the specified design work can, in some cases, cause elevated temperatures to be transferred to the bellows over the weld ends. The specified design was therefore altered (image on left) to the effect that the max. temperature values specified by Lummus are verifiably fulfilled in both the theoretical FE calculation and also in the subsequent practical operation. The structural design of the interior protection sleeve was able to significantly reduce the temperature effect.

The temperature measurement shows how the temperature reduces from inside to outside. Only a non-critical temperature of 187°C prevails at the bellows during operation. Consequently the service life and reliability of the overall plant is significantly improved.

With hot-application lines from approx. 550 °C, a highly-alloyed, heat-resistant stainless steel, such as 1.4876 (Alloy 800 H) is normally used as the material. In the specifications provided by Lummus Technologies, 321 H / 1.4878 is stipulated for the expansion joint design of the bellows. At high temperatures, this has significantly lower strength values. Lummus as the licence holder therefore set out highly-detailed specifications for the bellows temperatures and the connection of components under the influence of the hot medium. This means that the specified material can still be used at these high operating temperatures. This specification significantly intensified the design and the structural challenges.

Engineered Bellows

The high-temperature application requires special design work, e.g. raised bellows. This permits temperature insulation of the bellows from inside. The bellows were therefore able to be realised without the use of extremely expensive material.

Engineering: 3-D CFD calculations

The 3-D CFD (computational fluid dynamics) calculation is used to calculate pressures, temperatures and flow velocities of moving media within fixed geometries. In this case for the purge connection, in order to calculate the temperature and flow distribution of the injected propane gas, so that a barrier flow to the media inside the bellows geometry can be reliably determined.

Temperature measurements

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THE "COLD" ANCHORING

Anchorage system, patent pending

The challenge was to significantly reduce the heating of the anchorage parts by the media temperatures of 650 °C / 705 °C. The anchoring is usually welded directly onto the pipe socket. As a result, the medium temperature is transferred to the anchoring nearly unreduced. The result is a reduced load capacity of this hot anchoring. In addition, increased thermally-induced stresses since the anchoring part that lies outside of the insulation cools down very quickly. This then leads to elevated temperature gradients.

To protect the anchoring system of the expansion joints against the effects of heat, Witzenmann developed a "cold" anchoring with minimised heat introduction and a patent application has been filed.

The focus of the patent application was to achieve a low heat introduction into the anchoring, and to design the anchor box in such a way that the resultant stress peaks are reduced. Instead of a solid weld seam, there are now only 4 defined contact points to which the anchor box is connected to the pipe socket. The reaction force of the two anchors is thus uniformly distributed over the 4 contact points. Following the 3D FEM calculation, the anchor box and the fastening points were designed and tested. This permitted the use of the specified material (1.4878), despite increased process temperatures inside the expansion joint.

SAFETY THROUGH DETAILS

Centring pins and more...

The centring pin ensures that when installed in the horizontal position, the floating anchoring system cannot sag and is always centred on the patented contact surfaces in order to guarantee uniform force transfer. The spacer plates shown in the image are intended as installation supports during installation.

Confirmed by practice

In consultation with the customer, several temperature sensors were attached to various expansion joints. 3 months after set up, Witzenmann engineers were back on site to check whether everything is in order, the plant runs trouble-free and whether a readjustment might be necessary. The actually determined plant values were compared with the theoretically calculated values and fully confirm the engineering. The Witzenmann design therefore permits full compliance with the specified temperatures. Practice meets theory!

For the first time, a CATOFIN® expansion joint was calculated under practical conditions and confirmed through measurements!
### HIGH PRECISION TO 14,500 MM

The new expansion joints had to be accurately inserted on site into the existing pipeline system.

Alongside the engineering and design work, producing components accurate to a mm was a further focal point of this project. A production tolerance of ±1 mm had to be maintained over total lengths from 2300 to 14,500 mm and DN 1500 / DN 900. Because Borealis had specified that the components must be put together on site like a puzzle, in order to keep the installation as simple as possible.

To achieve this level of precision, the individual components - above all the anchors, which are ultimately crucial to the total length - are measured using laser technology and adjusted for an accurate fit during production.

### ASSEMBLY TOLERANCES IN THE MM-RANGE

Adjustable anchorage system

The forces caused by thermal expansion are introduced into the anchoring system via an adjustable steel structure (trunnion). The design work is such that it can be readjusted via clamping nuts - consequently, a slight adjustment is possible during installation on site.

**Trunnion with adjustable anchoring**

Trunnions are used whenever a floating anchoring system is difficult to implement in terms of design. Heat is introduced into the load-carrying anchors via the trunnions. In order to reduce the thermal induced stresses, these were partially insulated (hot box design).

<table>
<thead>
<tr>
<th>Assembly of the pipeline</th>
<th>Integrated expansion joint with trunnion</th>
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<td>Clamping nut</td>
<td>14500 ±1</td>
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![Assembly of the pipeline](image1)

![3D pipeline model with flexible elements](image2)

![Elbow with dummy leg](image3)

![Integrated expansion joint with trunnion](image4)

![Trunnion with adjustable anchoring](image5)

![Adjustable anchoring between trunnion and steel frame](image6)

![Elbow with trunnion](image7)
The correct (installation) position of the expansion joint, the problem-free installation, first test run, setting and adjustment of the spring and constant hangers, ... all are tasks of the Witzenmann engineers on-site before the plant can be commissioned.

Further examples of high-temperature applications

- Bayernoil: DN 600 – FCC expansion joints from 1.4876 and bellows from 2.4856 / 1.4878 with 780 °C maximum operating temperature, medium: hydrocarbons
- Total Leuna: DN 1200 – FCC expansion joints lined with concrete for 780 °C
- MIRO Karlsruhe: DN 1500 – Flue-gas expansion joints from 1.4910 (heat-resistant stainless steel) for 780 °C, total length =12,000 mm, a 3-joint system was supplied for minimising the connection forces for a turbine (energy recuperation)
- Carbon black for the production of printing ink and tyres. Temperatures: 670 °C and higher

Overall system

A Witzenmann engineer carrying out fine-adjustment of a constant hanger. A wide range of spring and constant hangers are designed, produced and installed for the Borealis project. Precisely matched to the overall system of pipelines, expansion joints and support components.

A project is only completed when everything fits and is running.