HYDRA®
Quality by Witzenmann

WITZENMANN
managing flexibility

FLEXIBLE ELEMENTS FOR CHEMICAL INDUSTRIES

Witzenmann GmbH

Östliche Karl-Friedrich-Str. 134
75175 Pforzheim, Germany
Tel. +49 7231 581-0
Fax +49 7231 581-820
wi@witzenmann.com
www.witzenmann.de

1702uk/2/05/20/pdf

PROJECT BAYER SHANGHAI: TDI PLANT – PHOSGENE PROCESS

MATERIALS: 2.4856 / ALLOY 625 AND 1.4562 / ALLOY 31

Specific: Comprehensive security concept due to a highly-toxic medium

The project

Bayer MaterialScience, Co., Ltd., built a plant in Shanghai for the production of TDI (toluylene diisocyanate). TDI is an important intermediate product in the plastics industry. It is produced using phosgene. A highly-toxic gas, which serves as a chemical reactant under slight overpressure. When water condenses in the pipework, the phosgene decomposes. Carbon dioxide and hydrochloric acid are produced as a result, which can cause acute pitting corrosion and eventually leakage from the components concerned.

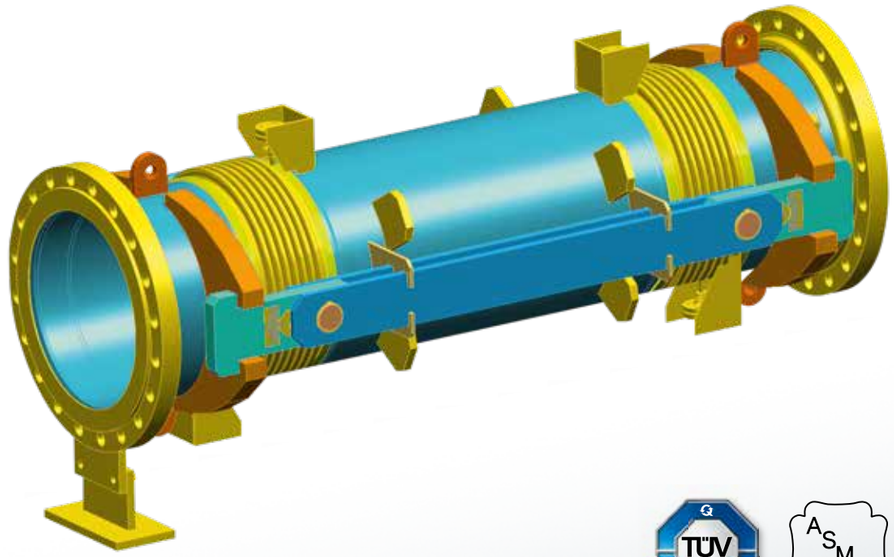
Phosgene is highly toxic and must not enter the environment. Therefore, components used in phosgene plants are designed to be highly corrosion resistant. Critical pipeline components, such as expansion joints, are removed every 6 months and inspected for corrosive attack and leak tightness.

The challenge

To develop a concept that allows the expansion joints to be simply and quickly exchanged every 6 months for prophylactic testing. Continuous leakage monitoring of the expansion joints during operation was also required.

The requirements in detail

- Design of the components for a total service life of 10 years
- Safety concept with integrated leak monitoring of the bellows
- Use of highly corrosion-resistant materials for bellows and connectors
- High mechanical protection of all components
- Quick and simple assembly and disassembly of expansion joints
- Facility to carry out pressure test while removed



THE IMPLEMENTATION

Expansion joints in the high safety area

Hinged Expansion joints

Leak monitoring

In order to satisfy the tough demands on the one hand and realise a troublefree assembly and disassembly on the other, expansion joints with the following characteristics were developed, designed and manufactured.

High precision in DN 600 x 2500 mm

The components are hinged expansion joints with pipe connections; designed as a welded construction. Due to the anchorage system, the total length of the expansion joints is fixed. The installation length cannot therefore be varied by the expansion or compression of the bellows. In terms of the manufacture, this meant exceptionally narrow production tolerances of +/- 1.5 mm over the overall length of 2,5 m to enable the expansion joints to be exchanged true to size during operation. Greater length tolerances could lead to gaps during installation, which cannot be compensated by gaskets or length changes in the plant.
The tolerances, narrower than specified in DIN EN ISO 13920 by a factor of approx. 10, were achieved by a specifically coordinated production sequence.

Leak monitoring system

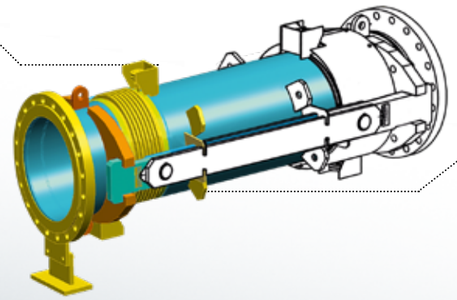
The expansion joint bellows consist of 4 layers. This combines a high pressure resistance and bursting safety with a high fatigue strength. In addition, the inner layers are monitored by two leak monitoring systems per bellows. If the inner layer is damaged, phosgene escapes into a sealed monitoring system in a controlled manner and is displayed. A display in the leak monitoring system indicates that the bellows need to be exchanged. Due to the 4-layer bellows construction, however, the leak tightness of the expansion joint remains guaranteed and an immediate plant shutdown is not required.

Material

The bellows were produced from solution annealed 2.4856 / Alloy 625 and designed for a service life of 10 years. The other media carrying pipe sections were produced from 1.4562, a high-alloy stainless steel which is resistant to pitting corrosion by hydrochloric acid.

Leak monitoring system

If the inner layer of the bellows leaks, phosgene escapes into a sealed and monitored intermediate cylinder space in a controlled manner.



Fixing device

Prevents deformation during installation and removal of the 1.5 tonne expansion joint and stabilises it during a pressure test with blind flanges

THE IMPLEMENTATION

Expansion joints in the high safety area

High-precision welded construction

Quality

Blind flanges

A pressure test in the removed state is carried out using gas and pressure-tight blind flanges

Blind flanges for inspections

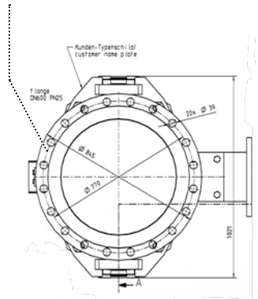
To enable the expansion joints to be tested for pressure resistance and leak tightness when removed, special blind flanges were produced. These permit both a helium leak test and a pressure test to be carried out.

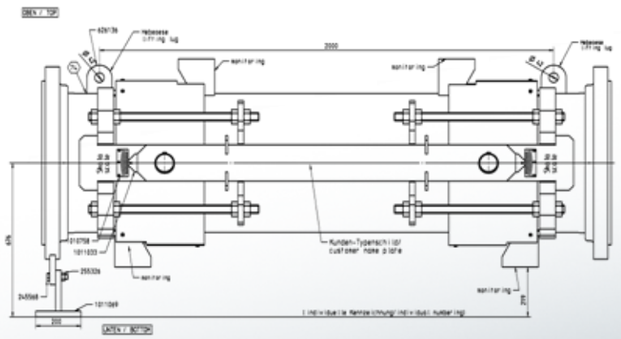
Quality

The highly-toxic medium necessitated extensive quality measures:

- X-ray and dye penetration tests of all medium and pressure-bearing weld seams
- Dual control principle: Checking all relevant documents by Witzenmann and the customer
- Preliminary examination of the design work by notified body
- Joint acceptance of the components by notified body, the customer and technical experts from Witzenmann
- Flow-through test for the leak monitoring system
- Full documentation, including inspection instructions for the on-site test

Type	HYDRA LFZ 25.0600.340.0 / Lateral expansion joint with fixed flanges, for movement in one plane
Nominal diameter	DN 600
Nominal pressure	PN 25
Operating pressure	-1 / 6 bar g
Operating temperature	-10 / +400 °C
Test pressure	37.5 bar
Movement	+/- 170 mm lateral
Load cycles	7000
Bellows material	2.4856 / Alloy 625
Pipe section material	1.4562 / Alloy 31
Weight	1600 kg

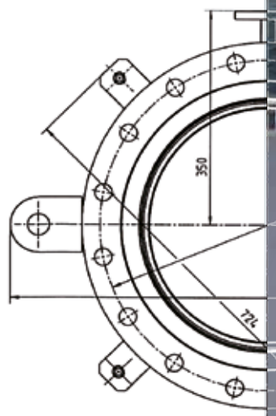




PROJECT RELIANCE, PTA PLANT

MATERIAL: TITANIUM

Specific: Forming processes and clean room welding under an argon atmosphere



The project

In India, two PTA plants were built. PTA (Purified Terephthalic Aid) is used primarily for the production of fibres for the polyester industry and for foodstuff packaging (PET beverage bottles). For the recovery of PTA, a 95% acetic acid is used as a reaction solvent, a highly-corrosive medium.

In total, the project comprised 170 expansion joints in 35 different designs. The customer provided specifications and boundary conditions (overall length, spring rates, friction in the joints, etc.). The plant was built in accordance with ASME B31.3 respectively to ASME standard. Witzenmann has the ASME U Stamp, and is therefore qualified for production according to ASME rules.

The requirements

- Design of steam lines for boilers in India Boiler Regulations (IBR)
- Design of individual expansion joints in titanium due to a highly aggressive medium (suspension of the PTA crystals, "acetic acid + bromide solution")
- Use of corrosion-resistant materials such as Inconel 625, Incoloy 825 or SS316Ti
- Documentation, quality assurance, inspection of the parts and components, as well as welding documentation according to ASME B 31.3 and IBR

Specifics of titanium

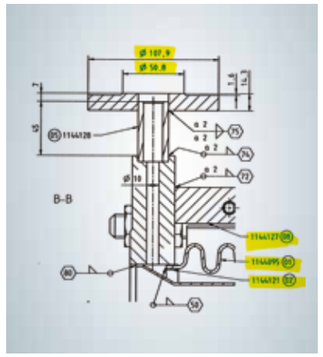
- Highly demanding forming process
- Complex welding process, since an absolutely ferrite-free environment has to be created
- Complex service life design, since there are no appropriate material fatigue curves for titanium

THE IMPLEMENTATION

The implementation faced multiple, unusual challenges: bellows design, forming, welding

Integrated flushing connection

Integrated flushing connection



The design of the bellows

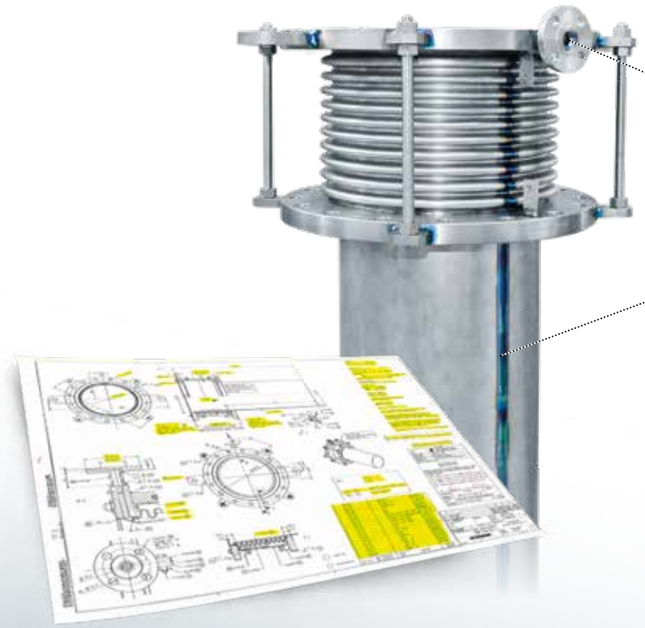
The purchaser demanded a defined service life for the components. As a rule, this is determined by the number of load cycles. However, there are no material fatigue curves for titanium from which the service life could be calculated. In order to achieve an operational reliability over the required service life, the material laboratory at Witzenmann carried out its own experiments to determine the design relevant service life values.

The metal forming

Due to its hardness, titanium is exceptionally difficult to form. For this reason, the traditional punching method cannot be applied to manufacture these bellows. The individual bellows corrugations are formed by successive high precision elastomeric forming.

The "ferrite problem"

Titanium reacts with ferrite. Even the smallest traces of ferrite can cause corrosion. Only completely ferrite free production guarantees flawless quality. Therefore, the titanium expansion joints were produced in a room designed specifically purpose of clean production. The verification of conformity to demonstrate that the environment is completely ferrite free was carried out by means of a phenanthroline test.
Likewise, the materials and tools to be processed were examined for contamination with tramp iron by the ferroxyl test, and cleaned accordingly. The complete welding process was carried out in a dome in an argon protective gas atmosphere (image page 7).



Leak monitoring

Continuous
leak monitoring

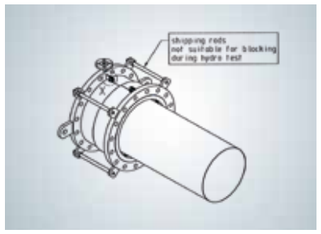
Weldseam

The weldseams were oxidised by a final anodising of the surfaces, thereby increasing corrosion resistance.

THE IMPLEMENTATION

Internal fatigue life tests created a reliable basis for the calculation

3D drawing



The comprehensive documentation

For each of the 170 items, manufacturer's documentation of up to 300 pages had to be produced. Comprising:

- Implementation of the specifications and description of the tests on the basis of a project-specific test instruction
- Inspecting the material certificates, welder and welding procedure qualification
- Confirmation of the quality requirements according to customer's specifications by TÜV Süd (TPIA)
- Inspection and acceptance of 18 expansion joints according to the Indian Boiler Regulation (IBR) and documentation according to IBR
- Issuing the certificates for the commissioning of the IBR components (IIIc certificate)

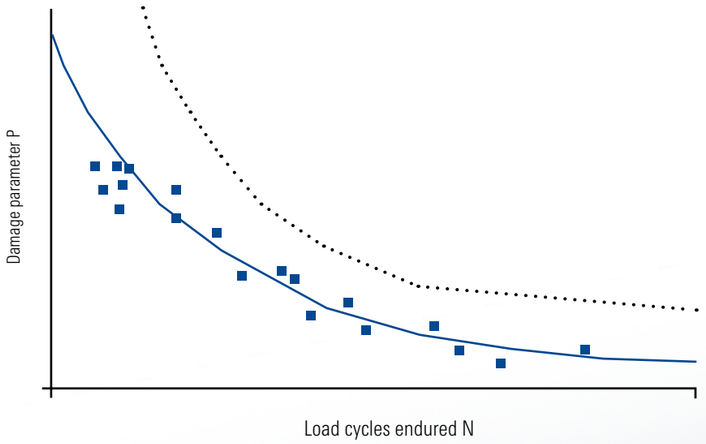
Experimental set-up
Fatigue test

Service life determination of titanium expansion joints in the material laboratory at Witzenmann

In the laboratory, two series of tests were run with titanium expansion joints.
In one series, a fatigue test with variable deflection at a room temperature of 20 °C and a pressure of 1 bar.
In the other, pressure tests to determine the bursting pressure.
An S-N curve was then derived from the load cycle tests. Depending on the load applied, the corresponding service life (load cycles N), dependent on the stresses present (damage parameters P), can then be read off.

Pressure test of titanium expansion joints

Service life curve for titanium



···· WI S-N curve 1.4571 / AISI 316Ti - 50%
— Witzenmann/titanium curve

PROJECT HUNTSMAN: RECOVERY OF TITANIUM DIOXIDE WITH SULPHURIC ACID

MATERIAL: TANTALUM

Specific: special engineering due to the extremely expensive material

The project

At the end of the 1990's, a plant was erected for the treatment of sulphuric acid. The acid is used within the plant to recover or wash out titanium dioxide (TiO_2) from existing slag. TiO_2 (titanium white) is used as a pigment in the cosmetics industry and for paints.
The technical challenge: sulphuric acid is highly-aggressive; steels, stainless steels, even nickel-based alloys (Hastelloy, Incoloy, Inconel) are not resistant to sulphuric acid.

The process

First, TiO_2 is washed out of the slag using sulphuric acid. In a downstream process, the TiO_2 is then separated from the solution. The sulphuric acid is diluted in the process. This is concentrated in a special plant section and then returned to the process. The sulphuric acid solution is heated to around 150 °C - 200 °C so that the water content evaporates.

The challenge with tantalum expansion joints

- Tantalum is a very expensive material
- Tantalum can only be welded to tantalum
- Solid components made from tantalum (pipe sections, rings or flanges with larges nominal diameters) are difficult to obtain and extremely expensive
- Tantalum has a low strength, as well as a low breaking elongation (~30 %w compared to 40-50 % for austenitic materials)

The requirements

Due to the highly corrosive nature, components and piping for sulphuric acid are enamelled or produced from graphite or PTFE. Because enamelled components or parts made from graphite are barely able to absorb stresses or thermal expansions, these must be compensated by expansion joints.

The expansion joints to be installed therefore had to meet the following requirement profile:

- Resistant to corrosion from sulphuric acid
- Pressure and temperature-resistant
- Weldable
- Malleable
- High flexibility with short overall length

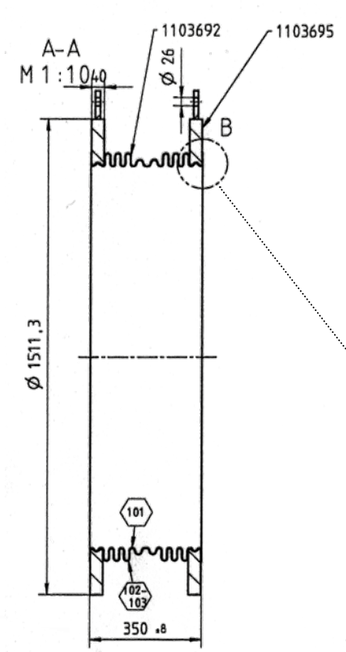
Because of these conditions, only tantalum appeared suitable for the medium-carrying parts of the expansion joints.

THE IMPLEMENTATION

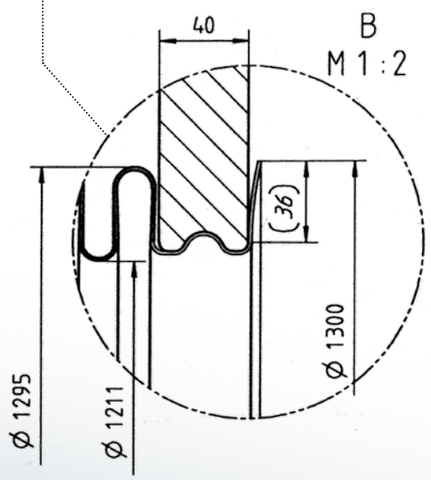
Economic efficiency through lap-joint flange

Axial expansion joint

Loose flange connection



Detail of a loose flange connection



In order to minimise the use of tantalum, multi-ply axial expansion joints with loose flanges were specified. The advantage: only the medium-carrying inner layer is produced from the expensive, highly resistant tantalum. All other layers consist of conventional stainless steel. The loose flanges of the expansion joints can also be produced from conventional ferritic steel.

The flange connection is a Van Stone design and therefore only the medium-bearing inner layer has to be produced from tantalum, not the entire bellows.

Further advantages

- Only one tantalum weldseam in the inner cylinder. This weldseam is made without filler material
- High pressure resistance due to multi-ply bellows design
- Vacuum resistance due to a adequately thick tantalum inner layer

Product	DN	PN
Axial expansion joints	100 - 1200	1 - 25, vacuum
Angular expansion joints	100 - 1200	1 - 25

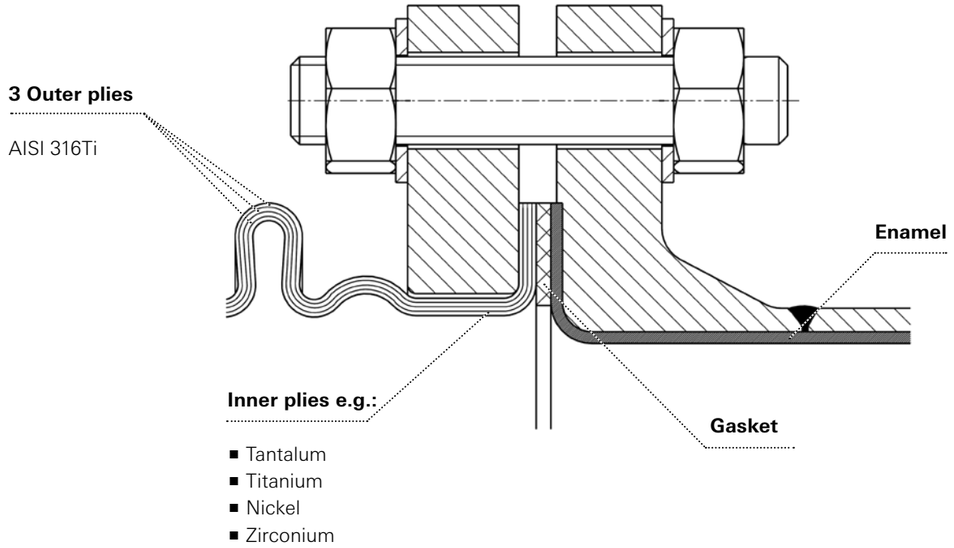
The bending of the bellows ends allows material intensive components such as flanges to be produced from conventional materials, as they do not come into contact with the aggressive medium.

MULTI-PLY DESIGN

Multi-ply design of expansion joints for highly-aggressive media

Multi-ply in detail
Sketch: multi-ply bellows with rotating flange

The multi-ply design of bellows permits the combination of a high pressure resistance and a large absorption of movements. Because the plies are made of dissimilar materials, highly corrosion resistant expansion joints can be produced in a resource efficient and cost efficient manner.



- Tantalum
- Titanium
- Nickel
- Zirconium

REFERENCES

Chemical industry
- Akzo Nobel (Netherlands)
- BASF (Germany, Belgium, China, USA)
- Bayer (Germany, China, France)
- Dow Chemicals (Germany, USA, China)
- DuPont (Germany, USA)
- Evonic (Germany, China)
- Kronos Tital (Germany)
- Linde (Germany)
- Lyondell Basell (Germany)
- Reliance (India)
- SABIC (Netherlands, Saudi Arabia)

Refineries
- BP (Belgium, Germany)
- Exxon Mobil / ESSO (Germany)
- IOCL (India)
- Lukoil (Russia, Rumania)
- MiRO (Germany)
- Reliance (India)
- SABIC (Netherlands)
- Shell (Germany)
- Sinopec (China)
- Stat Oil (Norway)
- Tamilnadu Petroproducts Ltd (India)
- Total (France, Germany)

Engineering
- Aker (Norway, China, France, India)
- CBI (USA)
- CTCI (Taiwan)
- Dealim (Korea)
- Fluor (Germany, China, Netherlands)
- Foster Wheeler (UK, India)
- Jacobs Eng. (UK, Netherlands, Germany)
- JGC, (Japan, China)
- Larsen & Toubro (India)
- Technip (France, Germany, China, Netherlands)
- Toyo (Japan, China)
- Sinopec Engineering Company, SEC (China)
- Wuhan Engineering Company (China)

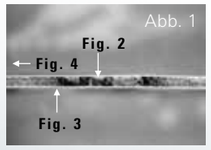
COMPETENCE IN MATERIAL

Deformation and welding of the dissimilar materials are key quality and engineering features of our production facility. We now have over 700 process audits. Of these, between 70 and 80 are renewed annually.

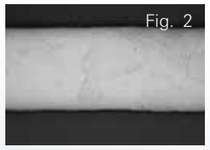
	Tantalum	**Titanium**	**Alloy 625 Grade 1 < 450 °C**	**Nickel**	**Zirconium**
	Ta (> 99 %)	Ti (> 99 %)	Ni (> 58 %)	Ni (> 99 %)	Zr (+HF > 99 %)
Temperature resistance	As per VdTÜV Page 382 from -10 to 250 °C	As per VdTÜV Page 382 from -10 to 250 °C Ti or 300 °C (Ti2, Ti3 and Ti4)	As per VdTÜV to 450 °C As per DIN EN 10095 900 °C	As per VdTÜV Page 345 600 °C	As per VdTÜV to max. 250 °C
Weldability with other materials	Good weldability, however in protective gas with high requirements for purity, can be welded only to tantalum	Good weldability, can be welded only to Ti	Good weldability to all standard steels and stainless steels	Good weldability	Weldable under certain preconditions can be welded only to Zr
Formability	High ductility, easy formable without chippings, low yield strength	Low formability	High ductility, good formability, High yield strength	Forgeable, ductile	Good mechanical processing, fine chippings and dusts are highly-flammable, low yield strength
Corrosion resistance Pitting *	Outstanding corrosion resistance in acids	Very good corrosion resistance	Very good corrosion resistance	High heat and corrosion resistance	Excellent corrosion resistance with high strength values and low specific weight
Sulphuric acid *	Resistant	Conditionally suitable to unsuitable, degrading corrosion up to 1 mm/year	Conditionally suitable to unsuitable, degrading corrosion up to 1 mm/year	Conditionally suitable to unsuitable, non-resistant to various forms of corrosion	
Hydrochloric acid *	Suitable at concentrations of up to 5%, at higher concentrations: non-resistant to various forms of corrosion	Conditionally suitable to unsuitable, degrading corrosion up to 1 mm/year, at higher concentrations: non-resistant	Not suitable	Conditionally suitable to unsuitable, non-resistant to various forms of corrosion	
Phosphoric acid *	Suitable and resistant	Suitable in concentrations of up to 20%	Suitable and resistant	Suitable at very low concentrations (1%), otherwise unsuitable	
Formic acid *	Suitable and resistant	Suitable at concentrations of up to 75%, otherwise unsuitable	Conditionally suitable, degrading corrosion up to 1 mm/year	Conditionally suitable, degrading corrosion up to 1 mm/year	
Aqua regia *	Resistant	Resistant	Non-resistant	Non-resistant	Non-resistant

** the corrosion rate is dependent on temperature and concentration*

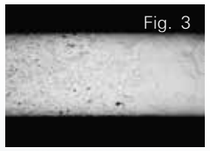
Tantalum butt weld investigation



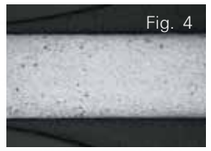
Labelling of detailed images



Microstructure in the weldseam



Weldseam/tantalum material transition



Microstructure in the uninfluenced tantalum material

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 loose 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.