HYDRA®

Quality by Witzenmann

WITZENMANN

managing flexibility

FLEXIBLE ELEMENTS FOR OIL AND GAS APPLICATIONS

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SUBSEA GASPRODUCTION

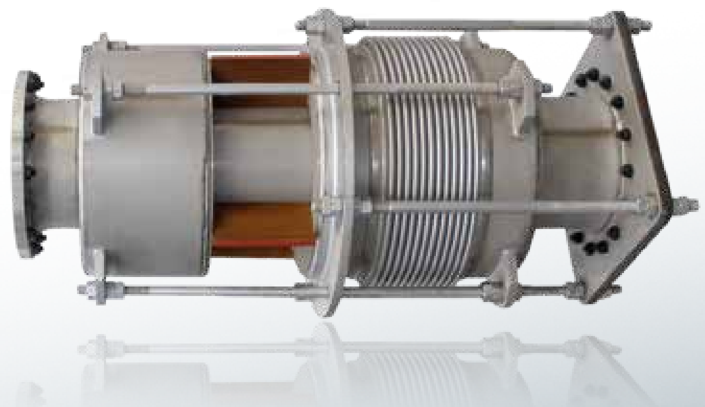
Image: 0037745.jpg; Eiliv Leren/ Statoil

Situated 1,100 metres below the surface of the North Atlantic ocean off the west coast of Norway, the Ormen Lange gas field will supply one-fifth of the British natural gas consumption in the upcoming decades.

The project
Ormen Lange, the "long snake", currently is the largest offshore gas production project throughout the world and poses immense technical challenges. Four unmanned high-tech compressor stations extract the valuable raw material from the porous sandstone on the ocean floor. The depth of the water, hydrodynamics, deep sea topography, and water temperature are just some of the challenges to be faced by design and technology. The service life is another. Once the installation at 1,100 metres below the ocean surface is completed and operations commence, no diver can remedy malfunctions should they occur.

The task
The individual pumping stations at the ocean floor are connected to each other through huge pipelines.
These pipelines are used not only for transporting gas and supplying energy, but also to control the individual pumping stations. The ports for this purpose are situated in cylindrical constructs to which the underwater power cables are connected. These cylinders are filled with oil. Firstly, in order to be able to withstand the enormous external pressure that exists 1,100 metres below the ocean surface, and, secondly, since oil is an excellent electrical insulator and ensures that the electrical systems work properly in the long term.

System-related motions and temperature variations lead to the oil changing in volume. This volume change needs to be balanced out in order to exclude damage to or malfunction of the facilities due to over- or underpressure.



SUBSEA GAS PRODUCTION

Technical solution for Bennex

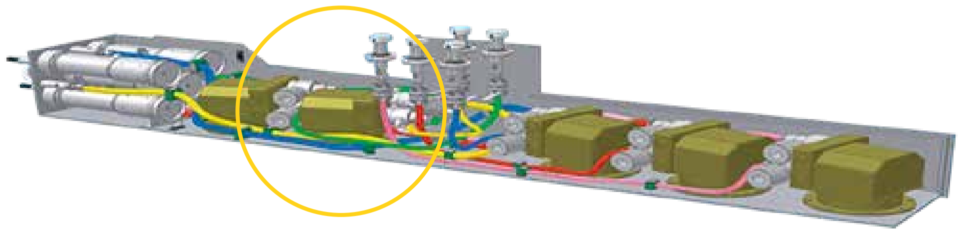
Titanium bellows for extreme requirements

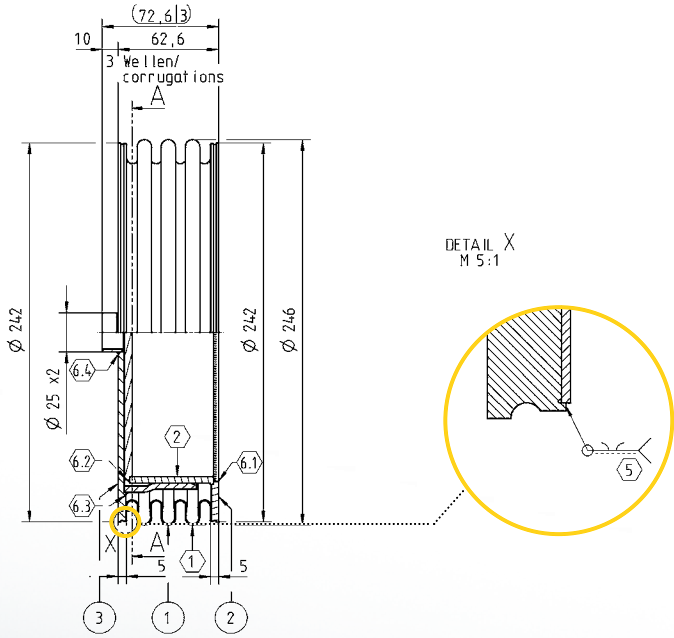
The system just before installation
Exemplary solution for Bennex

Image: Bennex

Implementation
Witzenmann developed pressure-tight and seawater-resistant bellows solutions for various customers supplying the Ormen Lange project. The units for Bennex were made from titanium. They ensure pressure equalisation between the interior and the ambient environment - a must for the devices to work trouble-free and at a stable pressure. The extremely robust material that was used in this case necessitated very laborious processing. Each of the 20 gas-tight bellows were welded in the presence of a protective gas. All components were subject to vacuum tightness tests and X-ray examinations before delivery. For validation of the product design and product quality, sample bellows were subjected to millions of load cycles under operating conditions. The large number of system-related motions and temperature variations resulted in the need for 1 million load cycles to be endured in the requisite service life of 40 years.

Special technical feature
The titanium bellows were welded in specialised clean-room cells in a protective gas atmosphere.





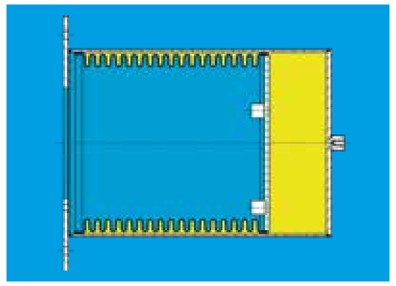
SUBSEA GAS PRODUCTION

Customer Solutions for Volume Compensation of Oil in Subsea Applications

Customer solutions for GE
Basically the same applications implemented in a different technical solution

Image: GE

Function principle



Seawater

Oil

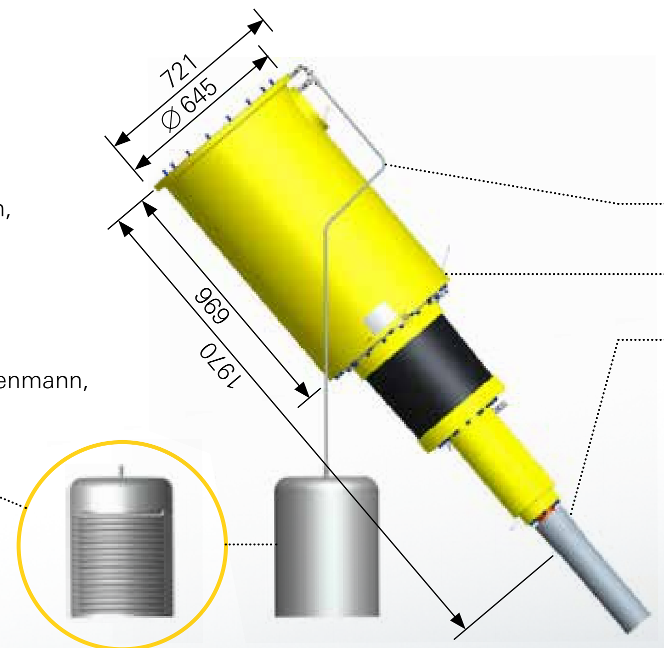
Customer

	Bennex/FMC	GE Oil and Gas	Siemens
Product	Axial Expansion Joint	Axial Expansion Joint	Pressure Balanced Expansion Joint
Bellows Design	Multi-Ply	Multi-Ply	Multi-Ply
Quantity	20	10	4
Length (NL) (mm)	72	540	2500
Diameter (ND) (mm)	200	300	2000
Weight (kg/ pc.)	2	74	1970
Main Material(s)	Titanium (3.7035, 3.7025)	Inconell 625 (2.4856)	Inconell 625 (2.4856)
Design Pressure (bar)	relative 2	relative 2	relative 2
Design Temperature °C	5 - 50	-25/ 60	-30
Application	Volume compensa-tion of oil in transfor-mation chamber	Volume compensa-tion of oil in connec-tion chamber	Volume compensa-tion of oil in transfor-mer container
Customers/ End-user	Chevron	Statoil	N. N.
Country	Norway	Norway	Norway
Year	2005 - 2012	2012	2012 - 2014
Medium	Transformer Oil/ Seawater	Transformer Oil/ Seawater	Transformer Oil/ Seawater
Design Standards/ Codes	EJMA; PED	EJMA; PED; NORSOK	EJMA; PED

Åsgard Subsea Compression,
72.5 kV Penetrator -
Main Components

Pressure Compensator Witzenmann,
DN300, PN2.5, Inconel

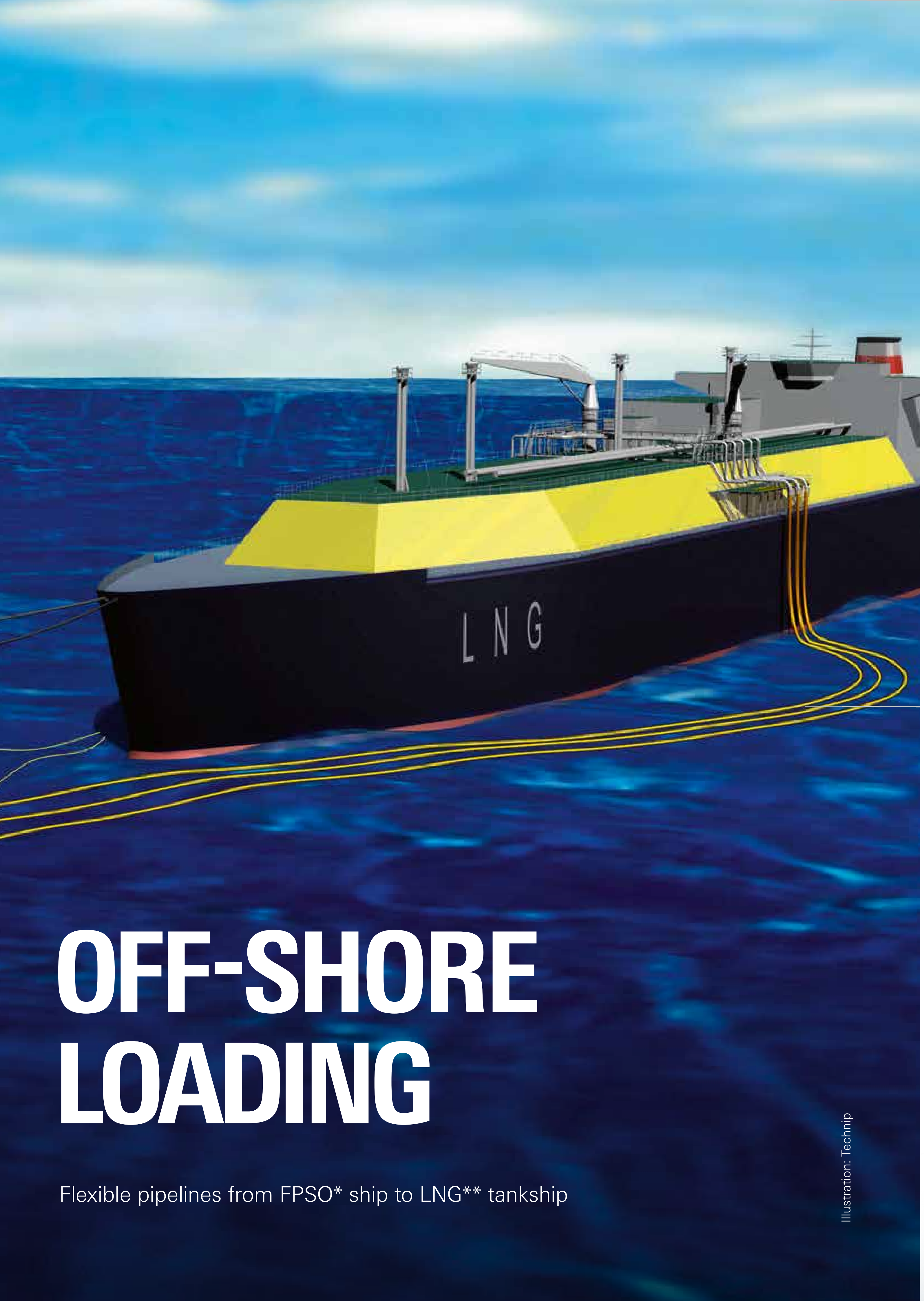
Bellow, section



Tubing, Inconel

Connection Chamber Oil filled

High Voltage Cable

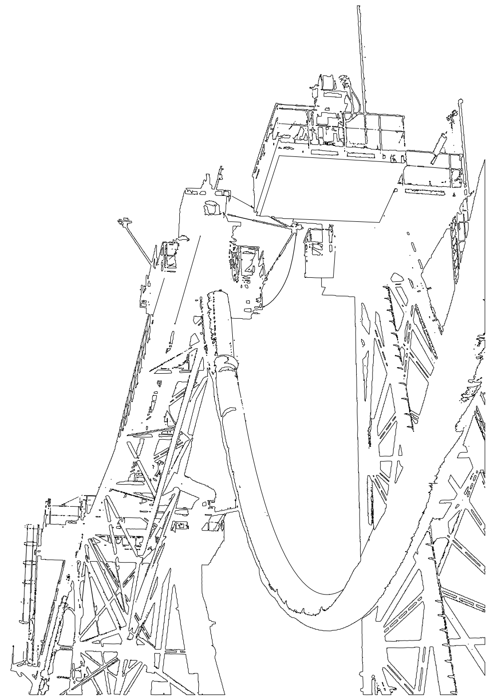


OFF-SHORE LOADING

Flexible pipelines from FPSO* ship to LNG** tankship

Illustration: Technip

Off-shore gas production, far away from the coastlines, is gaining in importance throughout the world.



The Project

When the distance from the mainland gets too large, the gas can no longer be transported to land through piping. Under these circumstances, FPSO* ships, i.e. huge floating gas liquefaction plants with a large intermediate storage volume, are used. These FPSO ships then have LNG** tank ships dock on them to load the gas and transport it over the oceans to the gas terminals of the world.

*FPSO: Floating Production Storage and Offloading Unit
**LNG: Liquid Natural Gas

The task

Implementation of a flexible pipeline system for transferring cryogenic liquefied gas (-163°C) from a storage ship (FPSO ship) to a transport ship (LNG tank ship). The challenge in this application is the combination of pressure, cryogenic temperature of the medium, extensive motions of the ships caused by the ocean and the tides, and the fact that the medium is highly explosive and has a total volume of 150,000 m³. This chain of requirements was made even more challenging by the fact that the complex loading process must not be interrupted under any conditions. Accordingly, the requirements in terms of the reliability of the product solutions were enormous.

OFFSHORE LOADING OF LIQUID GAS

Implementation

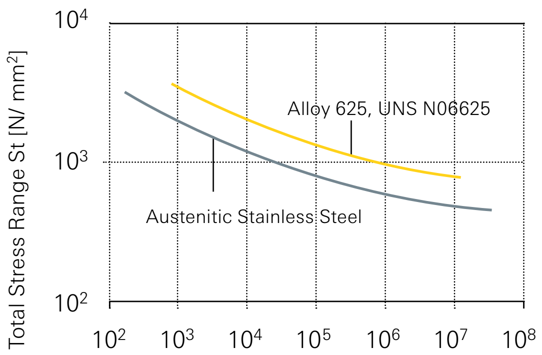
Test Offshore

LNG loading process

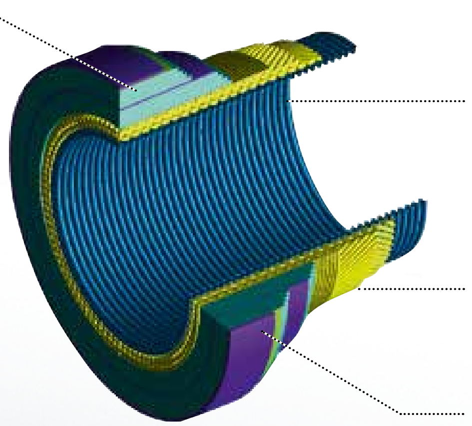
Collaborating with Technip S.A., a French plant engineering and construction company, Witzenmann developed a custom-made solution for the media-conducting interior part for these extreme conditions. The product, a pipeline with a length of 2-5 kilometres, is highly flexible and can withstand heavy seas with waves 12 m in height. To attain this, the corrugations of the flexible design elements had to be fully recalculated and reshaped. Extreme accuracy was required in the production of each individual corrugation geometry. Likewise, a welding procedure was developed to ensure that the longitudinal weld seams withstand the high cylindrical load. More than 100 samples were tested and destroyed until the requisite safety and reliability had been demonstrated and were certified in all phases by Bureau Veritas.

Technical features

- Multi-ply bellows DN 400 with burst protection to prevent explosive bursting if damaged
- Burst pressure 75 bar; design pressure 15 bar (safety margin more than 4-times)
- 100% X-ray examination of weld seams
- Use of cryogenic materials (1.4404 / AISI 316L)
- Pipeline length: 2,000 to 5,000 metres each
- Development of a specific welding procedure



Service life curve (EJMA)



Insulation
- Seawater-resistant
 -163° C Medium temperature
 (cryogenic temperature resistant)

Corrugated metal structure
- Temperature-resistant
- Highly flexible
- Tight
- Corrosion-resistant

Braiding
- Absorption of pressure reaction-forces
- Absorption of tension forces acting on the pipeline

Outer jacket
- Protection from mechanical damage
- No seawater leakage

TYPE APPROVAL

Life Cycle Tests are required for every Type Approval in the Off-Shore Business

A typical Test Report

For the life cycle test the expansion joint was attached to an inner expansion joint in order to keep the effective pressure reaction and thereby the forces small. The specimen was loaded with an axial displacement of ± 120 mm and an internal pressure of 1.0 bar. Because of the change of volume caused by the movement, a pressure increase is evident. A compensation tank with gas cushion was adapted to keep this pressure increase small. A pressure range between 1.0 bar at maximum displacement and 1.6 bar at minimum displacement remained. 1560 load cycles without failure were required.

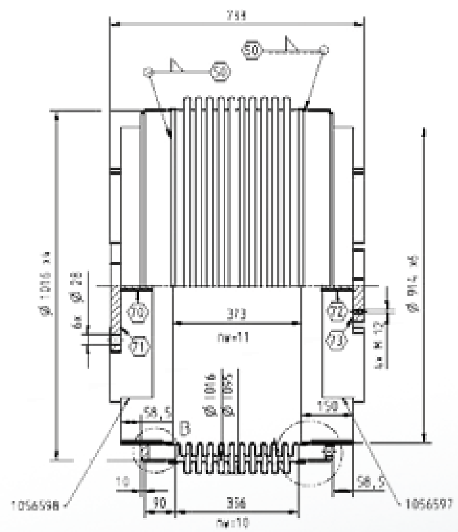
The test was started on 23 February 2011 at 7:00 am, with a test frequency of 192 seconds per load cycle. After a duration of 84 hours, 1,560 load cycles were reached without failure. The requirements are met. The test was continued. The test was aborted after a total of 6023 load cycles. The bellows are still leak-proof. The total duration of the test was 320 hours.

Maximum displacement

Minimum displacement

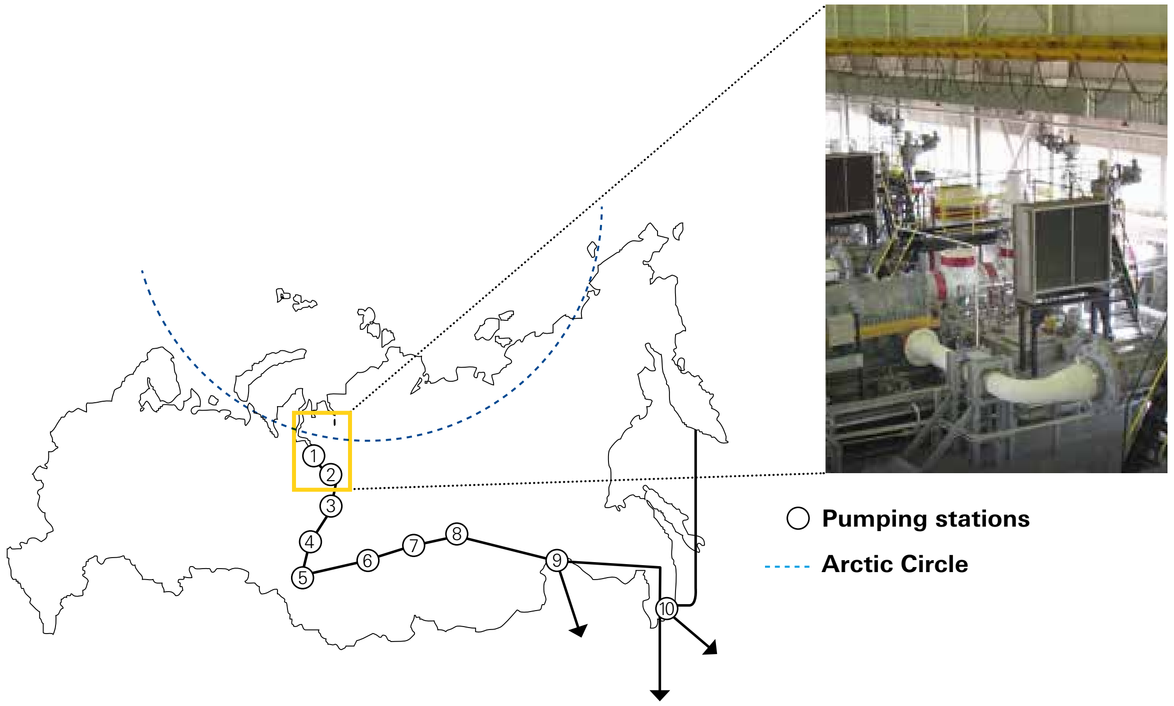
Specimen after 1560 load cycles

Specimen after 6023 load cycles



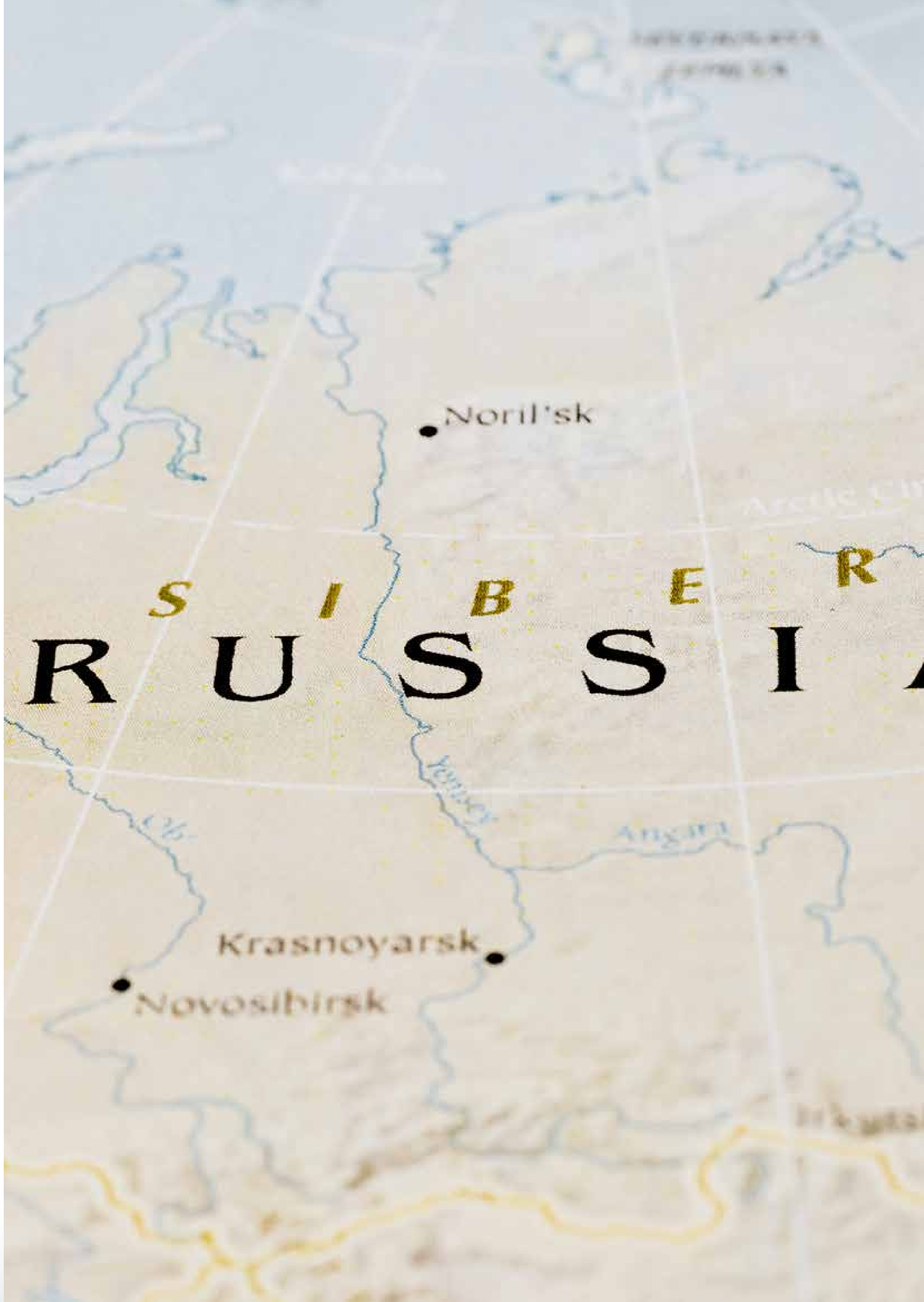
OIL PRODUCTION AND TRANSPORT

Pressure boosting stations of the Vankor pipeline



The Project
Vankor is one of the most important industrial projects in Russia. Vankor is an oil and gas field estimated to contain approx. 524 million tons of an extractable oil and gas concentrate. The Rosneft Group has been commissioned to develop this field. This includes construction of huge production facilities, intermediate storage tanks, and pipelines for transport of the crude oil. The engineering was contributed by the Russian company, Tomskneft, while Neftemash was commissioned to carry out the construction work. In all these projects, flexible elements were required that are able to absorb the motions and vibrations in the pipelines around the pumps and withstand the extreme conditions north of the arctic circle.

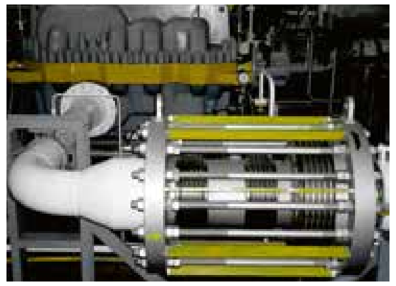
The Task
Pumping stations for temperature and pressure boosting are constructed at regular distances along the pipelines. Their purpose is to heat the oil, whose temperature is steadily declining along the pipeline, to 90°C in order to keep it at low viscosity and flowable. The pressure of the oil also declines during the transport and is re-boosted at the stations. This increases the flow rate of the oil in the pipelines several-fold. Heating of the oil causes the pipelines to expand. Expansion joints are used to decouple the pump from the pipeline and to prevent a damage of the pump by resulting forces and moments.



OIL TRANSPORT

Implementation

Pressure-balanced Universal expansion joint

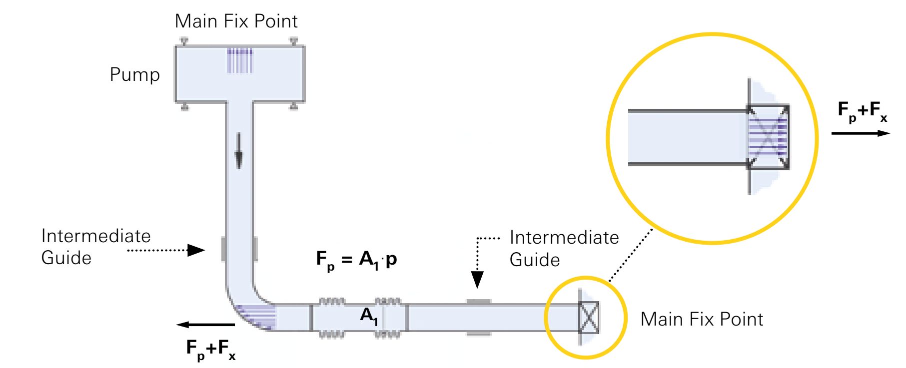


Pressure, diameter, and temperature (110 bar, DN 400-600, 100°C) were the challenges to be faced by the Witzenmann engineers. Not to forget the rough installation and operating conditions and a required service life of 20 years (since failure of the pumping stations would be associated with immense costs). Moreover, the pumps needed to stay free of loads by the pressure counter-forces generated through the compensation. Witzenmann designed a total of 12 pressure-balanced expansion joints with metal bellows made of high-strength "Superduplex" 1.4410 for the pressure boosting stations. Despite the use of high-strength materials, it was feasible to design the expansion joints such that they can absorb axial motions of 30 mm and lateral motions of 20 mm. The most sophisticated processing know-how was also needed for the welded joints.

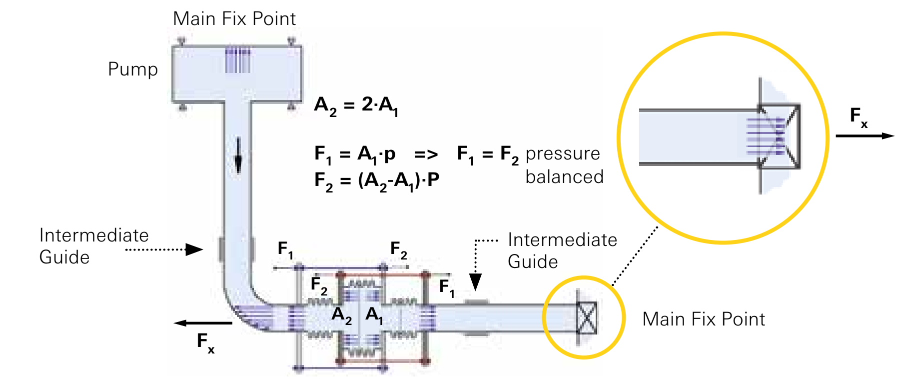
3D-CAD
of the expansion joint

Details of the design
In a conventional DN 400 universal expansion joint, as used here, the axial pressure counter-forces acting on the pipeline would be approx. 1623 kN at an operating pressure of 110 bar (Figure1). These forces would act directly on the pump ports and bearings of the pump block. The design of a pressure-balanced universal expansion joint prevents forces of this type. The fix points can therefore be designed to be smaller in size since only the adjustment forces of the expansion joint act on the fix points (Figure2).

Compensation through universal expansion joint (Figure 1)



Compensation through pressure-balanced universal expansion joint (Figure 2)



F_1= tractive force in the pipeline

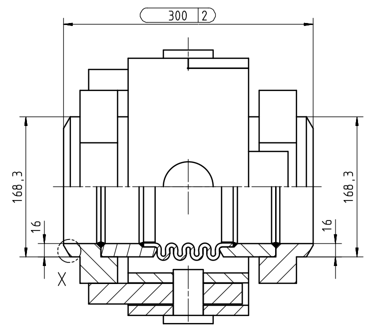
F_p= p (1623 KN in this case)

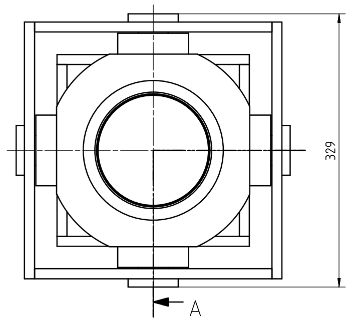
F_x= adjustment force of the expansion joint

75% LOWER WEIGHT - MEETING THE SAME REQUIREMENTS

Distinctive feature of the Vankor Project

Weight-reduced Cardanic expansion joint



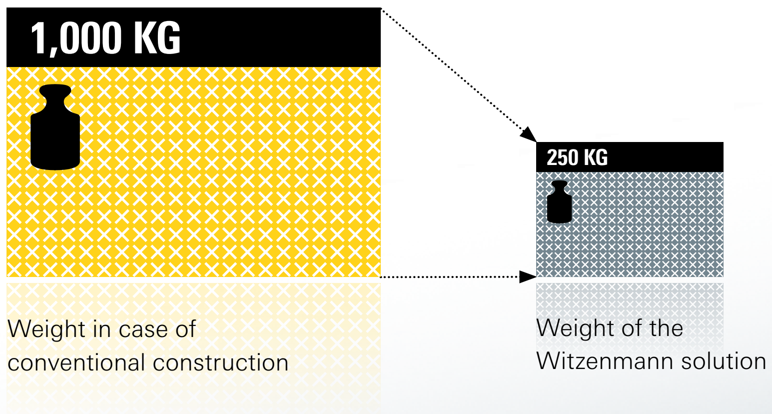


For another pumping station of the Vankor project, special light-weight expansion joints were required. These expansion joints had to weight no more than 250 kg, instead of the "conventional" design with a weight of 1,000 kg, since the entire pumping station rests on a "swinging" plate that uncouples the motions relative to the ground. The support plate could be exposed only to a certain total weight.

7 plies for less weight
This required a novel design for the planned expansion joints DN 250 and DN 150. The original design of the high pressures bellows (PN = 250 bar) was to use ring-reinforcing structure. High-strength austenitic stainless steels were used to reduce the weight (Superduplex for DN 250, Inconell 625 for DN 150). These materials are high-strength, but difficult to form. In order to attain the required flexibility, the bellows were constructed in 7 plies with a wall thickness of 1 mm each.

Novel anchoring
The anchorings also have a novel design. It is common to design expansion joints that have to absorb angular motions from all directions to have cardanic anchorings. Instead of a massive expansion joint that can absorb all motions, this design involved two expansion joints that can be constructed to be much more light-weight, even taken together, and absorb the requisite motions in angular and lateral direction in this application. Instead of the usual massive plates absorbing the forces, significantly smaller and lighter-weight ring structures were used for cardanic anchorings. This design achievement was a major contribution to attaining the properties required in the specification book.

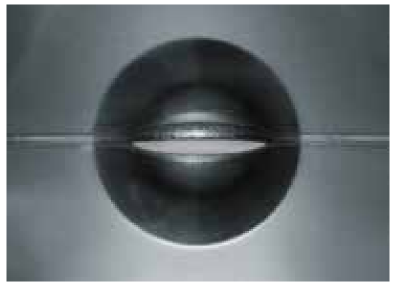
The Challenge
Weight reduction by 75 %



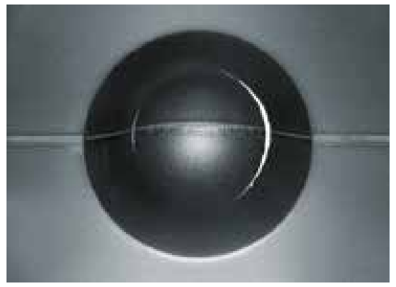
COMPETENCE IN WELDING

Welding Seam Testing with the Erichsen Cupping Test

Fracture along the weld seam
Scrapped material quality



Fracture occurs transverse to the weld seam Circular fracture about the weld seam - meets the quality requirement



The formability properties required in the production of bellows cannot be deduced from the materials certificates or specified at sufficient accuracy. In order to obtain reliable information, we conduct a extensive range of tests as appropriate for the specific use. One of these tests is the Erichsen cupping test.

Simple, yet efficient
EACH new belt batch of bellow material is subject to this test. For this purpose, a butt weld seam is produced on a sample of sheet metal. Welding is carried out according to the defined parameters that are used later in serial production as well. Then the cupping test is carried out. Only if the criteria are met (fracture occurs transverse to the weld seam), the new material is used in production of the bellows. Each material is subjected to this test.

Typical materials for offshore applications

Nickel alloys	**Nickel super alloys**
1.4306 (Type 304L)	1.4562 (alloy 31)
1.4541 (Type 321)	2.4856 (alloy 625)
1.4404 (Type 316L)	2.4816 (alloy 600)
1.4571 (Type 316Ti)	2.4858 (alloy 825)
1.4529 (N08925)	2.4610 (alloy C-4)
1.4539 (N08904)	2.4650 (alloy C-263)

Material number	ASME Type / UNS	Temperature	E-Modulus	Rp0,2
		°C	MPa	MPa
1.4541	321	-196 / +550	200,000	220
2.4856	alloy 625, N 06625	-196 / +900	207,000	380
2.4610	Hastelloy C-4, N 06455	-196 / +400	205,000	305
Titanium	R 50400	-10 / +250	107,000	280
Duplex	S 31803	-40 / +280	200,000	> 480
Super Duplex	S 32750	-40 / +250	200,000	> 550
1.0425	S 32750	-10 / 480	212,000	> 255
1.0566	SA-516 size 70	-40 / +400	212,000	> 345

OUR PRODUCT RANGE

HYDRA® Metal Hoses
Corrugated hoses from DN 6 to DN 300, for operating pressures up to 400 bar for temperatures from -270 °C to max. 600 °C.

HYDRA® Expansion Joints
Axial, lateral or angular expansion joints from DN 15 up to DN 12.000 with rotating flared flanges, fixed flanges, ends prepared for welding, … in various materials like stainless steel, tantalum, Incoloy, …

HYDRA® Metal Bellows
Corrugated high pressure resistant bellows and membrane bellows for different applications.

HYDRA® Hangers and Pipe Supports
Different types of maintenance-free hangers and supports for load bearing up to 500 kN.

HYDRA® Bearings
floating, guide, and fixed bearings, roller bearings for insulated and non-insulated pipelines in the nominal diameter range from DN 15 to DN 600.

FLEXPERTE® – Sizing Software
Flexperte was developed especially for planners and
designers for the selection of metal hoses, expansion joints, metal bellows and pipe supports with interface to PDMS, PDS.