WITZENMANN

Metal Bellows

Metal Bellows Manual

WITZENMANN

managing flexibility

HYDRA

Quality by Witzenmann

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Fully revised version of metal bellows manual.

As at: March 2009

Technical changes reserved.

Technical data can also be downloaded as a pdf file
at www.flexperte.de

You can also request our calculation and configuration software Flexperte. It contains all of the technical principles required for the configuration of expansion joints, metal hoses, metal bellows and pipe hangers.

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Manual of metal bellows

Contents

Witzenmann

1 | Witzenmann, the specialist for flexible metal elements

Solution competence
Flexible metal elements are used whenever flexible components must be sealed in a pressure-, temperature- and media-resistant manner, when deformations of pipe systems caused by changes in temperature or pressure must be compensated, when vibrations occur in piping systems, when media must be transported under p ressure or when a high vacuum must be sealed. They include e.g. metal bellows, diaphragm bellows, metal hoses or expansion joints.

Witzenmann, the inventor of the metal hose and founder of the metal hose and expansion joint industry is the top name in this area. The first invention, a metal hose which was developed and patented in 1885, was followed by a patent for the metal expansion joint in 1920.

Global presence
As an international group of companies with more than 3,000 employees and 23 companies, Witzenmann stands for innovation and top quality. In its role as technology leader, Witzenmann provides comprehensive development know-how and the broadest product programme in the industry. It develops solutions for flexible seals, vibration decoupling, pressure dampening, compensation of thermal expansion, flexible mounting or transport of media. As a development partner to customers in industry, the automotive sector, building equipment area, aviation and aerospace industry and many other markets, Witzenmann manufactures its own machines, tools and samples, and also has comprehensive testing and inspection systems.

An important factor in its cooperation with customers is the technical advice provided by the Witzenmann competence centre located at the Pforzheim headquarters in Germany. Here, teams of highly-qualified engineers work closely with customers to develop products and new applications.
Our experts support customers from the first planning stage up to series production.

Better products
This type of broad-based knowledge results in synergy effects which can be experienced in each product solution. The variety of application areas is nearly limitless. However, all product solutions have the following in common: maximum safety, even under sometimes extreme operating conditions. This applies to all Witzenmann solutions — ranging from highly-flexible metal hoses or expansion joints for use in industry to precision bellows for high-pressure fuel pumps, piezo injectors or pressure sensor glow plugs in modern vehicle engines.

2 | Products and production methods

2.1 | HYDRA metal bellows (corrugated bellows)

Metal bellows are thin-walled cylindrical components. Their surface area features a corrugated structure which is perpendicular to the cylinder axis. Because of this corrugated structure, the bellows are highly flexible during axial, lateral and/or angular deformation. At the same time, they are pressure-resistant, tight, temperature- and corrosion-resistant as well as torsion-resistant. Metal bellows are the preferred construction element anytime a combination of these properties is required; for example

- as pressure and temperature resistant sealants for valve shafts,
- as circuit breaker in high-voltage facilities,
- as flexible seals in pumps and pressure accumulators,
- as flexible as well as pressure- and temperature-resistant sealing element in modern gasoline injectors and glow plugs,
- as mechanical couplings,
- as tight spring elements in sliding ring seals or
- as tight and mechanically stress-free duct through container walls.

When configured correctly, HYDRA metal bellows are robust and maintenance-free components with a high degree of operational safety and a long service life.

HYDRA metal bellows are manufactured from thin-walled tubes by hydraulic shaping. Depending on the requirement profile, they can be designed either with one or multiple walls. Single-walled bellows feature low spring rates and are used particularly in vacuum technology. Multi-plied

2.1 | HYDRA metal bellows (corrugated bellows)

Figure 2.1.1.: HYDRA metal bellows with (left) and without (right) connecting parts

bellows are very pressure resistant and at the same time very flexible. They are used as e.g. valve shaft seals for operating pressures exceeding 400 bar.
Witzenmann generally manufactures the thin-walled tubes used to manufacture bellows of metal bands with a wall thickness of 0.1 mm to 0.5 mm with longitudinal welding using a continuous-drawing process (Figure 2.1.2. above left). These semi-finished products are also marketed in a separate piping program. Alternatively, longitudinally-drawn tubes or deep-drawn sleeves can also be used as semi-finished products. During the production of multi-plied bellows, several finely graduated tube cylinders are telescoped before the bellows is pressed (Figure 2.1.2. above right). During the pressing of the bellows, a cylinder portion is separated using outside and inside tools, subsequently hydraulic liquid with inside pressure is applied. The liquid pressure shapes the sealed tube section into the pre-corrugation. In the next work step the tool is axially closed and the actual bellows corrugation is formed as the pre-corrugation straightens up. Usually bellows corrugations are produced consecutively using the individual corrugation method. Using the same principle, more elaborate tools would allow for multiple corrugations to be formed in one step (simultaneous procedure, Figure 2.1.2. below), which is a more economic method when large numbers of units are produced.

The height and hence flexibility of the bellows corrugation is limited by the ductility of the material which is used. Using austenitic stainless steels and nickel-based alloys, the individual corrugation method achieves ratios between outside and inside diameter for bellows corrugations of between 1:1.5 (nominal diameter 15) and 1:1.3 (nominal diameter 150). The simultaneous procedure results in somewhat lower diameter ratios.

In order to remove the bellows from the tool, the profile may not be undercut subsequent to the pressing of the bellows (Figure 2.1.3. left). Such sinus-shaped or u-shaped non-undercut profiles are used for e.g. very low profile heights (flaring) or extremely pressure resistant bellows. Usually the bellows is also compressed in the direction of the axis, creating an undercut profile (Ω-profile, Figure 2.1.3. right). The advantages of the Ω-profile include a significantly lower spring rate per corrugation, and a shorter corrugation length. At the same production length, a bellows with a Ω-profile has more corrugations than a sinus-shaped profile and is therefore able to compensate larger movements.

Bellows with bottoms

Bellows with bottoms can be manufactured directly from deep-drawn or extruded sleeves. Bronze and tombac are particularly well-suited materials for this purpose. Stainless steel sleeves can also be produced by deep drawing or reverse extrusion; however, this involves a far more elaborate process. Since the production of the sleeves usually requires a special tool, for cost reasons this method is only recommended for larger quantities.

In the case of smaller quantities or multiplied bellows, it is more cost-efficient to solder turned or pressed workpieces into bronze or tombac bellows. Discs which are welded to the bellows to form a bottom are recommended for stainless steel bellows. A weld connection to swivel or press workpieces is also possible.

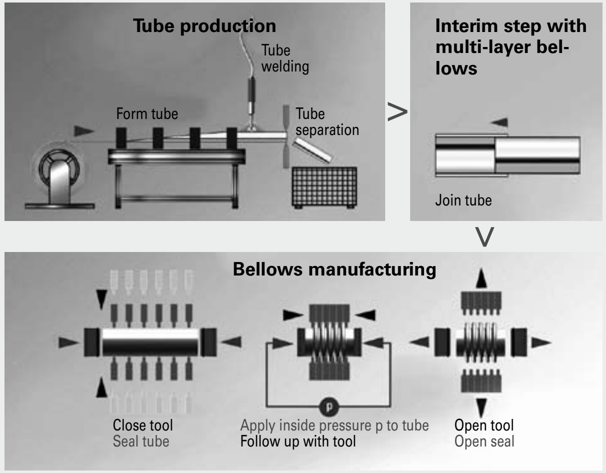


Figure 2.1.2.: Production of metal bellows in simultaneous procedure

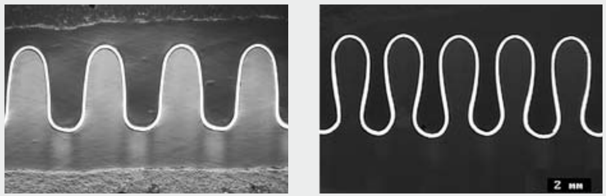


Figure 2.1.3.: Non-compressed (left) and compressed bellows profile (right)

2.2 | HYDRA precision bellows

As of 3 mm diameter

HYDRA precision bellows are used in the automotive industry as high-pressure resistant and flexible seals for piezo sensors and actuators. Applications such as gasoline injectors or pressure sensor glow plugs require a tolerance of pulsating pressures of approx. 300 bar on a permanent basis. Bellows with significantly increased pressure resistance, e.g. for a direct needle seal of diesel injectors, are also available.

Figure 2.2.1.: HYDRA precision bellows

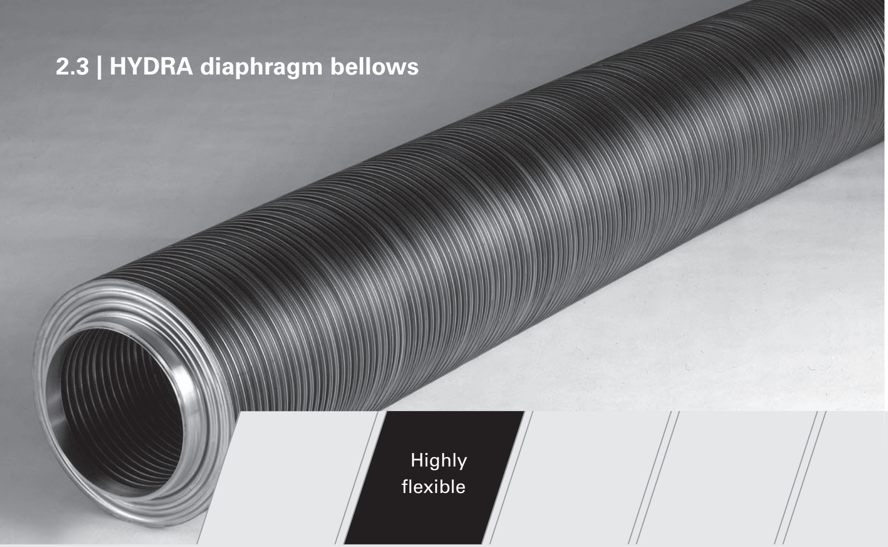
Precision bellows can also be used as highly flexible, non-pressure bearing seals. To displace large volumes, these bellows require a high range of movement; in addition, they usually also require a service life of more than 10^9 load cycles. These precision bellows are used in modern gasoline pumps, pressure accumulators or pressure attenuators.

HYDRA precision bellows are developed especially for specific operating conditions. Development services also include the mathematical verification of temperature and pressure resistance as well as service life, and a validation and re-qualification under near-application conditions.

2.2 | HYDRA precision bellows

Figure 2.2.2.: HYDRA precision bellows production under clean-room conditions

2.3 | HYDRA diaphragm bellows



HYDRA diaphragm bellows consist of diaphragm discs, which are welded together in pairs. Figure 2.3.2. shows the schematic structure of a diaphragm bellows as well as a typical diaphragm bellows profile in the form of a metallographic cut. Diaphragm bellows feature high specific expansion compensation (up to 80% of production length), very low spring rates as well as a high hydraulic cross-section. Pressure resistance is usually limited to a few bars. Therefore diaphragm bellows are especially suited for low-pressure or vacuum applications.

HYDRA diaphragm bellows are used in measurement and control devices, vacuum technology, aerospace and aviation industry, medical technology, specialised controls and instrument engineering, sliding ring seals as well as volume compensation units in oil-cooled high-voltage facilities. By virtue of their design, diaphragm bellows are subject to high notch stresses at the weld seams. To guarantee a long service life, tensile stress should be minimised as much as possible. This can be achieved by dividing the axial displacement into 80% compression (shorten bellows) and 20% stretching (extend bellows). Other load distributions should be installed pre-stressed into the bellows.

Figure 2.3.1.: HYDRA diaphragm bellows

2.3 | HYDRA diaphragm bellows

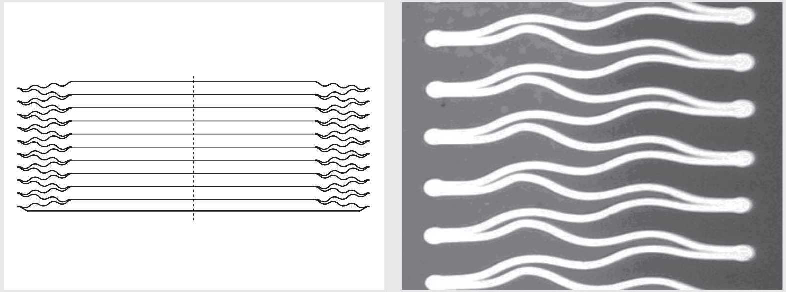


Figure 2.3.2.: Diaphragm bellows profile as a diagram (left) and as a metallographic cut (right)

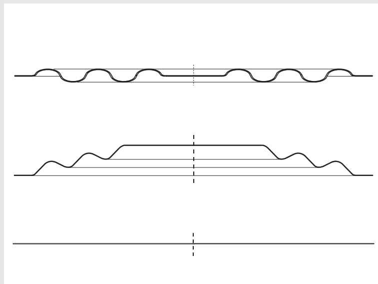
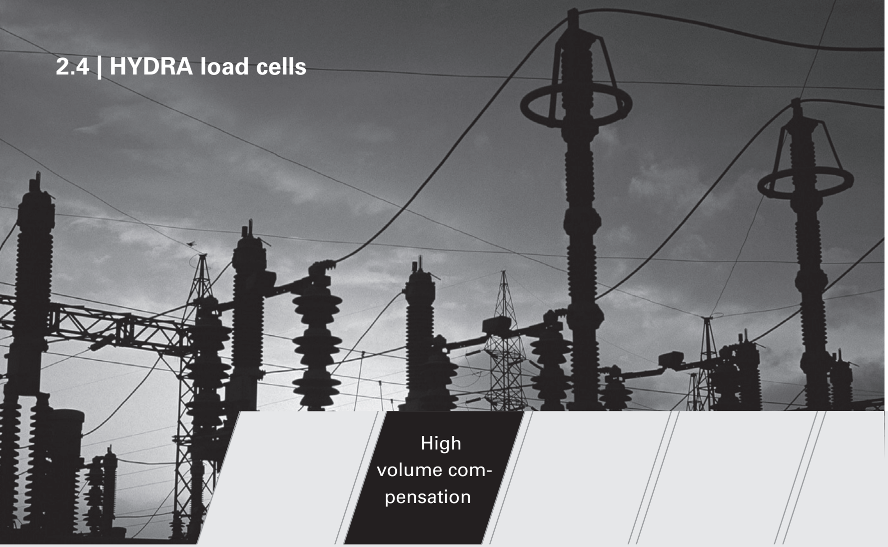


Figure 2.3.3.: HYDRA diaphragm discs: rilled diaphragm discs (above), rilled diaphragm discs with flat bottom (centre) as well as flat diaphragm discs (below)

Additional items which are available on request are:

- Diaphragm discs (Figure 2.3.3 above),
- Diaphragm discs with flat bottom (Figure 2.3.3 centre) as well as
- Diaphragm discs (Figure 2.3.3 below)

with wall thicknesses of 0.1 mm, 0.15 mm, 0.2 mm, 0.25 mm and 0.3 mm. These diaphragm discs lend themselves to conditions where working strokes or volumes displaced are small, and a high degree of system rigidity is required.



2.4 | HYDRA load cells

High
volume com-
pensation

HYDRA load cells are used to absorb changes in volume. Their advantages include high volume compensation with minimal reaction pressure, corrosion and temperature resistance as well as long-term diffusion tightness and long service life.

Due to their functionality, HYDRA load cells are not very pressure resistant. However, pressure resistance can be significantly increased through the use of support rings or specially profiled cores. The pressure-volume characteristic curves for HYDRA load cells are non-linear (Figure 2.4.2.); the related increase in volume $\delta V/\delta p$ decreases as pressure increases.

HYDRA load cells are manufactured of drawn stainless steel diaphragms with special profiling, which are welded to each other at the circumference. Standard connections include easy-to-mount brass clamp ring connections. Other connections are available on request. Installation possibilities include, among others, column configurations, whereby multiple cells can be coupled to achieve greater volumes.

One application area of HYDRA load cells includes the compensation of temperature-dependent volume changes for insulating oils in high-voltage converters. In this case, the insulating oil is hermetically sealed to the outside within the load cell, thus protecting the inside area of the insulator.

2.4 | HYDRA load cells

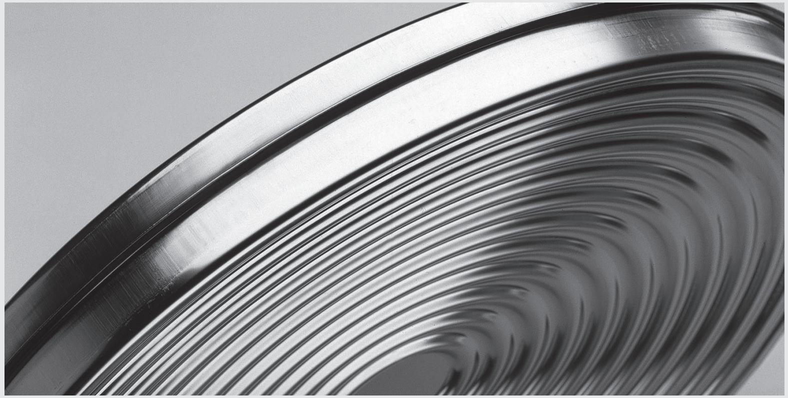


Figure 2.4.1.: HYDRA load cell

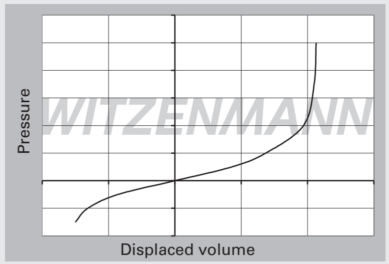
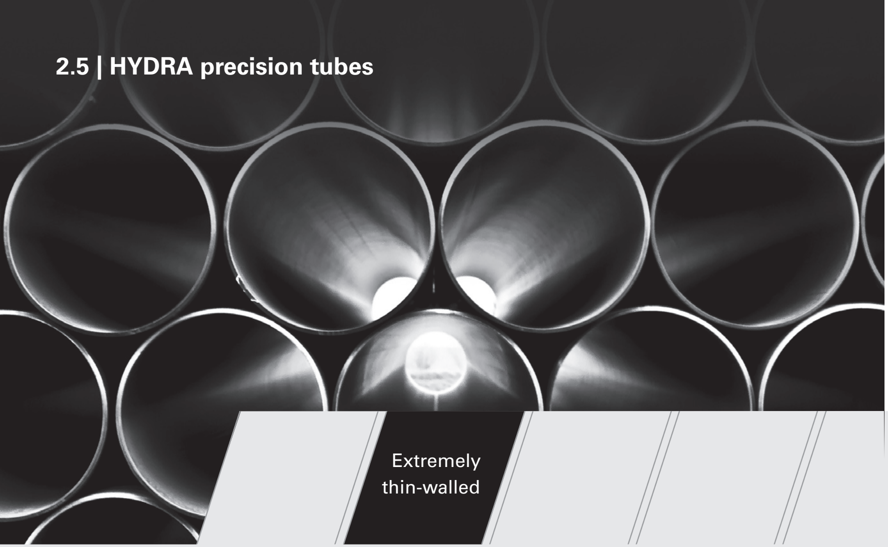


Figure 2.4.2.: Characteristic curve for a HYDRA load cell (diagram)



Thin-walled stainless steel tubes with a longitudinally welded butt weld are manufactured as semi-finished products for the manufacture of metal bellows. Whereas 1.4571 is a standard material, the majority of sizes is also available in stainless steel 1.4541, 1.4828 as well as titanium, nickel or nickel-based alloys Inconel 625, Incoloy and Hastelloy. The tolerances for tube diameter and length are in the range of ±0.1 mm. The maximum production length of a tube is 6.50 m; shorter dimensions are available in any length.

Figure 2.5.1.: HYDRA precision tubes

2.6 | Bellows materials

Bellows materials must feature a high degree of deformability. For this reason, metals with a face centred cubic structure are preferred. The most significant material families for bellows production are austenitic stainless steels, nickel and nickel-based alloys as well as copper and bronze. Materials are selected on the basis of requirements as regards **media and corrosion resistance, temperature resistance as well as yield strenght and fatigue resistance.**

Table 2.6.1. provides an overview of available bellows materials and their suitability for corrugation and diaphragm bellows production.

The standard material for metal bellows is the Ti-stabilized austenitc stainless steel 1.4571. It features a high corrosion resistance, a high yield and fatigue strength, an excellent workability and weldability as well as a favourable material price.

In the case of metal bellows, because of the method used, Ti(CN)-precipitations discharges which are typical for titanium-stabilised materials are configured parallel to the bellows surface, so that they do not impair the performance of the bellows either as a mechanical notch or possible diffusion path.

Stainless steel 1.4404 or 1.4441, which often are not titanium-stabilised, are used in food, medical and vacuum technology applications. These materials feature higher degrees of cleanliness as compared to 1.4571, as well as slightly reduced yield strenght, minimally reduced fatigue resistance and higher tendency for heat fractures during welding.

2.6 | Bellows materials

Available bellows materials, standard materials are indicated in bold

Material number	Material type/ Trade name	Suitability for Corrugated bellows	Suitability for Diaphragm bellows	Comment
1.4541	Titanium-stabilised austenitic stainless steel	++	++	
1.4571		++	++	**Standard material**
1.4404	Titanium-free austenitic stainless steel	++	++	Food and vacuum technology
1.4441		++	++	On request
1.4828	Scale-resistant stainless steel	+	+	
1.4876	Incoloy 800 H	++	++	Suitable for temperatures over 550 °C
1.4564	17-7 PH	++	+	Hardened stainless steel
1.4568				
–	AM 350	+	+	
2.4816	Inconel 600	+	+	On request
2.4856	**Inconel 625**	++	++	**Standard materials for high pressures, temperatures and/or increased corrosion requirements**
2.4819	**Hastelloy C-276**	++	++	
2.4610	Hastelloy C-4	+	–	High degree of acid resistance
2.4617	Hastelloy B-2	+	–	
3.7025	Pure titanium, Grade 1	+	+	
3.7035	Pure titanium, Grade 2	+	+	
2.4360	Monel	+	–	On request
2.4060	Pure nickel	+	–	
2.1020	Bronze CuSn6	++	–	
2.1030	Bronze CuSn8	++	–	

Table 2.6.1.

2.6 | Bellows materials

In the valve area, bellows made of nickel-based alloys are used with higher corrosion requirements as well as at high pressures and temperatures. Standard materials include 2.4819 and 2.4856. Based on their higher yield strenght, bellows made of these nickel-based alloys are also more pressure resistant than similar bellows made of austenitic stainless steel.

The service life of bellows made of nickel-based alloys at room temperature is shown in figure 4.8.1. as compared to the service life of austenitic stainless steel bellows. The use of nickel-based alloys is advantageous for up to approx. 50,000 load cycles. In contrast, once the number of load cycles increases, the fatigue resistance of austenitic stainless steels is higher.

In the high-temperature range, the service life of nickel-based alloys is generally higher than that of stainless steels.

For special applications, hardened stainless steel or hardened nickel-based alloys may also be used.
These materials are subjected to heat treatment following the bellows formation, which results in a considerable increase in yield strenght and fatigue resistance. These features are countered by reduced corrosion resistance, higher material costs as well as the extra heat treatment process during production.

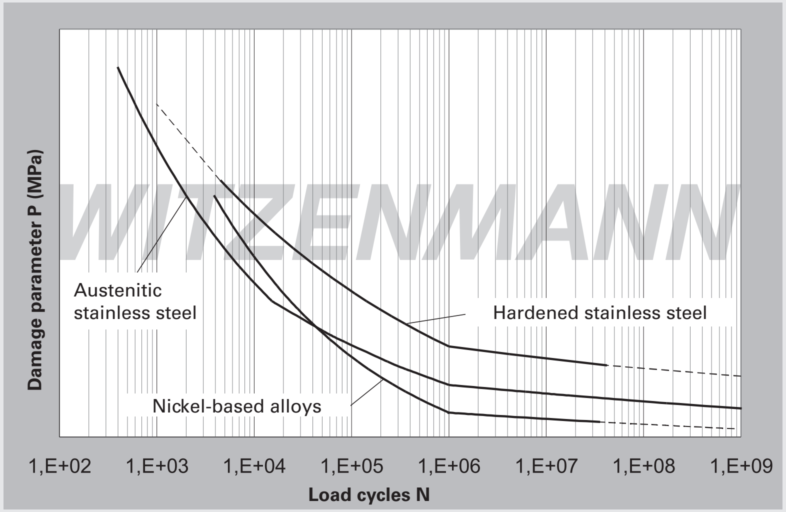
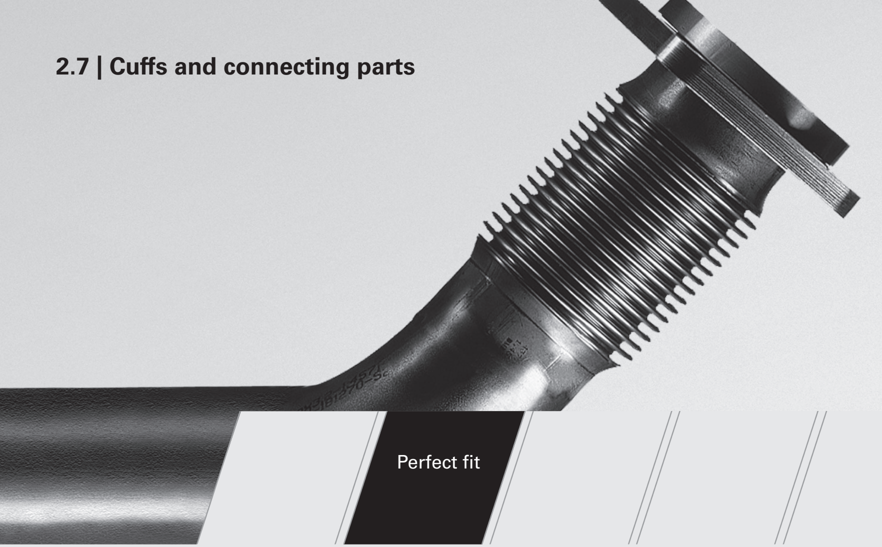


Figure 2.6.2.: 50% S-N-curve at room temperature for metal bellows made of austenitic stainless steel, nickel-based alloys and hardened stainless steel in comparison.

2.7 | Cuffs and connecting parts



Perfect fit

The bellows cuffs are used to connect the bellows with their connecting parts. This connection must meet the same requirements as the bellows with regard to tightness, temperature and media resistance, pressure resistance and service life. For this reason the connection must be selected and executed carefully. It is mainly governed by the connection type and the stress on the bellows.
The following standard cuffs are available:

Bellows without machined cuffs
Bellows with these cuffs can be supplied in all types on short notice.

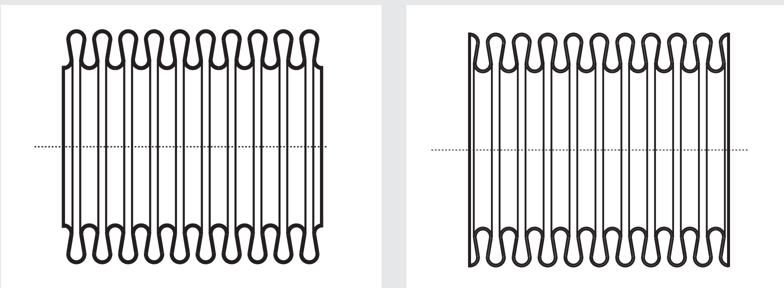


Figure 2.7.1.: Bellows cut off at inside lip (left) and cut off at outside lip (right)

2.7 | Cuffs and connecting parts

B-cuff
This type is simple and cost-effective to produce from a bellows corrugation, either by punching or turning. The connecting part geometries are simple. The B-cuff is suitable for laser, microplasma or arc welding. Bellows with up to 1 mm total wall thickness are welded without, whereas bellows with larger total wall thickness are welded with additional materials.
A disadvantage of the B-cuff is the notch effect of the round seam and its positioning in a mechanically stressed zone. For this reason this type of connection is not recommended if large load cycles are required, or in the case of (pulsating) inside pressure loads. On the other hand, the B-seam is well suited for valve shaft bellows with high outside pressure loads, since in this case the effect of the outside pressure is to close the notch and hence increase the service life. Other advantages of the B-cuff include the low production length and the gap-free connection between bellows and connection part on the outside of the bellows. The latter is particularly important for bellows applications in the food industry and vacuum technology.

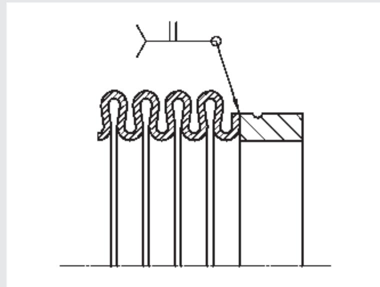


Figure 2.7.2.: Metal bellows with B-cuff and connecting part

S-cuff / Ja-cuff
The S-cuff is formed through rolling from a bellows corrugation. In this case the weld seam is positioned in such a way that only very little mechanical stress occurs. The S-cuff is recommended for dynamic and highly-stressed components. This type is suitable for welding, soldering and glue joints.
The design of the connection parts is more elaborate than for B-cuffs, since the bellows must be placed on the connecting part in a manner that is nearly gap-free, to ensure a high-quality weld.

2.7 | Cuffs and connecting parts

For glue-based or solder connections, the connecting part should be fitted with a slot that corresponds with the cuff (compare also figure 2.7.1.). For larger series, the S-cuff can be produced hydraulically by expanding the J-cuff (Ja-cuff).

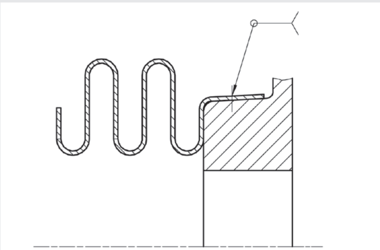


Figure 2.7.3.: Metal bellows with S-cuff and connecting part

J-cuff
The J-cuff is an easy-to-manufacture cylindrical cuff with the diameter of the outgoing tube. Similar to the S-cuff, it is suitable for weld, solder and glue connections. A J-cuff connection can be done gap-free, and is frequently used for vacuum valves. The gap-free joining of the J-cuff to the connecting part is more elaborate than pressing the S-cuff, hence it has only limited suitability for large series.

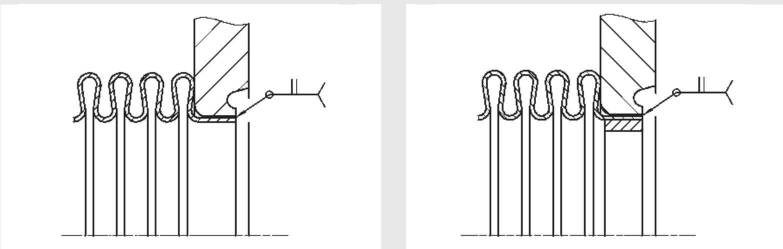


Figure 2.7.4.: Metal bellows with J-cuff and connecting part without (left) and with head ring (right)

V-cuff
The V-cuff enables the detachable joining of bellows with tubes or other bellows using V-cuff clamps. This connection is also used for high-temperature applications, such as exhaust lines in large engines. The V-cuff is a special unit which is made with a special tool kit.

Geometry of the connecting parts
The geometry of the connecting parts must be adapted to the selected cuff form and joining method. For thermal joining methods, care must be taken to ensure consistent heat input into the thin-walled bellows and the thick-walled connecting part, using weld lips, among others. They are targeted cross-section reductions at the connecting part, which reduce heat outflow from the weld zone.

Advantages and disadvantages of the individual cuff forms are illustrated in Table 2.7.1. The preferred connecting part geometries and dimensions for standard cuffs of HYDRA metal and diaphragm bellows are listed in section 6.

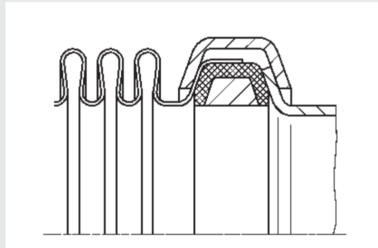


Figure 2.7.5. Metal bellows with V-cuff, V-cuff-clamp and connecting part

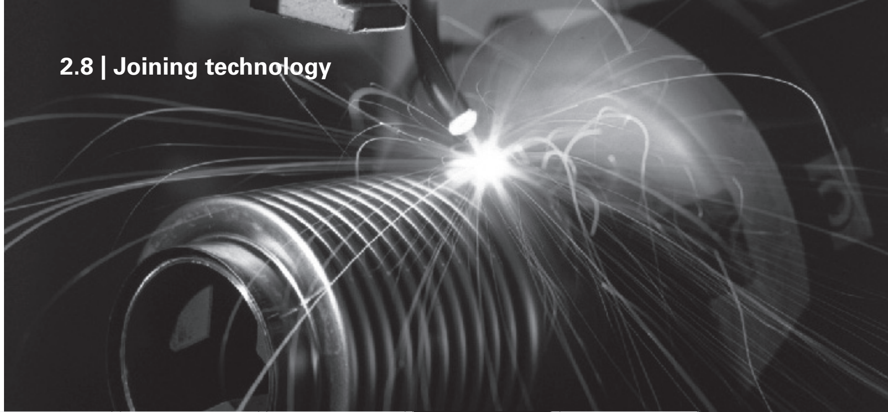
2.7 | Cuffs and connecting parts

Advantages and disadvantages of individual cuff forms

	B-cuff	Ja- / S-cuff	J-cuff	V-cuff
Producibility for				
thin-walled bellows	++	+	++	– [1]
thick-walled bellows	++	– [1]	+	– [1]
Fatigue resistance	+	++	++	+
Pressure resistance under				
inside pressure	+	++	++	– [2]
outside pressure	++	++	+	– [2]
Tightness	++	++	++	– [2]
Detachability	–	–	–	++ [2]
Suitability for				
welding	++	++	+	–
soldering	–	++	++	–
gluing	–	++	++	–
clamping	–	–	–	++

Table 2.7.1.
1) Requires special tools
2) Clamp connection

2.8 | Joining technology



100 %
Perfection

Bellows and connecting parts made of steel, stainless steel, nickel or nitrogen-based alloys, titan or the respective material combinations are usually welded together. This technology, in connection with proper weld seam preparation and the appropriate design of the weld lip, represents the ideal integration of the bellows into its functional system. For commonly-used material combinations the welding procedures are certified acc. to AD data sheet H1.

Welding methods available at Witzenmann include arc welding with and without additional materials, microplasma welding, electric resistance welding as well as continuous and pulsating laser welding methods. The latter are especially suited for welding round seams with minimal heat input and are free of temper colours. Another advantage of laser welding is its minimal effect on the structure of the base materials, as heat is applied on a very limited area. At the same time, laser welding requires more mechanical preparation of the joining area and finer tolerances for the connecting parts.

In welding, the material combination bellows / connecting part has a great influence on the quality of the weld seam. Optimal welding results are obtained with the use of titanium-stabilised stainless steels 1.4541 or 1.4571 as connecting materials. This applies both to bellows made of austenitic stainless steel 1.4541 or 1.4571 as well as bellows made of nitrogen-based alloys, such as 2.4819 (Hastelloy C 276) or 2.4856 (Inconel 625). Bellows made of 1.4541 or 1.4571 with connecting parts made of stainless steel 1.4306, 1.4307 or unalloyed quality steels, e.g. 1.0305 are also very suitable for welding. The material combination 1.4404 / 1.4404 is more difficult to weld due to heat fracture

2.8 | Joining technology

tendencies in the case of a non ferritic primary solidification.
Soldering is the most commonly used joining method for non-ferrous metals or connecting parts. Application examples include bellows for circuit breakers or actuator bellows for thermostat valves in heaters. Bronze bellows are usually soft soldered with the usual tin solder. In addition, there are also special soft solders for temperatures up to approx. 220 °C.
To prevent bellows cuffs from annealing during open-flame soldering, we recommend slot soldering. Hard soldering is not recommended for non-ferrous metals, since the high soldering temperatures glow out the cuff corrugations and hence significantly reduce service life.

Prerequisite for all soldering methods is ensuring the bellows is thoroughly wetted with the solder, which requires a very clean bellows surface.

Glue-based or force-fit connections are of minor importance. Worthy of mention is the cost-effective flange connection for bellows with loose, i.e. rotating flanges.

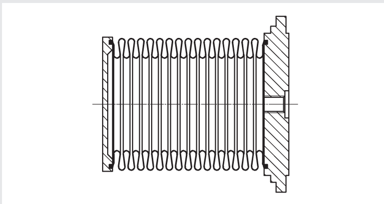


Figure 2.8.1.: Example of a solder or glued connection

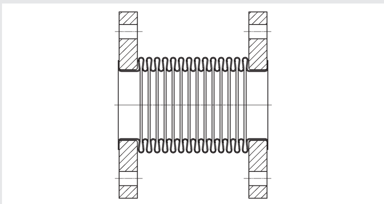


Figure 2.8.2.: Metal bellows with rotating flanges

2.9 | Quality management

Witzenmann's quality assurance system not only ensures that our products meet the high quality requirements, but also guarantees the highest degree of service quality for its customers. Our quality assurance system is audited on a regular basis.

Quality assurance is organised in two levels. Central quality assurance has responsibility over superordinate organisational and technical quality assurance measures. The quality agencies of our product areas assume quality planning, quality direction and quality inspection as part of order processing.

The quality assurance department is independent from production on an organisational level. It may issue instructions to all employees who carry out tasks which have an influence on quality.

Precise controls of suppliers
We only work with suppliers with whom we have concluded a quality assurance agreement, and who are certified according to ISO 9001, at minimum.

For semi-finished products such as bands, sheet metal, tubes and wires we require test certificates which are aligned according to the purpose of the component. Incoming inspections conducted at receiving and material laboratories ensure that deliveries conform with our order and approval specifications. In this vein, we sometimes additionally restrict and define in more detail ranges for materials which are permissible according to DIN or other data sheets.

2.9 | Quality management

Production monitoring and traceability
Operational monitoring which forms a part of the production process is tasked with the responsibility of monitoring and maintaining production equipment, as well as ensuring proper production as per the prescribed manufacturing documents. Our PPS system and archived production papers guarantee that all products can be fully tracked.
We have on hand approval reports as per EN 10204 - 3.1. for all bellows materials.

Complete monitoring of welding methods
Welding work is regulated by written instructions. Welders are certified as per EN 287-1 (EN ISO 9601-1) / EN ISO 9606-4. The most important and most commonly used welding methods are verified through process inspections. The supervision of welding activities corresponds with the corresponding requirements according to the AD Data Sheet HP3.

Monitoring of measuring and test facilities
All measuring and test facilities are regularly checked for accuracy and reliability. Calibration dates are confirmed with monitoring indicators.

Approval tests
Prior to delivery, all products are subject to measurement and visual testing, i.e. a visual inspection of bellows, weld seams and connecting parts as well as an inspection of installation and connecting dimensions.
In addition, other approval testing as per customer specifications may also be carried out, including

- Leakage testing,
- Spring rate measurements,
- Pressure resistance testing at room temperature,
- Pressure resistance testing at operating temperature,
- Load cycle testing in a non-pressurised environment at room temperature,
- Load cycle testing in near-operating conditions.

The type and scope of the tests is coordinated with the customer. The testing can be monitored by a Witzenmann representative authorised to provide approvals, by an authorised representative of the customer, or an external certified agency. Series components are tested for re-qualification as per ISO TS 16949.

Test certificates
Test certificates for the material used can be requested; band material which is usually in stock can be confirmed by way of test certificate 3.1. or 3.2. as per DIN EN 10204.
Possible certificates related to the testing undertaken are listed in DIN EN 10204 (see Table 2.9.1.)

2.9 | Quality management

Test certificate as per DIN EN 10204

2.10 | Certifications and customer-specific approvals

Worldwide leader

Test certificate as per DIN EN 10204

Description	Test certificate	Type	Content of certificate	Conditions	Confirmation of certificate
2.1	Plant certificate	non-specific	Confirmation of conformity with order.	As per the delivery conditions in the order or - if required - in accordance with official regulations and also applicable technical rules	by manufacturer
2.2	Test report		Confirmation of conformity with order with information on results of non-specific testing.		
3.1	Inspection certificate 3.1	specific	Confirmation of conformity with order with information of results of specific testing.		by manufacturer's representative in charge of approvals who is independent of the production department.
3.2	Inspection certificate 3.2		Confirmation of conformity with order with information of results of specific testing.	In accordance with official regulations and also applicable technical rules.	by manufacturer's representative in charge of approvals who is independent of the production department, and by representative in charge of approvals as authorised by the ordering party, or the representative in charge of approvals named in official regulations.

Table 2.9.1.

In 1994, Witzenmann was the first company in the industry to be certified according to DIN ISO 9001. Today, Witzenmann GmbH possesses the following general quality and environmental certifications:

- ISO TS 16949:2002
- DIN EN ISO 9001:2000
- ISO 14001:2004
- EN 9100:2003
- Pressure equipment directive
- AD2000 – Data sheet W0/TRD100
- AD2000 – Data sheet HP0 and DIN EN 729-2
- KTA 1401 and AVS D100/50

2.10 | Certifications and customer-specific approvals

Specific approvals (selection)

Gas/Water

DVGW	German Gas and Water Association	Germany
ÖVGW	Austrian Association for Gas and Water	Austria
SVGW	Swiss Association for Gas and Water	Switzerland
AFNOR	Gas Association Française de Normalisation	France

Shipping

GL	Germanischer Lloyd	Germany
ABS	American Bureau of Shipping	USA
BV	Bureau Veritas	France
DNV	DET NORSKE VERITAS	Norway

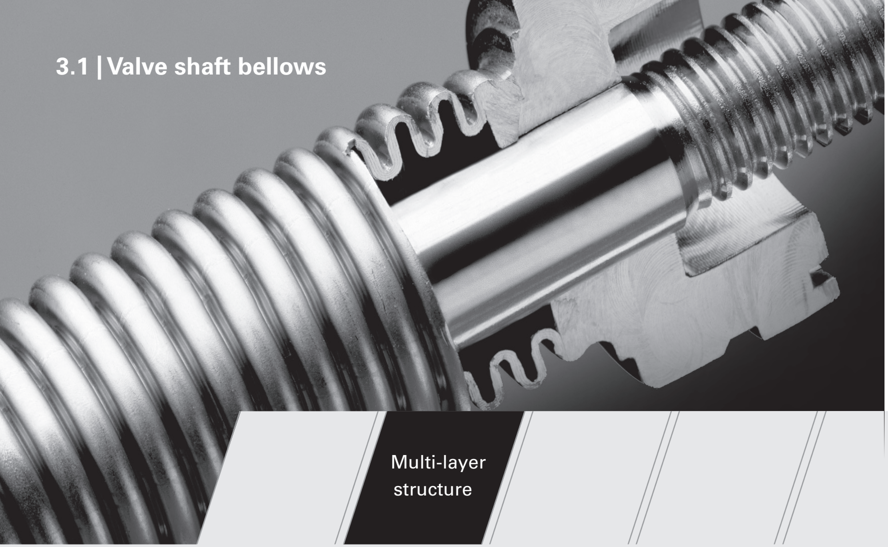
Shipping

LRS	Lloyd's Register of Shipping	UK

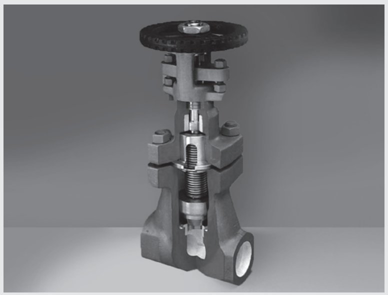
Other

BAM	Federal Agency for Material Research and Testing	Germany
VDE	Association of Electrical Engineering, Electronics	Germany
VdS	German Association of Property Insurers	Germany
FM	Factory Mutual Research	USA
LPCB – Loss Prevention	Certification Board	UK
RTN – RosTechNadzor	Federal Supervisory Authority for Ecology, Technology and Nuclear Energy	Russia

3 | Typical bellows applications



Metal bellows are used for the gland-free sealing of high-quality valves. This type of valve design features absolute tightness, high pressure-, temperature-, media-, wear-resistance. In this case the metal bellows is used as a flexible, pressure-bearing seal, and compensates the relative movements between the valve plate and housing when the valve opens or closes (Figure 3.1.1. / 3.1.2.). Valve shaft bellows are usually multi-layered in order to achieve short production lengths. Pressure is hence distributed over multiple thin layers. The bellows corrugations are mainly stressed during bending, so that corrugations that are made up of many thin layers are able to tolerate larger deformations than those which consist of one or fewer thicker layers (compare Figure 3.1.3.). Accordingly, permissible



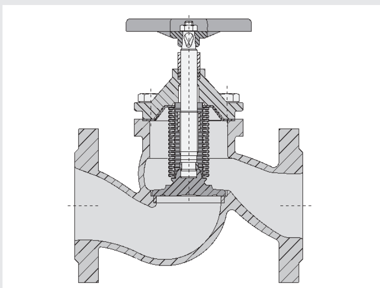


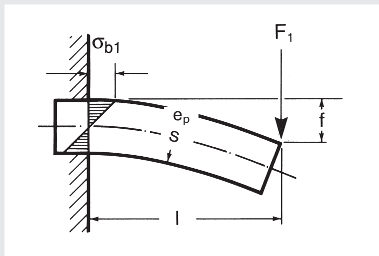
Figure 3.1.1.: Valve with metal bellows as shaft sealing

3.1 | Valve shaft bellows

movement increases with the same production length, and pressure resistance increases as the number of layers increase.

The bellows material is determined by the ambient medium and operating temperature. The preferred material for temperatures up to 550 °C is austenitic stainless steel 1.4571. For higher temperatures or with very aggressive media, nitrogen-based alloys, such as 2.4819 (Hastelloy C 276) or 2.4856 (Inconel 625) are also available. In addition to increased corrosion resistance, nickel-based alloys also feature higher strength and heat resistance values than austenitic stainless steel, and are therefore more pressure and temperature resistant. The layer structure of the bellows (number of layers and thickness of individual layers) is determined by the operating pressure. To prevent the bellows from buckling, outside pressure should always be applied to valve shaft bellows.

The number of corrugations and hence production length of the bellows is determined by the stroke and the required service life. A typical load cycle number for blocking valves is 10,000 operations. Larger load cycle numbers with reduced stroke are required for bellows for regulator valves, among others.



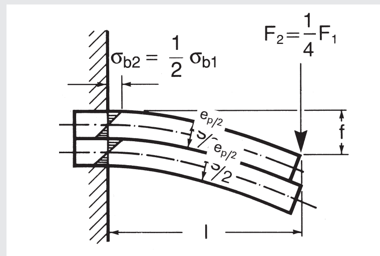


Figure 3.1.3.: Stress distribution in one- or two-layer beams

3.2 | Valve shaft bellows for nuclear power plants

Absolutely safe

Valve shaft bellows for nuclear power plants are sized according to the same technical configuration criteria as conventional valve shaft bellows. However, most of the time only 85% of the permissible pressure resistance is utilised. More documentation and testing are required in this case, and are determined by the rules of the Nuclear Committee (KTA) and the respective specifications of nuclear power plant operators on a case-by-case basis, and are governed by the requirement level at which the bellows was classified. Typical requirements include:

- testing and confirmation of calculation for pressure resistance and service life of the bellows by an independent individual in charge of approvals,
- certification of materials and production methods as per KTA, EN 9001 and AD 2000; which also includes special approvals for welding methods and welding personnel,
- tensile testing, hot tensile testing, grain size determination and testing of corrosion resistance of the strip steel,
- X-ray and dye penetration testing on weld seams, as well as
- leak testing, pressure and load cycle testing on bellows.

3.3 | Vacuum applications

Absolutely tight

Metal bellows are also used in vacuum technology as flexible sealing elements. The main areas of application include shaft seals in vacuum valves as well as the sealing of circuit breakers (compare figure 3.3.1.). These are used in the medium-voltage range, hence in grids ranging from 1 kV to 72 kV. They shut off power through the mechanically driven separation of two copper contacts in a vacuum area, and are configured for a high switching frequency with a high degree of freedom of maintenance.
Based on the small differential pressures, vacuum bellows feature a single wall, and usually have a bellows profile with a high flexibility. This means narrow and high corrugations. Design criteria include the required stroke and associated service life, which usually ranges between 1,000,000 and 10,000,000 load cycles. Often a low spring rate for the bellows is also required, in order to achieve high switching speeds.

Figure 3.3.1.: High-voltage circuit breaker with metal bellows seal

Bellows for vacuum valves are welded with their connecting parts. A gap-free design of the weld seams are preferred to allow for a safe evacuation process, leading to a preferred use of J- or B-cuffs. Bellows for high-voltage switches are soldered into the connecting parts. A process-safe soldering procedure is dependent on a bellows surface that is free of oxides and organic residues, necessitating the integration of corresponding cleaning processes into the production process.

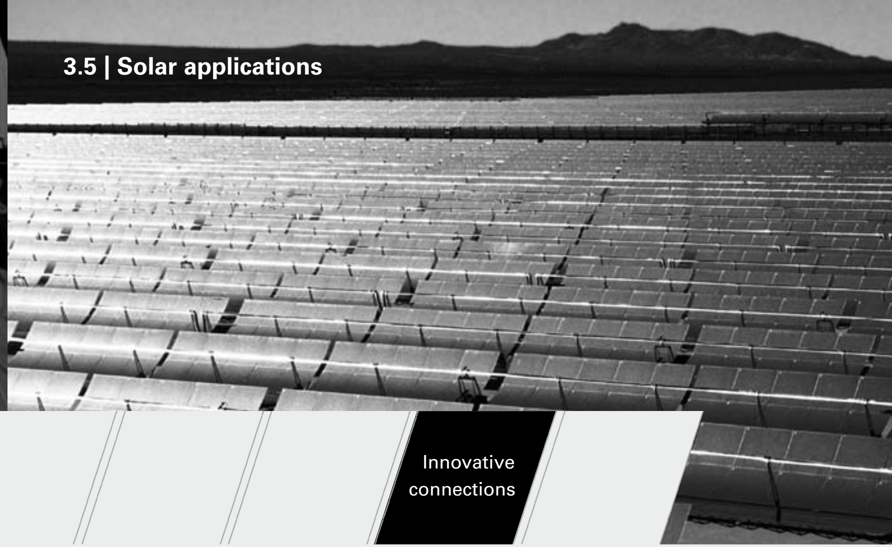
3.4 | Expansion joints

Universal applications

Expansion joints are used to compensate for thermal expansion and mounting mis-alignments in piping systems, as well as to absorb tube movements. The metal bellows forms the heart of each expansion joint, as it guarantees flexibility, tightness and pressure resistance. The main loads placed on axial expansion joint in plant settings generally involve the start-up and shutting down of equipment. For this reason, the required service life is usually only 1,000 load cycles. Significantly higher load cycle demands are placed on expansion joints which are used to compensate for thermal expansions in the exhaust equipment of large engines. In addition to start/stop processes, these applications generally also result in vibration loads, which must be tolerated on a permanent basis. Axial expansion joints can be used for smaller nominal diameters and/or low pressures. A typical building design – one bellows with two rotating flanges which are attached with angular rings – is shown in Figure 3.4.1.. Bellows with weld cuffs are also often used as expansion joints. An example of such an application can be seen in Figure 2.1.1. In case of larger nominal diameters or higher operating pressures, expansion joints designs capable of absorbing reaction forces are preferred. These include lateral or pressure-released expansion joints. Comprehensive information on this topic, as well as our expansion joint product range can be found in the Witzenmann handbook of expansion joint technology.

Figure 3.4.1.: Axial expansion joint with rotating flanges

3.5 | Solar applications



Innovative connections

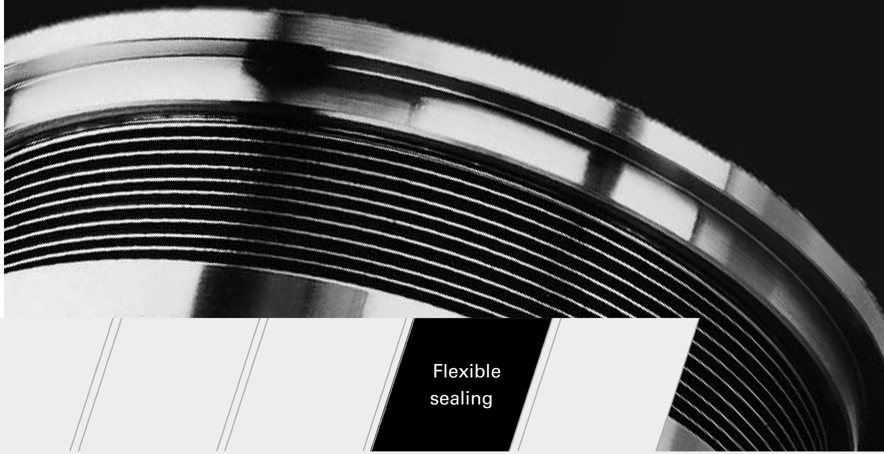
Solar thermal is becoming a increasingly significant factor in energy generation; both for solar power plants as well as building technology. Combining materials with different thermal expansion coefficients results in thermal expansions that must be compensated at all solar thermal facilities. In liquid closed loops, this is achieved with metal bellows.

3.5 | Solar applications

Examples include collector tubes for solar power plants, or collector connections in building technology. Collector tubes are the heart of parabolic-trough power plants. They are configured along the focal line of parabolic mirrors; thermo-oil which is heated by thermal radiation passes through them. The heated thermo-oil is then used to generate steam for a conventional power plant. The collector itself consists of an outer sheathing tube made of layered and highly-transparent borosilicate glass, and an inner absorber tube made of specially-coated steel. The space inbetween is evacuated to prevent heat loss. Metal bellows at both cuffs of the collectors compensate for the different thermal expansions of glass and steel, and ensure a vacuum-tight connection of both tubes. Similarly, solar collector fields used in building technology also involve the compensation of thermal expansion at the connection points of individual collectors, using flexible collector connections. Figure 3.5.1. shows a metal bellows design which can be attached on the copper piping of the collectors. Hydraulically formed O-ring grooves and flanges are integrated for attachment purposes at the cuff of the bellows.

Figure 3.5.1.: Flexible collector connection for building technology

3.6 | Sliding ring seals



Sliding ring seals are dynamic seals for rotating shafts. The main components are a spring-supported sliding ring and a counter ring, whose gliding surfaces are pressed against each other by spring force. One of the rings rotates with the shaft, while the other one is permanently mounted on the housing. When the medium enters into the small seal gap between the sliding surfaces, a grease film is produced and a sealing effect is obtained. Sliding materials used for this purpose include graphite, resin-bound carbon, metal or ceramic.
To press the sliding rings, as well as to achieve secondary sealing between sliding ring and corrugation, or sliding ring and housing, metal bellows or diaphragm bellows are used in high-quality sliding ring seals. The latter is preferred for its shorter production length. Figure 3.6.1. shows an example of a sliding ring holder with a HYDRA diaphragm bellows.

Bellows for sliding ring seals must be pressure- and temperature-resistant, and also resistant against the transported media. In addition, the pre-load of the sliding ring seal may not relax during operation, which is why hardened bellows materials are often used for this purpose. Typical hardened materials for HYDRA diaphragm bellows include AM 350 or Inconel 718 (2.4668) for higher demands on corrosion-resistance.

Figure 3.6.1.: Sliding ring holder with HYDRA diaphragm bellows

Similar to a piston, metal bellows can convert pressure into force or movement and vice versa. For this reason they can be used as sensors and actuators, whose characteristic is defined by the spring rate and hydraulic cross-section of the bellows. The main demands placed on sensors and actuators are that they are free of hysteresis and feature a constant characteristic curve, so that here too hardened bellows materials can be used to their advantage. Examples include the pressure-force converter used to make fine adjustments to optical systems which is shown in figure 3.7.1 or sensors for gas-insulated switching cabinets. These switching cabinets are filled with SF_6 under positive pressure. In the case of a leak, pressure on the inside of the cabinet decreases. A gas-filled and hermetically sealed metal bellows is used as a sensor for the pressure in the switching cabinet.

Figure 3.7.1.: Metal bellows actuators

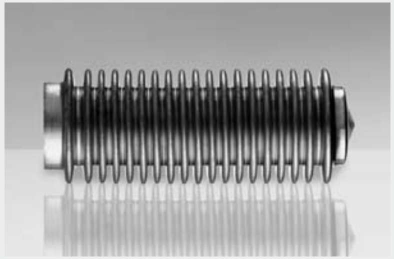


Figure 3.7.2.: Bronze bellows for radiator thermostats

Its length always adjusts as to create a force equilibrium of the spring force of the bellows and the pressure resulting from the bellows interior, and the pressure in the switching cabinet. A decrease in switching cabinet pressure results in an enlargement of bellows lengths and can thus be detected.

Other application examples of a metal bellows actuator are regulators for heater thermostats (Figure 3.7.2.). To this cuff, bronze bellows filled with alcohol are used. The alcohol enclosed in the bellows expands as temperatures rise, and as a result the bellows lengthens in an axial direction. The lengthening of the bellows is used to throttle the valve, and the capacity of the heater decreases. If room temperature decreases, the bellows becomes shorter again. This further opens the regulator valve and heating capacity increases again.

3.8 | Metal bellows accumulator

Diffusion-tight

Gas-loaded accumulators are used as energy storage in hydraulic systems. They consist of a gas and liquid space which are separated by a flexible diaphragm. The more liquid is pumped into the accumulator, the more the gas volume is compressed and storage pressure increases. Alternatively, liquid may be withdrawn, decreasing the storage pressure.
Multi-layer diaphragms or rubber bubbles are often used as media separators. They are not however completely diffusion-tight and are subject to ageing. For example, if the diffusion of storage gases in brake systems is not permitted, or the accumulator must be guaranteed to be maintenance-free for long periods of time, the plastic diaphragm may be replaced by a metal or diaphragm bellows. To enable large working volumes, storage bellows feature thin walls, high flexibility and low pressure resistance.

These features are not critical during the storage operation, since the only pressure differential between the gas and liquid is caused by the spring rate of the bellows. To protect the metal bellows from damages, care must be taken to ensure that there are enough valves to prevent a complete emptying of the metal bellows storage chamber, and hence always maintain the pressure balance between the gas and liquid side.

Figure 3.8.1.: Sectional model of a metal bellows accumulator

3.9 | Metal bellows couplings

Maintenance-free

Metal bellows are flexible and torsion-resistant. For this reason they are well suited for use as maintenance-free corrugated couplings (figure 3.9.1.) for torsional transfer and to compensate for layer tolerances. Metal bellows couplings are loaded for torsion and rotating bend. The latter requires a fatigue-endurable configuration.
In order to transfer large amounts of torsion and to safely prevent torsional buckling, coupling bellows are often short and have a large diameter.

Figure 3.9.1.: Metal bellows coupling

3.10 | Metal bellows for modern vehicle engines

Temperature- and corrosion-resistant

Reductions in fuel consumption through efficiency increases as well as adherence to statutorily prescribed emission limits pose a significant challenge to future combustion engines. One important approach is to downsize the engines, i.e. reduce the cylinder capacity while maintaining capacity. This is made possible by turbo charging, an increase in injection pressures, improved engine management and spray-formed combustion processes for gasoline engines.

HYDRA precision bellows have proven themselves as reliable, highly flexible, pressure- and temperature-resistant sealants in piezo injectors, fuel pumps or pressure sensor glow plugs for such modern engines.
Based on the smallest flow cross-sections and metallic seals, metal bellows in high-pressure fuel systems are subject to a maximum cleanliness requirements, which are met through production in clean rooms.

Piezo injector
Spray-form direct injection reduces fuel consumption of gasoline engines at the same or even higher engine performance. Criteria for spray-form combustion consist of highly exact dosages and fine atomisation of the injected fuel. These requirements can be met with quick switching piezo injectors and injection pressures which exceed 200 bar. The key component of the injector is a piezo actuator, which extends with voltage and then opens the injection needle.

Any type of contact with the fuel would lead to a short circuit and destroy the piezo actuator. For this reason, a seal which can resist pulsating pressures of up to 300 bar and also allows for over 300,000,000 needle movements is required. HYDRA precision bellows meet these requirements with a component failure probability rate of less than 1 ppm.

Figure 3.10.1.: Injector bellows (Witzenmann) and piezo injector (Continental Automotive GmbH)

3.10 | Metal bellows for modern vehicle engines

Figure 3.10.2.: Pump bellows (Witzenmann) and high-pressure fuel pump (Continental Automotive GmbH)

Fuel pump
High-pressure pumps are required to supply fuel to direct-injection gasoline engines. These pumps can be designed as one- or multiple-piston pumps with oil-lubricated pistons. HYDRA precision bellows ensure that the fuel is not contaminated by pump oil. For each piston, a bellows acts as a highly flexible seal and transfer element for pump movements. The bellows are mainly operated in pressure-compensated mode and must execute over 12,000,000,000 pump movements over the life of a vehicle.

Pressure sensor glow plugs
To ensure adherence to statutorily prescribed thresholds for NO_x and CO_2 emissions, an improved regulation of the combustion process in diesel engines is required. By performing an in-situ measurement of the pressure in the combustion chamber, the pressure sensor glow plug provides an important input signal. Besides reducing emissions, the optimised engine control which is achieved with the assistance of the pressure sensor glow plugs allows for the utilisation of higher combustion pressures. This is used to increase performance or downsize the engines.

In contrast to conventional glow plugs, the plug tip of the pressure sensor glow plugs is mounted for movement. Forces from the pressure in the combustion chamber which is acting on the plug tip is measured with a piezo-resistive sensor. A HYDRA precision bellows allows for a friction- and hysteresis-free transfer of combustion pressure to the piezo sensor. Furthermore it compensates for heat expansion during the glow operation, and seals the sensor and electronics from the combustion chamber.

Besides combustion chamber pressures and temperatures, this application also requires the metal bellows to tolerate a high degree of repeated loads in a manner that secures operations. The repeated loads are caused by the resonance initiation of the glow plug tips which are mounted for movement by way of engine vibrations.

Figure 3.10.3.: Metal bellows (Witzenmann) and pressure sensor glow plug (PSG, Beru AG)

4 | Bellows calculation and characteristics

The main requirements for metal bellows are

(1) media and corrosion resistance,
(2) temperature resistance,
(3) tightness,
(4) pressure resistance,
(5) flexibility and service life.

Corrosion and temperature resistance can be achieved by selecting the appropriate bellows material. The tightness of the bellows is guaranteed by the production process. Pressure resistance and service life on the other hand are ensured by the appropriate bellows design, and can be verified by calculation.
The principal procedure for preparing a stress analysis for metal bellows is shown in figure 4.1.1. The stresses which occur in the bellows are determined on the basis of the bellows geometry and operating loads – these are pressure, torsion and deformation. Suitable stress parameters can be derived from these stresses, and compared against the corresponding strength of the component. The comparison provides the safety factors for the respective load status.
An essential ingredient in a reliable stress analysis is knowing exactly how strong the component is. For this purpose, Witzenmann has performed more than 1,300 pressure resistance tests and more than 1,600 load cycle tests, of which approximately 250 are conducted under operating pressure and at high temperatures; this database is continuously updated and expanded.

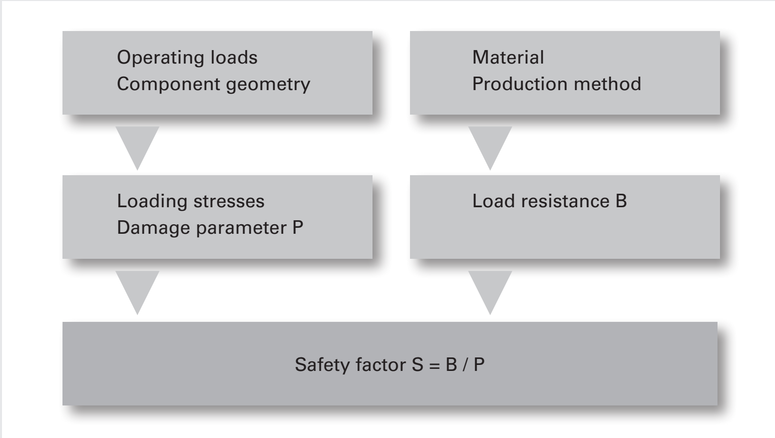
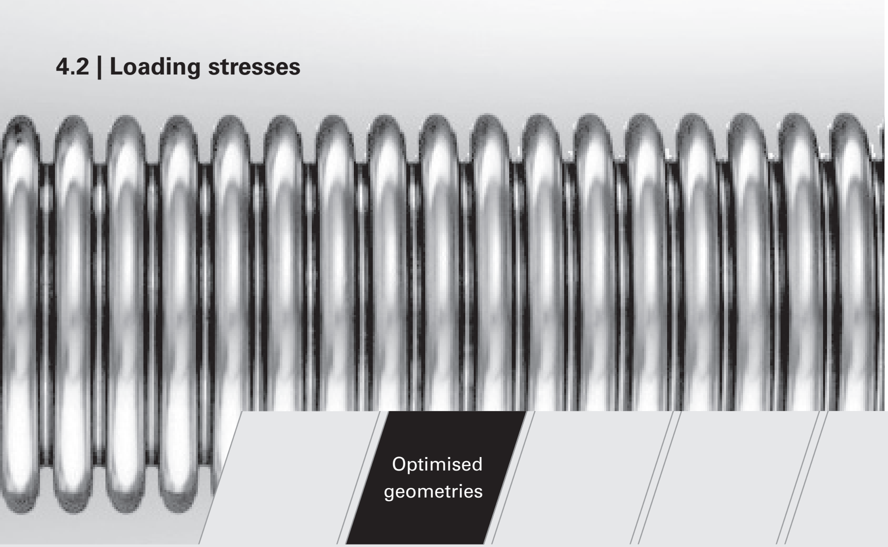


Figure 4.1.1.: Principal procedure for the strength by calculation analysis for metal bellows

Stress calculation and stress analyses for HYDRA corrugated bellows are illustrated below. However, the same principle can be also applied to configure HYDRA diaphragm bellows, HYDRA diaphragm discs or HYDRA load cells.



Loading stresses are caused by pressure as well as displacements or rotations of the connecting cross sections of the bellows towards each other. The following section discusses the stresses resulting from pressure and axial deformation, since these are the most significant loads for bellows.
Lateral and angular deformations can be converted into equivalent axial deformations (Section 4.5) – torsion will be discussed separately in Section 4.6. In the case of typical bellows geometries, the largest stress component is always the meridional stress. It is oriented in the longitudinal direction of the bellows, parallel to its surface. Both pressure as well as axial movement result in bending stress conditions with defined stress maxima in the area of the crests. Figure 4.2.1. shows this by way of example for a two-layer metal bellows. The position of the stress maxima corresponds with the typical fracture positions of fatigue fractures. Since similar stress conditions always exist, stress from pressure and movement may be superimposed by way of addition to analyse the combined loads.

Figure 4.2.1.: Meridional stress on a two-layer metal bellows at axial tension (left) and outside pressure (right)

Abandoning the membrane stresses, which are small as compared to the bending stresses, the following applies to **meridional stress from axial movement** (δ):

$$\sigma_{B,\text{meridional}}(\delta) \approx \frac{5\,E \cdot s}{3\,n_w \cdot h^2} \cdot \frac{\delta}{C_d}$$

(4.2.1.)

E is the modules of elasticity of the bellows material, s is the ply thickness of the individual layer, n_w is the number of corrugations and h is the height of the corrugation. C_d is a dimension-less correction factor (Anderson factor) which depends on the geometry of the bellows corrugation.
Equation 4.2.1. shows that the permissible movement of a bellows corrugation (flexibility) increases as wall thickness (s) decreases and corrugation height (h) increases. Increasing the number of corrugations (n_w) also increases the bellows' range of movement since loads on single corrugations are reduced.

For this reason narrow corrugation profiles are often used for highly flexible bellows, as they allow for the maximisation of the number of corrugations in a given installation space.

Not considering the membrane stresses, the following also applies to **meridional stresses resulting from pressure (p)**:

$$\sigma_{B,\text{meridional}}(p) \approx \frac{h^2}{2\,n_L \cdot s^2} \cdot C_p \cdot p$$

(4.2.2.)

whereby n_L is the number of bellows layers, C_P is again a dimension-less and geometry dependent correction factor (Anderson factor).

In accordance with equation 4.2.2., pressure-resistant profiles feature a large ply thickness (s) and/or large number of layers (n_L), as well as a low corrugation height (h).

When subjected to outside overpressure, metal bellows usually fail by way of corrugation buckling which is preceded by a plastic deformation at the inner crests (figure 4.3.1.). For bellows with very minimal corrugation height, as compared to the diameter, ovalisation under outside pressure is also possible. However, the corrugation height of the bellows profiles listed in the technical tables is always large enough that this type of failure does not occur. The typical type of failure associated with inside pressure loads is column buckling (figure 4.3.3.). Corrugation buckling may also occur under inside pressure with very short bellows; for flat and thick-walled bellows profile, bursting with fractures that run parallel to the bellows axis may also occur.

The pressure resistance of metal bellows is dependent on the yield strenght of the bellows material, so that the use of a higher-strength material with the same profile can achieve an increase in pressure resistance. Pressure resistance decreases with increasing temperatures in accordance with the reduction in the yield strenght.

Plastic flow and corrugation buckling
Figure 4.3.1. shows the damage profile for corrugation buckling. Damage begins with a plastic deformation of the inner crest through a global exceedance of the yield limit; subsequently the profile collapses. For this reason, sufficient protection against incipient global plastic deformation at the inner crest is required to prevent corrugation buckling.

The verification may be done by calculation or on experimental basis. For an experimental recording of the pressure-volume characteristic, the bellows is fixed axially

and increasing pressure is applied. The volume displaced by the deformation of bellows corrugations is outlined as a function of the pressure in the form shown in figure 4.3.2. The pressure-volume curve thus obtained corresponds to a stress-strain-curve in the tensile test, and is analysed in analogueous matter. The nominal presure (P_N) of the bellows is that pressure which at initial loading results in a 1% permanent change to the volume enclosed in the bellows corrugations (profile volume).

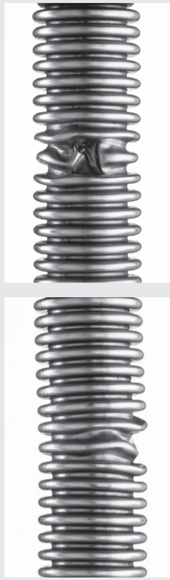


Figure 4.3.1.: Corrugation buckling of a metal bellows under outside pressure

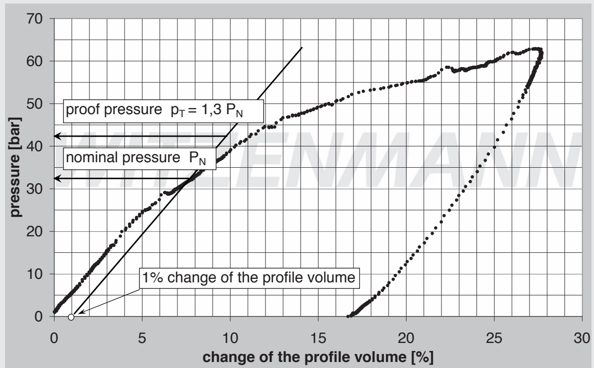


Figure 4.3.2.: Pressure-volume characteristic of a metal bellows and nominal pressure determination as per the Witzenmann method

Nominal pressure must be equal to or larger than the maximum operating pressure at room temperature (design pressure (p_{RT})). With higher operating temperatures TS, the maximum permissible operating pressure (PS) decreases in proportion to the reduction in the yield strength of the bellows material.

$$PS = p_{RT} \cdot \frac{R_{P1.0}(TS)}{R_{P1.0}(20\ °C)}$$

(4.3.1.)

Pressure capacity

$$\eta_P = \frac{p_{RT}}{p_N} = \frac{PS}{p_N} \cdot \frac{R_{P1,0}(20\ °C)}{R_{P1,0}(TS)} \leq 1$$

(4.3.2.)

is described as the ratio of design pressure to nominal pressure.

For short time periods, it is possible to obtain a proof pressure (p_T) of 130% of nominal pressure. Higher proof pressures may damage the bellows profile and are therefore not permitted.

For systems in which the proof pressure exceeds 130% of operating pressure at room temperature, the nominal pressure of the bellows is determined in accordance with equation 4.3.3. by way of the proof pressure. In this case, the nominal pressure is higher than the permissible operating pressure at room temperature.

$$p_N \leq \frac{p_T}{1.3}$$

(4.3.3.)

When using valves, a bellows whose nominal pressure corresponds with the maximum operating pressure at room temperature may also be used. In that case, pressure testing of the valve must be carried out when the bellows is removed.

The configuration criteria to determine the nominal pressure of metal bellows by calculation consist of the maximum meridional stress in the bellows crests as well as circumferential stress averaged over the

bellows profile, whereby conditions 4.3.4. and 4.3.5. must be met. In this vein, C_m describes the increase in material strength as compared to the value determined for the strip steel by way of hardening, support effects and stress transfers.

$$\sigma_{\text{meridional}}^{\text{max}} \leq C_m \cdot \min \begin{cases} R_{P1,0}(T)/1.5 \\ R_m(T)/3 \end{cases}$$

(4.3.4.)

$$\sigma_{um} \leq \min \begin{cases} R_{P1,0}(T)/1.5 \\ R_m(T)/3 \end{cases}$$

(4.3.5.)

Using a bellows configuration corresponding to standard, e.g. EJMA, AD2000, EN13445 or EN14917, the values for C_m as indicated in the respective standard are used. These deviate from each other and are usually smaller than the value resulting from the experimental pressure resistance determination. One exception is the ASME standard, which explicitly allows for an experimental determination of pressure resistance (ASME 2007, Section III, NB 3228.2) The recommended method (ASME 2007, Section III, II-1430) results in only minimally higher nominal pressures than the Witzenmann method.

Column buckling

With the exception of very short bellows, the permissible inside pressure of metal bellows is limited by column buckling (figure 4.3.3.). Since the buckling pressure is usually significantly lower than the pressure resistance of the bellows profile, metal bellows should be configured with outside pressure loads.

If this is not possible, buckling may also be prevented by an inner or outer guidance of the bellows corrugations. The column buckling of bellows can be calculated as Eulerian buckling, whereby the sum of the reaction force of the bellows' inside pressure and the spring rate of the bellows acts as the buckling force. The following applies to buckling pressure under these conditions:

$$p_K = \pi \frac{c_{ax}}{2\,\lambda_E^2\,(l_f + \delta)} + \frac{4 \cdot c_{ax} \cdot \delta}{\pi \cdot d_{hyd}^2}$$

(4.3.6.)

4.3 | Pressure resistance and buckling resistance

whereby d_{hyd} is the hydraulically effective diameter of the bellows (cp. Section 4.7.) and

$$l_f = n_w \cdot l_w \qquad (4.3.7.)$$

the flexible bellows lengths. For a bellows firmly clamped on both sides the following applies: $\lambda_E = 0.5$.

Protection against buckling should be carried out with a safety factor $S > 2.5$. Analogous to the spring rate, the buckling pressure decreases as temperature increases. The decrease is proportional to the reduction in the modules of elasticity of the bellows material.

Bursting
The bursting of bellows is usually preceded by a large degree of plastic deformation, so that resistance to bursting is already provided by the protection against plastic flow (equation 4.3.5.). For applications which explicitly require a minimum bursting pressure for the bellows, verification using a burst pressure test under near-operating installation conditions is recommended.
Experimental protection against bursting pressure is also useful for high-strength materials with an elastic limit R_{P01}/R_m near 1.

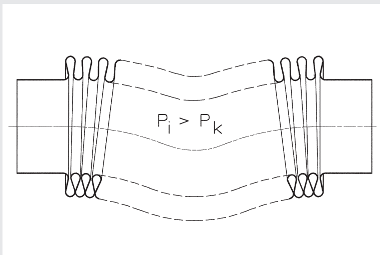
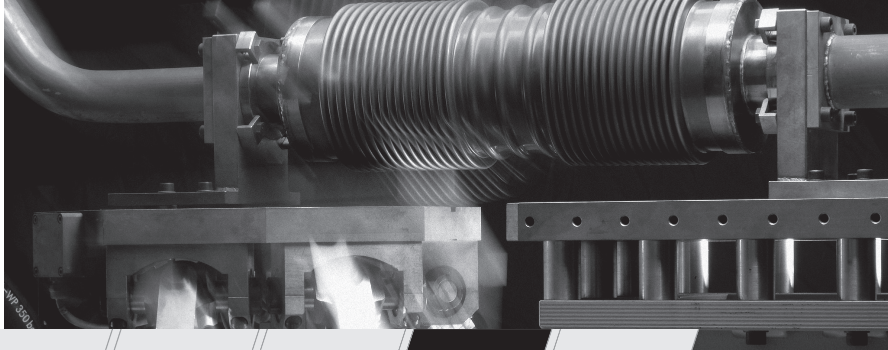


Figure 4.3.3.: Column buckling of a metal bellows under inside pressure (schematic)

4.4 | Fatigue life



R + D

The main damage mechanism which limits the service life of bellows is fatigue under cyclical loads. Bellows may be subjected to cyclical loads in the form of a recurring deformation, pulsating pressure or a combination of both. Stresses induced by such loads which occur at different times result in the formation and growth of fatigue cracks in the material and finally to failure by way of fatigue fractures. Only very high pulsating pressure causes a different damage presentation – failure through cyclic creeping and subsequent corrugation buckling. Fatigue fractures in the inner crest running in the direction of the circumference or at the transition of the inner crest to the flank corrugation are typical for metal bellows. In these cases the fracture is always located at the bellows side with the larger bend. Fractures at the outer crest only occur with strongly non-symmetrical bellows profiles or a characteristic load combination of pulsating pressure and movement. Figure 4.4.1. on page 68 shows fatigue fractures on the inner crest of a bellows on the left side. In the metallographic cut (right), the fracture progression originating from the bellows surface with the more pronounced bend can be seen clearly.
Crack formation and growth are subject to statistical influencing factors. For this reason load cycle test results feature a spread.

4.4 | **Fatigue life**

The dependence of the fatigue life on the load is described by using S-N-curves. Figure 4.4.2. shows the Witzenmann S-N-curve for metal bellows made of austenitic steel. The diagram also contains the test results for metal bellows. They are distributed in the form of a statistical spread around the S-N-curve.

Besides the actual cyclical load (recurring deformation and/or pulsating pressure), the fatigue life is also affected by primary and secondary mean stress, internal stress resulting from bellows production, micro support effects, pressure capacity or failure mode (fatigue fracture of all layers or layers facing pressure and subsequent corrugation buckling under excessive pressure). The life calculation for a general load cycle can be done by Witzenmann at request.

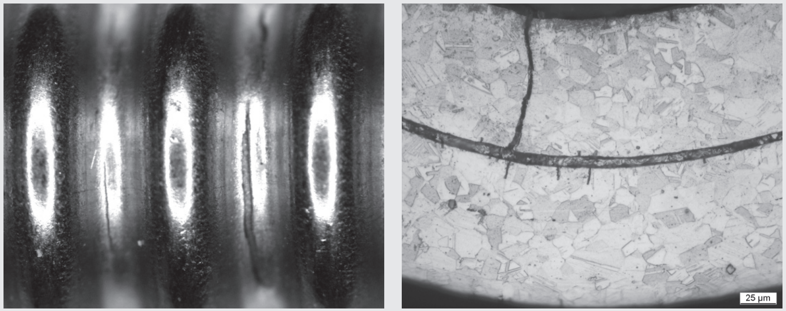


Figure 4.4.1.: Fatigue fracture at inner crest of a metal bellows in top view (left) and as a metallographic cut (right)

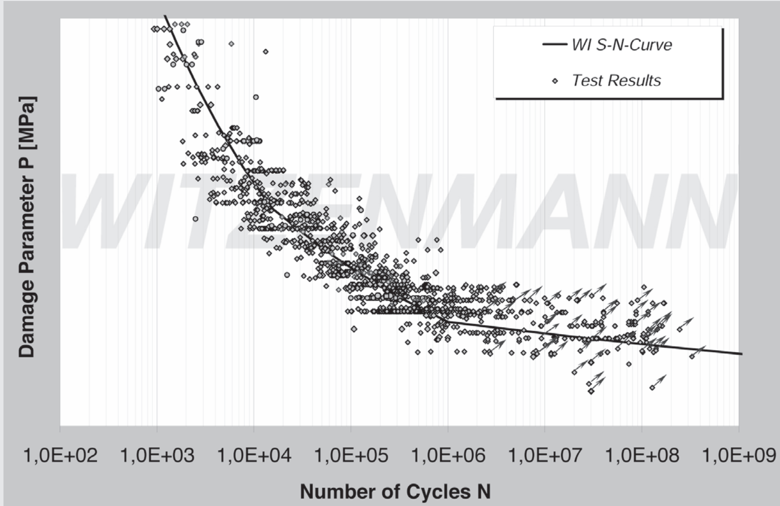


Figure 4.4.2.: Witzenmann S-N-curve for austenitic stainless steel metal bellows. Tests marked with an arrow were suspended without failure of the bellows

In the special case of a static pressure loaded bellows, load cycles (N) may be estimated as a function of stroke(δ) and pressure capacity (η_P) using the tables indicated in Section 6.1.

Where bellows are stressed at several load levels, overall damage or a damage-equivalent load cycle number for a constant amplitude load can be determined using a damage accumulation calculation. This is done by assuming that the damages for each load level accumulate. An overall damage of 100% correlates with a failure probability of 50%:

$$D = \sum_{\text{Load level}} \frac{N_{required}}{N_{50\%}}$$

(4.4.3.)

Damage accumulation with load cycle numbers in the fatigue limit ($N_{50\%} > 1$ million), which are derived from the S-N-curve for a constant amplitude load, is not conservative, since e.g. prior damage from large loads is not taken into account.
A more conservative estimate is provided by the elementary Miner rule. It also determines the load cycle numbers $N_{50\%}$ for the fatigue limit using the extended S-N-curve from the fatigue strength area.

Design know-how

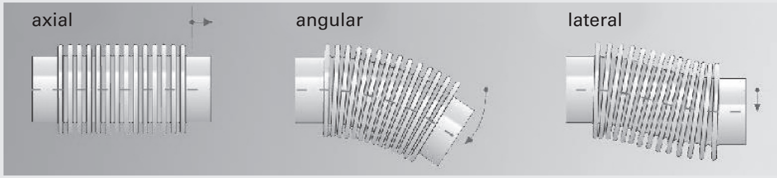


Figure 4.5.1.: Axial, angular and lateral bellows deformation

Metal bellows may also deform perpendicularly to the bellows axis. The basic movement forms – displacement of bellows cuffs perpendicular to bellows axis (lateral deformation) without an incline, or an incline and displacement of bellows cuffs along with a constant bending of the bellows (angular deformation) – is shown by figure 4.5.1. This type of angular or lateral deformation frequency occurs with expansion joints, for example. Generally, it is possible to illustrate any torsion-free bellows deformation as a combination of axial (δ), lateral (λ) and angular (α) deformation.

Subject to the conditions of elementary bending theory, equivalent axial deflections ($\delta_{äq}$) can be derived for lateral (λ) and angular deformations (α). These are theoretical axial deflections which lead to the same stress or load cycles as the original lateral or angular deflection. The following applies to angular loads:

$$\delta_{äq} = \frac{D_m}{2} \cdot \alpha$$

(4.5.1.)

4.5 | Angular and lateral deformation

The following applies to lateral deflection:

$$\delta_{äq} = \frac{3D_m}{l_f} \cdot \lambda = \frac{3D_m}{n_w \cdot l_w} \cdot \lambda$$

(4.5.2.)

The denominator of equation 4.5.2. contains the corrugation quantity, i.e. in the case of a laterally-loaded bellows, the equivalent axial deflection decreases as the number of corrugations increase. Since the tolerable axial deformation of the bellows also increases proportionally with the number of corrugations (equation 4.2.1.), the permissible lateral deformation is not linear, but rather dependent on the square of the number of corrugations.
It is also possible to calculate composite deformations. It is important to note the prefixes of lateral and angular deflection, as well as taking into account that the angular deflection shown in figure 4.5.1. always contains a displacement of the bellows cuffs with the amount:

$$\lambda^* = \frac{l_f}{2} \cdot \alpha$$

(4.5.3.)

As a result, the following applies to a combined deformation, which is described by a displacement (λ) and incline (α) of the bellows cuffs to each other:

$$\delta_{äq} = \frac{3D_m}{l_f} \cdot (\lambda \pm \lambda^*) \pm \frac{D_m}{l_f} \cdot \alpha = \frac{3D_m}{l_F} \cdot \lambda \pm 2D_m \cdot \alpha$$

(4.5.4.)

These calculations accurately apply to long bellows not subject to pressure loads. For laterally loaded short bellows ($l_f \leq D_m$), the lateral shear acts to diffuse the load. The equivalent axial deflection as per equation 4.5.4. then represents a conservative estimate.
High outside or inside pressure loads ($p > 0.25\ p_K$) change the bending line particularly for angular deflected bellows, so that local bending maxima occur. These can reduce the service life. An exact calculation of the load for these cases goes beyond the scope of this handbook, however, more information may be obtained from Witzenmann.

4.6 | Torsion and torsional buckling

Design know-how

Metal bellows are flexible and torsion-resistant. For this reason, as coupling bellows they are well suited to transfer torque (M_T) and compensate load tolerances. In this application case, the torsion resistance and protection against torsional buckling must be verified in addition to service life under lateral and/or angular loads. A verification of torsion resistance for metal bellows is done using critical shear stresses. These appear at the inside crest and may be determined as per

$$\tau = \frac{2M_T}{\pi\,(d_i + n_L \cdot s)^2 \cdot n_L \cdot s}$$

(4.6.1.)

d_i is the inside diameter of the bellows.

Using the shear stress hypothesis, one obtains the safety factor S_F against plastic deformation:

$$S_F = \frac{R_{P\,1,0}}{2\tau} = \frac{\pi \cdot (d_i + n_L \cdot s)^2 \cdot n_L \cdot s}{4M_T} \cdot R_{P\,1,0}$$

(4.6.2.)

In addition to protection against plastic flow, protection against torsional buckling must also be verified. Once the critical torsional moment ($M_{T,c}$) is exceeded, the bellows changes from its straight configuration into a configuration with a curved helical line shape. The following applies to the critical torsional buckling moment of a bellows that is firmly clamped on both sides:

$$M_{T,C} = 1.12 \cdot c_{ax} \cdot D^2_m$$

(4.6.3.)

4.6 | Torsion and torsional buckling

D_m is the average bellows diameter, i.e. the arithmetic average from the bellows inside and outside diameter. Equation 4.6.3. provides protection against torsional buckling of

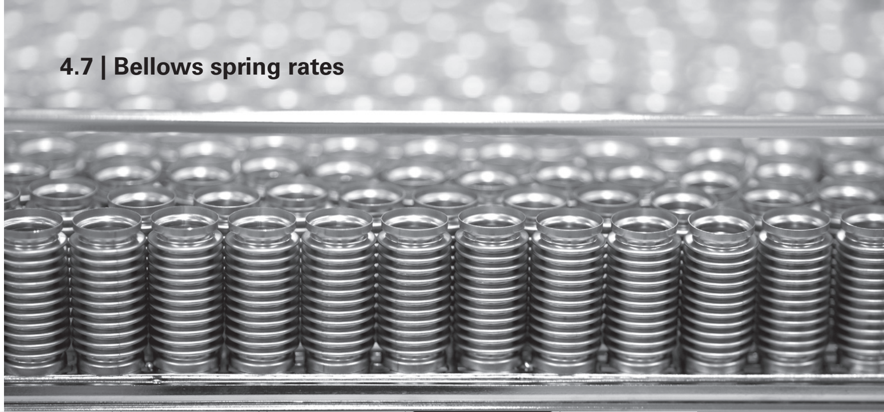
$$S_K = \frac{M_{T,c}}{M_T} = \frac{1.12 \cdot c_{ax} \cdot D^2_m}{M_T}$$

(4.6.4.)

whereby significantly higher safety ($S_K \geq 3$) is required against buckling than against plastic flow ($S_F \geq 1.3$).

Since the axial spring rate of a bellows decreases as the number of corrugations increase, the torsional buckling moment also decreases as the number of corrugations or bellows length increases. For this reason coupling bellows are usually quite short and only have few corrugations.

4.7 | Bellows spring rates



better with more layers

An important characteristic of a bellows is its spring rate under axial, angular or lateral deformation.
The **axial spring rate** of a metal bellows may be calculated in accordance with:

$$c_{ax} \approx \frac{E}{2 \cdot (1 - \nu^2)} \cdot \frac{\pi \cdot D_m \cdot s^3}{h^3} \cdot \frac{n_L}{n_w} \cdot \frac{1}{C_f}$$

(4.7.1.)

C_f is a dimension-less correction factor which is dependent on the geometry of the bellows corrugation (Anderson factor). The spring rate is stronger dependent on wall thickness(s) and corrugation height (h) than the stresses (cp. 4.2.1. and 4.2.2.) and therefore reacts more sensitively to small changes in bellows geometry. For this reason, the spring rate for standard bellows is defined at a tolerance of ±30%.

The **lateral** and **angular** bellows spring rate may be derived from the axial spring rate:

$$c_{lat} = \frac{3}{2} \left(\frac{D_m}{l_f} \right)^2 \cdot c_{ax}$$

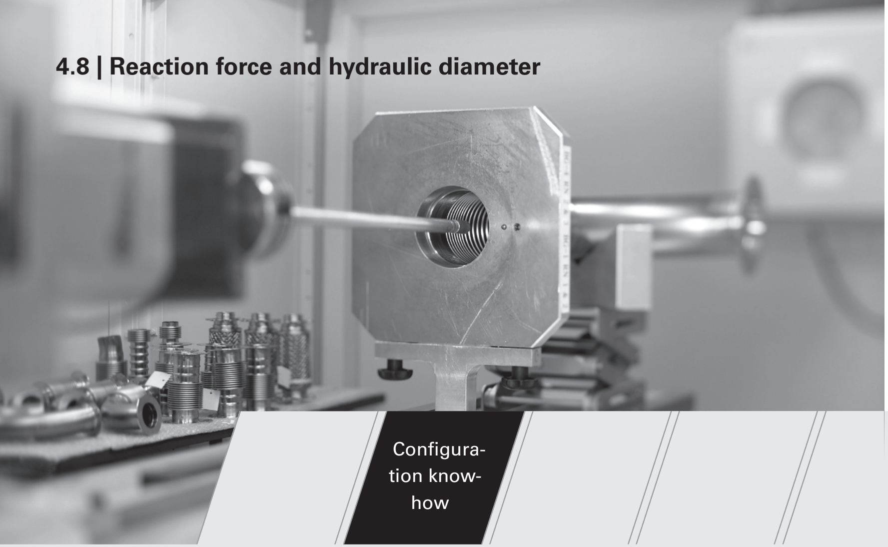
(4.7.2.)
and

$$c_{ang} = \frac{D^2_m}{8} \cdot c_{ax}$$

(4.7.3.)

At higher temperatures the bellows spring rate decreases in proportion to the elasticity module of the bellows material.

4.8 | Reaction force and hydraulic diameter



Configura-tion know-how

In contrast to a rigid pipe, the flexibility of the bellows results in reaction forces which act on subsequent pipelines or components. It is possible to accurately determine the hydraulic diameter (d_{hyd}) of the bellows on a numerical or experimental basis. As a very good approximate value the average diameter (D_m) can be used. For closed bellows, the reaction force is

$$F = \frac{\pi \cdot d^2_{hyd}}{4} \cdot p \approx \frac{\pi \cdot D^2_m}{4} \cdot p$$

(4.8.1.)

For bellows with connecting parts, the amount and direction of the reaction force depend on the ratio of the pressure-applied diameter at the connecting parts (D_{AT}) to the hydraulic diameter:

$$F = \frac{\pi \cdot (d^2_{hyd} - D^2_{AT})}{4} \cdot p \approx \frac{\pi \cdot (D^2_m - D^2_{AT})}{4} \cdot p$$

(4.8.2.)

Figure 4.8.1. illustrates these linkages. If the pressure-applied diameter of the connecting part corresponds with the hydraulic diameter of the bellows, no reaction forces will occur in the connection.

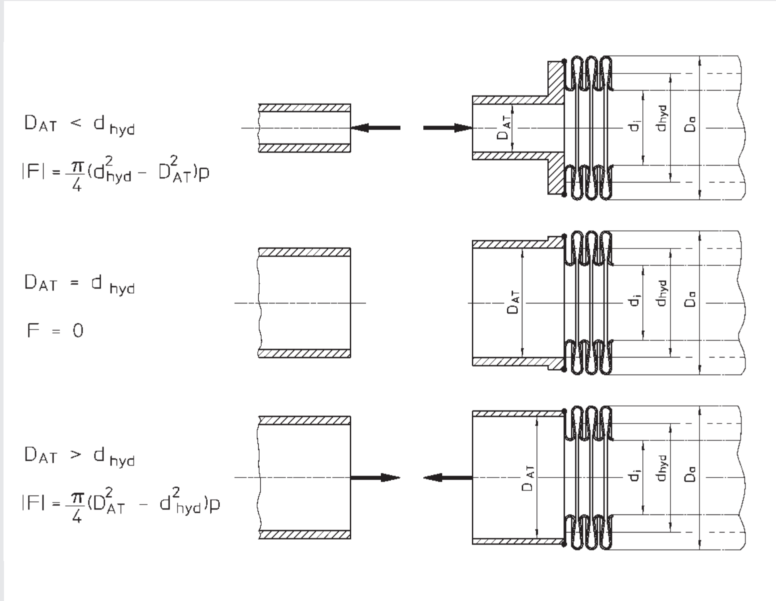


Figure 4.8.1.: Reaction forces on a bellows connection under inside pressure.

5 | Product testing at Witzenmann

5.1 | Overview of testing and analysis options

Development partners

Witzenmann has a comprehensive set of testing and analysis options at its disposal to determine and test product characteristics at an experimental level. The test field includes, among others:

- Movement test stands for axial load cycle testing, also under pressure and/or high temperatures,
- Multiple axis test stands to represent complex movements,
- Electro-dynamic shakers,
- One pressure impulse stand,
- Test stands for pressure testing as well as
- Leakage test stands.

Furthermore, Witzenmann has a material laboratory for mechanical, technological and metallographic testing as well as for welding-related method and approval testing. The laboratory equipment includes the following:

- Tension and impact-bend test machines,
- Comprehensive preparation technology for metallographic grinding,
- Raster electronic microscope with integrated X-ray spectrography
- Clean cabinet,
- Corrosion test stands, as well as
- X-ray radiography equipment.

The following procedures may be carried out or produced:

- Testing of mechanical characteristics as well as corrosion resistance for bellows and connecting part materials at room temperature or at elevated temperatures,

5.1 | Overview of testing and analysis options

- Macro grindings to evaluate geometry of bellows and weld seams,
- Micro grindings to analyse structure, determine grain size and δ ferrite.
- Hardness measurements,
- Analyses of material composition and local element distribution,
- Fracture surface and inclusion analyses and
- Cleanliness analyses.

Other tasks of the metallographic laboratory include assessments of bellows which failed at the customer or during testing, as well as an analysis of the damage cause.

Our material laboratory is recognised by the main approval and classification companies as a production-independent testing authority for destructive and non-destructive material testing, and is also approved to issue approval certificates.

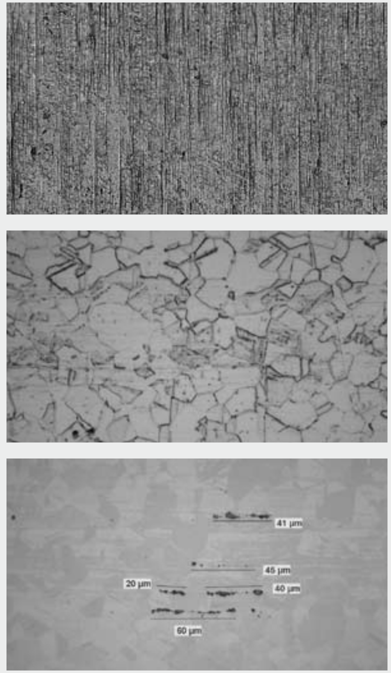
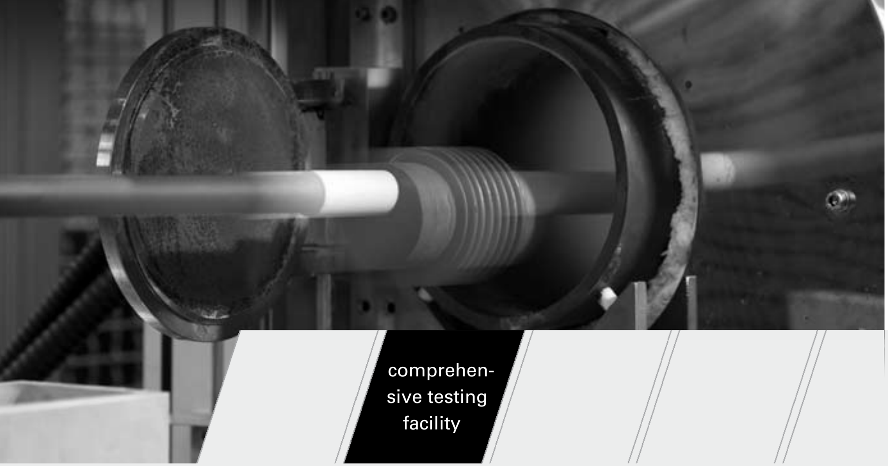


Figure 5.1.1.: Surface (above), structure (centre) and non metallic inclusions (below) analysis on precision band made of 1.4571 material.

5.2 | Typical testing for metal bellows



Tightness test
All bellows equipped with connecting parts that are suitable for sealing purposes are subjected to a tightness test with nitrogen or air under water at room temperature. Inside positive pressure is 0.5 - 2 bar, the rest period is 20 - 60 seconds. No visible bubble formation may be detected.
This test detects leak rates exceeding approximately 10^{-4} mbar l/sec.
For more stringent tightness requirements as well as to test diaphragm bellows, the helium leak test is used as a standard test. The vacuum method employed by the helium leak test consists of a high-resolution tightness test. The component to be tested is evacuated and the surface not exposed to the vacuum is subjected to a helium atmosphere. Using a mass spectrometer, helium atoms entering the vacuum can be detected.

The sensitivity of the measurement increases with the duration of the test period. The verification limit is approximately 10^{-10} mbar l/sec. Leak rates of 10^{-6} mbar l/sec can be well shown in practice; this represents a volume flow of approx. 0.03 l/year under normal conditions. Table 5.2.1. provides an overview of leak sizes and associated volume flows under normal conditions for other leak rates.

Testing of weld seams
An X-ray radiography test is used to examine the longitudinal butt weld of bellows cylinders prior to deformation. Connecting seams are subjected to a dye penetration test using the colour penetration method. This inspection is done visually; the red-white method during daylight, and the fluorescent method under UV lighting.

5.2 | Typical testing for metal bellows

Leak rates and associated volume flows for helium leak test

Leak rate [mbar l / sec]	Leak diameter [µm]	Volume flow [l / sec]	Volume flow [l/ year]	Notes
		(under normal conditions)		
10^{-10}	0.001	10^{-13}	3.15×10^{-6}	verification limit
10^{-8}	0.01	10^{-11}	3.15×10^{-4}	highly vacuum-tight*
10^{-7}	0.03	10^{-10}	3.15×10^{-3}	gas-tight*
10^{-6}	0.1	10^{-9}	0.032	
10^{-5}	0.33	10^{-8}	0.315	
10^{-4}	1	10^{-7}	3.15	vapour-tight*
10^{-3}	3.3	10^{-6}	31.5	water-tight* one air bubble (Ø 1 mm) per sec
10^{0}	100	10^{-3}	31500	leaky tap

*Table 5.2.1. / *Non-standard representation, no exact definition for a leak rate*

If an X-ray test of bellows connection seams is required, bellows and connecting part must feature a particular design. The usual weld geometries are not suited to radiography testing.

Proof pressure testing
Figure 5.2.1. shows a proof pressure test under inside pressure. As part of the test, the metal bellows is axially positioned, and inside or outside pressure is applied in accordance with the operating conditions.

The reaction forces must be absorbed by the axial positioning.
The standard test pressure is 1.3 times the operation pressure. No measurable plastic deformations may occur, and the bellows must retain its functionality. Usually the test is done at room temperature, but can also be carried out at high temperatures.
If required, the test may be continued until the bellows bursts.

5.2 | Typical testing for metal bellows

Figure 5.2.1.: Pressure resistance testing on a metal bellows.

Figure 5.2.2.: Axial load cycle test.

Load cycle testing

Proof of service life for metal bellows can be carried out by calculation or as part of a test. A service life in the range of finite life time may be confirmed by experiment with very little effort.

On the other hand, experiment-related requirements and duration of tests increase significantly with high numbers of load cycles and/or small permissible failure probabilities. In these cases it is often simpler to calculate the service life and use experiments only to prove that the tested bellows do not significantly deviate from the population of all bellows.

For statistical reasons, load cycle testing should always be carried out on several test objects. The standard number of test objects at Witzenmann is 6 test objects per load level.

Load cycle testing may be carried out for design approval, as tests for approval purposes, such as for metal bellows for nuclear application, material batch approval or as a regular re-qualification test for components subject to VDA 6.1.

The axial movement test in a non-pressure state at room temperature shown in 5.2.2. is the basic fatigue test for metal bellows. However, also complex deformations may be applied during load cycle testing or load cycle tests may be performed under operating pressure and temperature.

Characterisation of components

Experiments may also be used to determine component characteristics, which are then confirmed with a test certificate; this includes the following:

- optical measurement of bellows geometry,
- measurement of bellows spring rate,
- measurement of reaction force and determination of hydraulic diameter,
- recording pressure-volume curves (compare Figure 2.4.2. and 4.3.2.),
- determining natural frequencies as well as characterisation of dynamic behaviour of bellows

6 | Technical tables

When selecting a bellows from the technical tables, the bellows profile is initially set using the diameter and required pressure resistance. For this purpose, the bellows in the tables are listed according to ascending reference diameters and ascending nominal pressure. The required corrugation number and installation length then results from the required movement and associated number of load cycles.

Pressure resistance for outside pressure loads
The crucial factors in determining nominal pressure are design pressure (p_{RT}) and proof pressure (p_T):

$$P_N \geq \max \begin{cases} p_{RT} = PS/K_{p\vartheta} \\ p_T / 1.3 \end{cases} \quad (6.1.1.)$$

For temperatures TS > 20 °C, the pressure reduction factor takes into account

$$K_{p\vartheta} = \frac{PS}{p_{RT}} = \frac{R_{p1.0}\,(TS)}{R_{p1.0}\,(20\ °C)} \quad (6.1.2.)$$

the reduction in the bellows' pressure resistance. Values for $K_{P\vartheta}$ are indicated in Table 6.1.1. for bellows materials 1.4571 (austenitic stainless steel) and 2.1020 (bronze).

Pressure resistance with inside pressure loads
The buckling pressure for metal bellows listed in this handbook is usually significantly lower than the pressure resistance of the bellows profile. For this reason they should preferably be configured with an outside pressure load.

For the configuration of expansion joints, please refer to the handbook for expansion joints technology.

Reduction factors for pressure $K_{P\vartheta}$

Temperature [°C]	Reduction factor $K_{P\vartheta}$		Temperature [°C]	Pressure reduction factor $K_{P\vartheta}$	
	austenitic stainless steel 1.4571	bronze 2.1020		austenitic stainless steel 1.4571	bronze 2.1020
20	1.00	1.00	300	0.69	–
50	0.92	0.95	350	0.66	–
100	0.85	0.90	400	0.64	–
150	0.81	0.80	450	0.63	–
200	0.77	0.75	500	0.62	–
250	0.73	0.70	550	0.62	–

Table 6.1.1

In the event of inside pressure loads,

$$P_N \geq \max \begin{cases} p_{RT} = PS/K_{p\vartheta} \\ p_T / 1.3 \end{cases} \quad (6.1.1.)$$

buckling resistance under inside pressure must be checked in addition to condition

$$P_{RT} \leq 2\ \frac{c_\delta}{n_W^2 \cdot l_W} \quad (6.1.3.)$$

witch results in safety factor S ≈ 3 against column buckling. The spring rate per corrugation (c_δ) and corrugation length (l_W) are indicated in the bellows tables.

Where sufficient buckling resistance does not exist, buckling must be prevented by inside or outside guidance of bellows corrugations.

Load cycles and distribution of movement
A load cycle (2δ) consists of the entire movement of the bellows from any starting position to the extreme value on one side, back to the extreme value of the other side over the starting position, and then back to the starting position.

A symmetrical distribution of movement (50% compression / 50% expansion) is preferred for **metal bellows**. Deviating movement distributions only have little effect on the service life, as long as the corrugations do not come into contact during the compression phase.

Diaphragm bellows require a movement distribution of 80% compression / 20% expansion. Larger expansion may damage the bellows. Movements which deviate from this distribution require that the bellows is installed pre-stressed.

Range of movement per corrugation
The bellows tables include the nominal deflections per corrugation ($2\delta_{n,0}$, $2\lambda_{n,0}$, $2\alpha_{n,0}$) for axial, lateral and angular deforming. It relates to a service life of at least 10,000 load cycles at room temperature and nominal pressure.
Depending on the required load cycles and pressure capacity, the permissible deflection per corrugation ($2\delta_n$, $2\lambda_n$, $2\alpha_n$) from

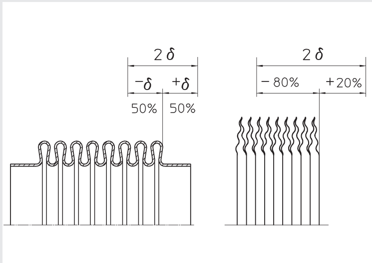


Figure 6.1.1.

the nominal deflection per corrugation ($2\delta_{n,0}$, $2\lambda_{n,0}$, $2\alpha_{n,0}$) and correcting factors $K_{\Delta N}$ and $K_{\Delta P}$ for the load cycles and pressure result in the following:

Axial load:
$$2\,\delta_n = K_{\Delta N} \cdot K_{\Delta P} \cdot 2\delta_{n,0} = K_\Delta \cdot 2\delta_{n,0} \qquad (6.1.4.a)$$

Lateral load:
$$2\,\lambda_n = K_{\Delta N} \cdot K_{\Delta P} \cdot 2\lambda_{n,0} = K_\Delta \cdot 2\lambda_{n,0} \qquad (6.1.4.b)$$

Angular load:
$$2\,\alpha_n = K_{\Delta N} \cdot K_{\Delta P} \cdot 2\alpha_{n,0} = K_\Delta \cdot 2\alpha_{n,0} \qquad (6.1.4.c)$$

Influence of load cycles on impulse

Load cycles	Correction factor $K_{\Delta N}$	Load cycles	Correction factor $K_{\Delta N}$	Load cycles	Correction factor $K_{\Delta N}$
1,000	1.6	25,000	0.8	800,000	0.3
1,700	1.4	50,000	0.7	2,000,000	0.2
4,000	1.2	100,000	0.6	5,000,000	0.1
10,000	1.0	200,000	0.5	10,000,000	0.05
14,000	0.9	400,000	0.4	–	–

Table 6.1.2

If less than 10,000 load cycles are required, the deflection per corrugation ($2\delta_n$, $2\lambda_n$, $2\alpha_n$) may exceed the nominal deflection per corrugation ($2\delta_{n,0}$, $2\lambda_{n,0}$, $2\alpha_{n,0}$); on the other hand, to obtain larger load cycle figures, loads must be reduced below nominal deflection. The corresponding influencing factor $K_{\Delta N}$ is shown in Table 6.1.2.

Reduction in pressure capacity

$$\eta_P = \frac{p_{RT}}{P_N}$$

(4.3.2.)

increases the permissible impulse in accordance with Table 6.2.3.

Influence of pressure capacity on impulse

pressure capacity η_P	1.0	0.8	0.6	0.4	0.2	0.0
Influencing factor $K\Delta_P$	1.0	1.03	1.07	1.1	1.13	1.15

Table 6.1.3

6.1 | Bellows selection from manual

Pressure pulsations

Pressure pulsations or pulsating loads on top of static pressure can reduce the service life of the bellows. The effect of these factors can be determined by calculation, and depends on the degree of pulsating loads and their frequency. For pulsating loads $\Delta p > 0{,}25\ P_N$ we recommend an additional safety confirmation.

Determination of corrugation quantities

The required number of corrugations results from the required deflection of the bellows (2δ, 2λ, 2α) and the permissible deflection per corrugation ($2\delta_n$, $2\lambda_n$, $2\alpha_n$):

axial loads: (6.1.5.s)

$$n_W \geq \frac{2\delta}{2\delta_n}$$

lateral load: (6.1.5.b)

$$n_W \geq \sqrt{\frac{2\lambda}{2\lambda_n}}$$

angular load: (6.1.5.c)

$$n_W \geq \frac{2\alpha}{2\alpha_n}$$

axial and angular load: (6.1.5.d)

$$n_W \geq \frac{2\delta}{2\delta_n} + \frac{2\alpha}{2\alpha_n}$$

axial and lateral load: (6.1.5.e)

$$n_W \geq \frac{2\delta}{2 \cdot 2\delta_n} + \sqrt{\left(\frac{2\delta}{2 \cdot 2\delta_n}\right)^2 + \frac{2\lambda}{2\lambda_n}}$$

Bellows spring rate

The bellows tables contain the spring rate per corrugation (c_δ, c_λ, c_α). The following applies to the spring rate of a bellows with corrugations n_W:

Axial load: (6.1.6.a)

$$c_{ax} = \frac{c_\delta}{n_W}$$

Angular load: (6.1.6.b)

$$c_{ang} = \frac{c_\alpha}{n_W}$$

Lateral load: (6.1.6.c)

$$c_{lat} = \frac{c_\lambda}{n_W^3}$$

Reduction factors $K_{c\vartheta}$ for the Bellows spring rate

Temp. (°C)	Material 1.4571
20	1.00
100	0.97
200	0.93
300	0.90
400	0.86
500	0.83

Table 6.1.4

At higher temperatures the bellows spring rate decreases proportionately with the elasticity module of the bellows material. The corresponding reduction factors are contained in Table 6.1.4.

$$c(T) = c\ (20\ °C) \cdot K_{c\vartheta} = c\ (20\ °C) \cdot \frac{E(T)}{E\ (20\ °C)}$$

(6.2.7.)

6.2 | Bellows selection with Flexperte

Knowledge by Witzenmann

FLEXPERTE

Knowledge by Witzenmann

Flexperte is a configuration software for flexible metallic elements. It is a specially developed software which selects the appropriate products for each case as per current configuration rules from standard production series. In addition to metal bellows, the program can also be used to configure expansion joints, metal hoses and pipe supports.

Upon entering the operating conditions, the program provides a selection of suitable products along with all necessary information and drawings for direct further processing in the form of an inquiry or an order.

We would be pleased to send you a copy of the software at your request. A fully functional version of the program for direct use is also available at www.flexperte.de.

6.3 | HYDRA stainless steel bellows

Preferred dimensions

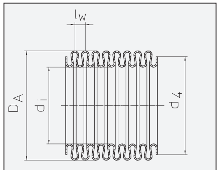
HYDRA metal bellows feature a high degree of flexibility and pressure resistance with minimal installation length. The standard material for metal bellows made of a longitudinally welded tube is 1.4571. Other materials are available on request. Bellows with a small diameter are made from seamless tubes made with 1.4541 material.

Bellows description
The bellows description describes the bellows profile, i.e. diameter, number of layers and thickness of individual layers, corrugations and material used. The first letters indicate whether the bellows described concerns a bellows without connecting parts (BAO) or a bellows with connecting parts (BAT).

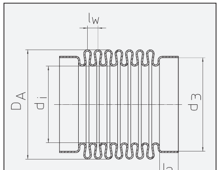
Bellows description (example):

BAT		60.0	x	82.0	x	6	x	0.3		15W		1.4571
BAT: Bellows with connecting parts		Inside diameter d_i = 60 mm		Outside diameter D_A = 82 mm		Number of single layers n_L = 6		Single layer thickness s = 0.3 mm		15 corrugations acc. to Section 6.1		Material 1.4571

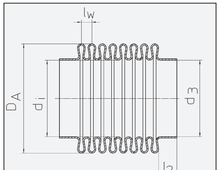
6.3 | Hydra stainless steel bellows
Preferred dimensions



B-cuff



S-cuff

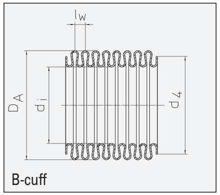


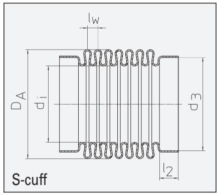
J-cuff

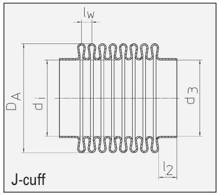
Reference diameter	Nominal pressure P_N*	Bellows profile d_i	D_A	n_L	s	Material	Corrugation length l_w	Max. number of corrugations	Ø Tolerances d_i	Ø Tolerances D_a	B-cuff Ø d_4	S-cuff Ø inside d_3	S-cuff Length l_2	J-cuff Ø inside d_3	J-cuff Length l_2	Nominal deflection per corrugation (for 10,000 load cycles) axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	Spring rate per corrugation (± 30%) axial c_δ	angular c_α	lateral c_λ	Effective cross-section A	Weight per corrugation
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	mm	mm	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
3	400	3.35 x	4.7	x 2	x 0.06	1.4541**	1.00	10	–0.1/+0.1	±0.1	–	4.2	2	–	–	±0.025	±0.50	–	1475	0.052	–	0.12	0.02
4	90	4.06 x	6.1	x 1	x 0.07	1.4541**	0.80	37	–0.4/+0.1	±0.3	5.5	–	–	4.06	5	±0.040	±0.70	±0.002	260	0.016	15500	0.21	0.02
5	65	5.3 x	8.0	x 1	x 0.08	1.4541**	0.95	63	–0.4/+0.1	±0.3	7.0	–	–	5.34	5	±0.065	±1.10	±0.003	180	0.020	13500	0.36	0.04
	100	5.3 x	8.0	x 1	x 0.10	1.4541**	0.85	70	–0.4/+0.1	±0.3	7.0	–	–	5.30	5	±0.045	±0.75	–	420	0.050	–	0.36	0.05
	150	5.3 x	8.5	x 1	x 0.15	1.4541**	1.10	45	–0.4/+0.1	±0.3	7.0	–	–	5.30	5	±0.035	±0.55	–	830	0.080	–	0.37	0.08
	200	5.3 x	8.5	x 1	x 0.20	1.4541**	1.20	41	–0.4/+0.1	±0.3	7.0	–	–	5.30	5	±0.025	±0.40	–	1850	0.19	–	0.38	0.11
	500	5.3 x	8.5	x 2	x 0.20	1.4541**	1.20	42	–0.4/+0.1	±0.3	7.0	–	–	5.30	5	±0.017	±0.20	–	6300	0.65	–	0.37	0.19
6	55	6.2 x	9.7	x 1	x 0.10	1.4541**	1.20	63	–0.4/+0.1	±0.3	8.5	8.5	1.8	6.30	5	±0.090	±1.00	±0.004	160	0.022	11100	0.51	0.07
8	26	8.0 x	13.0	x 1	x 0.10	1.4571	1.40	135	–0.4/+0.1	±0.3	11.0	11.6	1.8	8.00	6	±0.17	±1.30	±0.006	120	0.028	10500	0.87	0.13
	68	8.0 x	13.0	x 2	x 0.10	1.4571	1.60	277	–0.4/+0.1	±0.4	11.0	11.6	1.8	8.00	6	±0.15	±1.20	±0.006	245	0.058	15800	0.87	0.26
	115	8.0 x	13.0	x 3	x 0.10	1.4571	1.80	242	–0.4/+0.1	±0.5	11.0	11.6	1.8	8.00	6	±0.13	±1.10	±0.005	385	0.092	19700	0.87	0.39
	150	8.0 x	13.5	x 4	x 0.10	1.4571	2.00	150	–0.5/+0.1	±0.5	11.0	–	–	8.00	6	±0.13	±1.00	±0.004	460	0.116	19900	0.91	0.44
9	22	9.0 x	14.5	x 1	x 0.10	1.4571	1.35	234	–0.4/+0.1	±0.3	13.4	13.1	2.0	9.00	6	±0.21	±1.60	±0.008	75	0.022	8500	1.08	0.17
	55	9.0 x	14.5	x 2	x 0.10	1.4571	1.75	233	–0.4/+0.1	±0.4	13.0	13.1	2.0	9.00	6	±0.19	±1.40	±0.008	160	0.048	10600	1.08	0.34
	90	9.0 x	14.5	x 3	x 0.10	1.4571	1.85	198	–0.4/+0.1	±0.5	13.0	13.1	2.0	9.00	6	±0.17	±1.30	±0.008	260	0.080	15000	1.08	0.52
	250	9.0 x	13.0	x 4	x 0.10	1.4571	1.50	258	–0.5/+0.1	±0.5	13.0	–	–	9.00	6	±0.07	±0.50	±0.003	1230	0.32	98000	0.94	0.43
10	16	10.0 x	16.5	x 1	x 0.10	1.4571	1.65	189	–0.4/+0.1	±0.3	14.5	14.3	2.5	10.0	6	±0.25	±1.70	±0.010	60	0.023	5800	1.38	0.22
	38	10.0 x	16.5	x 2	x 0.10	1.4571	1.90	216	–0.4/+0.1	±0.4	14.5	14.3	2.5	10.0	6	±0.23	±1.60	±0.010	120	0.045	8700	1.38	0.44
	60	10.0 x	17.0	x 3	x 0.10	1.4571	2.00	208	–0.4/+0.1	±0.5	14.5	15.1	2.5	10.0	6	±0.22	±1.50	±0.010	170	0.070	11600	1.43	0.66
	90	10.0 x	17.0	x 4	x 0.10	1.4571	2.40	125	–0.5/+0.1	±0.5	14.5	–	–	10.0	6	±0.21	±1.30	±0.008	250	0.10	11900	1.43	0.88
	130	10.0 x	17.0	x 5	x 0.10	1.4571	2.70	111	–0.5/+0.1	±0.5	14.5	–	–	10.0	6	±0.19	±1.10	±0.007	310	0.12	11600	1.43	1.10
12	13	12.0 x	19.0	x 1	x 0.10	1.4571	1.90	168	–0.4/+0.1	±0.4	18.0	16.8	2.5	12.0	6	±0.30	±1.70	±0.010	65	0.038	6300	1.89	0.30

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)
** seamless tube 1.4571 or 1.4541

6.3 | **Hydra stainless steel bellows** HYDRA
Preferred dimensions



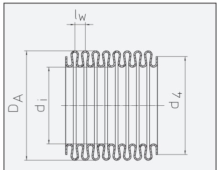




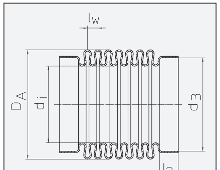
Reference diameter	Nominal pressure P_N*	Bellows profile d_i	D_A	n_L	s	Material	Corrugation length l_w	Max. number of corrugations	Ø Tolerances d_i	D_a	B-cuff Ø d_4	S-cuff Ø inside d_3	S-cuff Length l_2	J-cuff Ø inside d_3	J-cuff Length l_2	Nominal deflection per corrugation (for 10,000 load cycles) axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	Spring rate per corrugation (± 30%) axial c_δ	angular c_α	lateral c_λ	Effective cross-section A	Weight per corrugation
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	mm	mm	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
12	26	12.0 x	20.0 x	2 x	0.10	1.4571	2.10	178	–0.4/+0.1	±0.5	18.0	17.6	2.5	12.0	6	±0.33	±1.70	±0.011	95	0.053	7500	2.01	0.60
	40	12.0 x	20.0 x	3 x	0.10	1.4571	2.45	163	–0.4/+0.1	±0.5	18.0	17.6	2.5	12.0	6	±0.30	±1.50	±0.011	135	0.075	8600	2.01	0.90
	60	12.0 x	20.0 x	2 x	0.15	1.4571	2.40	166	–0.4/+0.1	±0.5	18.0	17.6	2.5	12.0	6	±0.24	±1.40	±0.011	300	0.17	20000	2.01	0.92
	90	12.0 x	20.0 x	3 x	0.15	1.4571	2.40	166	–0.4/+0.1	±0.5	18.0	–	–	12.0	6	±0.20	±1.30	±0.010	560	0.32	37000	2.01	1.39
	260	12.4 x	18.5 x	4 x	0.15	1.4571	2.50	144	–0.5/+0.1	±0.5	16.3	–	–	12.4	6	±0.12	±1.20	±0.008	1745	0.90	100000	1.86	1.39
	360	12.8 x	18.5 x	5 x	0.15	1.4571	2.50	155	–0.5/+0.1	±0.5	16.3	–	–	12.8	6	±0.09	±0.65	±0.006	3400	1.80	199900	1.92	1.73
	385	12.4 x	19.0 x	6 x	0.15	1.4571	3.00	137	–0.5/+0.1	±0.5	16.3	–	–	12.4	6	±0.08	±0.55	±0.005	4000	2.15	164000	1.94	2.20
13	20	13.0 x	19.0 x	1 x	0.10	1.4571	1.80	153	–0.4/+0.1	±0.5	16.3	16.8	2.5	13.0	6	±0.26	±1.60	±0.008	74	0.040	8800	2.01	0.24
	45	13.0 x	19.0 x	2 x	0.10	1.4571	1.85	204	–0.4/+0.1	±0.5	16.3	16.8	2.5	13.0	6	±0.24	±1.50	±0.008	160	0.090	18000	2.01	0.48
	110	13.2 x	19.0 x	2 x	0.15	1.4571	2.15	186	–0.4/+0.1	±0.5	16.3	16.8	2.5	13.2	6	±0.17	±1.20	±0.007	600	0.34	50500	2.04	0.72
	165	13.2 x	19.0 x	3 x	0.15	1.4571	2.20	155	–0.4/+0.1	±0.5	16.3	16.8	2.5	13.2	6	±0.13	±1.00	±0.006	900	0.51	72000	2.04	1.10
14	17	14.6 x	21.0 x	1 x	0.10	1.4571	1.90	145	–0.4/+0.1	±0.5	19.0	18.3	4.0	14.6	6	±0.28	±1.40	±0.011	85	0.065	11200	2.51	0.30
	30	14.6 x	22.0 x	2 x	0.10	1.4571	2.15	196	–0.4/+0.1	±0.5	20.0	18.3	4.0	14.6	6	±0.30	±1.40	±0.010	130	0.093	14100	2.63	0.66
	55	14.2 x	22.0 x	2 x	0.15	1.4571	2.30	170	–0.5/+0.1	±0.5	20.0	18.8	4.0	14.2	6	±0.22	±1.20	±0.009	330	0.24	30600	2.57	1.01
	110	14.6 x	22.0 x	3 x	0.15	1.4571	2.75	151	–0.4/+0.1	±0.5	20.0	–	–	14.6	6	±0.17	±1.00	±0.008	720	0.55	48000	2.63	1.35
	150	14.2 x	22.0 x	4 x	0.15	1.4571	2.80	142	–0.5/+0.1	±0.5	20.0	–	–	14.2	6	±0.14	±0.70	±0.007	800	0.57	50000	2.57	1.70
	220	14.2 x	21.2 x	5 x	0.15	1.4571	2.80	149	–0.5/+0.1	±0.5	18.5	–	–	14.2	6	±0.12	±0.60	±0.006	1300	0.88	77900	2.46	2.00
	280	14.2 x	22.0 x	6 x	0.15	1.4571	3.40	88	–0.5/+0.1	±0.5	20.0	–	–	14.2	6	±0.14	±0.50	±0.005	1500	1.070	63800	2.57	2.50
16	14	16.6 x	24.0 x	1 x	0.10	1.4571	2.00	138	–0.4/+0.1	±0.5	21.5	21.1	4.0	16.6	6	±0.33	±1.60	±0.011	60	0.05	9000	3.25	0.37
	28	16.6 x	24.0 x	2 x	0.10	1.4571	2.00	179	–0.4/+0.1	±0.5	21.5	21.1	4.0	16.6	6	±0.32	±1.50	±0.011	126	0.11	19200	3.25	0.73
	70	16.8 x	24.0 x	2 x	0.15	1.4571	2.30	155	–0.4/+0.1	±0.5	21.5	21.1	4.0	16.8	6	±0.20	±1.00	±0.009	420	0.38	49600	3.25	1.10
	110	16.4 x	24.0 x	3 x	0.15	1.4571	2.50	160	–0.4/+0.1	±0.5	21.5	21.1	3.5	16.4	6	±0.20	±1.00	±0.009	680	0.60	66600	3.20	1.70

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

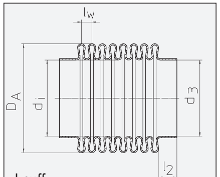
6.3 | **Hydra stainless steel bellows** HYDRA
Preferred dimensions



B-cuff



S-cuff



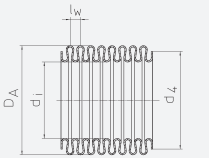
J-cuff

Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff Ø	S-cuff Ø inside	S-cuff Length	J-cuff Ø inside	J-cuff Length	Nominal deflection per corrugation (for 10,000 load cycles) axial	angular	lateral	Spring rate per corrugation (± 30%) axial	angular	lateral	Effective cross-section	Weight per corrugation
	P_N*	d_i	D_A	n_L	s		l_w		d_i	D_a	d_4	d_3	l_2	d_3	l_2	$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	mm	mm	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
16	185	16.4	24.0	4	0.15	1.4571	3.00	140	–0.5/+0.1	±0.5	21.5	–	–	16.4	6	±0.18	±0.80	±0.009	1000	0.89	68000	3.20	2.36
	250	16.4	24.0	5	0.15	1.4571	3.50	85	–0.5/+0.1	±0.5	21.5	–	–	16.4	6	±0.16	±0.70	±0.008	1420	1.26	71000	3.20	2.80
	300	16.0	24.5	4	0.20	1.4571	3.80	105	–0.5/+0.1	±0.5	21.5	–	–	16.0	6	±0.13	±0.50	±0.007	2150	1.92	91600	3.22	3.30
	370	16.0	24.5	5	0.20	1.4571	4.10	73	–0.5/+0.1	±0.5	21.5	–	–	16.0	6	±0.12	±0.40	±0.006	2800	2.50	102500	3.22	3.80
18	16	18.0	28.0	1	0.15	1.4571	2.40	130	–0.4/+0.1	±0.5	25.0	25.2	3.0	18.0	6	±0.36	±1.50	±0.014	90	0.11	12400	4.10	0.83
	38	18.0	28.0	2	0.15	1.4571	2.70	143	–0.3/+0.2	±0.5	25.0	25.2	3.0	18.0	6	±0.34	±1.30	±0.013	185	0.21	20100	4.05	1.73
	70	18.0	28.0	3	0.15	1.4571	3.20	137	–0.3/+0.2	±0.5	25.0	25.2	3.0	18.0	6	±0.32	±1.10	±0.013	310	0.36	24000	4.15	2.63
	75	18.0	28.0	2	0.20	1.4571	3.10	137	–0.3/+0.2	±0.5	25.0	25.2	3.0	18.0	6	±0.28	±1.00	±0.012	600	0.69	49500	4.15	2.40
	105	18.0	28.0	4	0.15	1.4571	3.50	118	–0.3/+0.2	±0.5	25.0	–	–	18.0	6	±0.27	±0.90	±0.013	485	0.56	31400	4.15	3.52
	125	18.0	28.0	3	0.20	1.4571	3.50	120	–0.4/+0.2	±0.5	25.0	–	–	18.0	6	±0.24	±0.80	±0.012	1000	1.15	64800	4.15	3.50
	200	18.0	28.0	3	0.25	1.4571	3.80	115	–0.3/+0.2	±0.5	25.0	25.2	3.0	18.0	6	±0.17	±0.70	±0.009	1700	1.96	93400	4.15	4.30
	260	18.0	28.5	4	0.25	1.4571	4.00	100	–0.4/+0.2	±0.5	25.0	–	–	18.0	6	±0.16	±0.60	±0.008	2400	2.83	121600	4.15	6.00
	375	18.0	26.5	4	0.25	1.4571	3.40	115	–0.4/+0.2	±0.5	23.5	–	–	18.0	6	±0.11	±0.50	±0.005	4580	4.92	293000	3.87	4.50
	450	18.0	27.0	5	0.25	1.4571	4.00	75	–0.4/+0.2	±0.5	22.5	–	–	18.0	6	±0.09	±0.40	±0.005	5400	6.00	256300	3.98	5.90
20	14	19.7	30.0	1	0.15	1.4571	2.40	119	–0.4/+0.1	±0.5	24.5	26.0	3.0	19.7	8	±0.40	±1.50	±0.012	120	0.16	19200	4.85	1.20
	50	19.8	28.0	2	0.15	1.4571	2.60	153	–0.3/+0.2	±0.5	24.5	25.0	3.0	19.8	8	±0.30	±1.20	±0.010	430	0.53	54500	4.41	1.65
	90	19.0	28.0	3	0.15	1.4571	3.30	125	–0.3/+0.2	±0.5	24.5	25.0	3.0	19.0	6	±0.28	±0.90	±0.013	650	0.78	49400	4.35	2.40
	165	19.0	27.0	4	0.15	1.4571	2.90	137	–0.4/+0.2	±0.5	24.5	–	–	19.0	6	±0.18	±0.70	±0.007	1100	1.27	103800	4.15	2.80
	190	19.3	29.0	3	0.25	1.4571	3.50	114	–0.4/+0.2	±0.5	24.5	–	–	19.3	6	±0.16	±0.60	±0.006	2000	2.54	142800	4.58	4.30
	315	19.3	28.0	4	0.25	1.4571	3.40	107	–0.4/+0.2	±0.5	24.5	–	–	19.3	6	±0.11	±0.50	±0.005	4600	5.60	332000	4.39	4.90
	410	19.1	28.0	5	0.25	1.4571	3.80	80	–0.4/+0.2	±0.5	24.5	–	–	19.3	6	±0.09	±0.40	±0.004	6500	7.93	377000	4.39	5.90
21	15	21.0	31.5	1	0.15	1.4571	2.70	102	–0.3/+0.2	±0.5	29.0	27.9	4.0	21.0	8	±0.42	±1.60	±0.014	116	0.18	16500	5.40	1.02

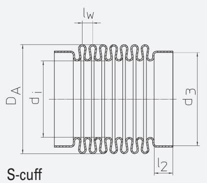
* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.3 | Hydra stainless steel bellows HYDRA

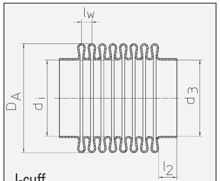
Preferred dimensions



B-cuff



S-cuff

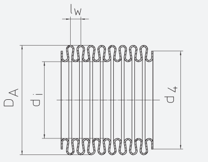


J-cuff

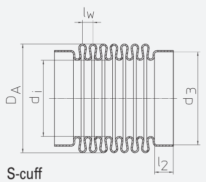
Reference diameter	Nominal pressure P_N*	Bellows profile d_i	Bellows profile D_A	Bellows profile n_L	Bellows profile s	Material	Corrugation length l_w	Max. number of corrugations	Ø Tolerances d_i	Ø Tolerances D_a	B-cuff Ø d_4	S-cuff Ø inside d_3	S-cuff Length l_2	J-cuff Ø inside d_3	J-cuff Length l_2	Nominal deflection per corrugation (for 10,000 load cycles) axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	Spring rate per corrugation (± 30%) axial c_δ	angular c_α	lateral c_λ	Effective cross-section A	Weight per corrugation
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	mm	mm	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
21	32	21.0	31.5	2	0.15	1.4571	2.70	138	–0.3/+0.2	±0.5	29.0	27.9	4.0	21.0	8	±0.37	±1.40	±0.012	214	0.32	30000	5.40	1.98
22	11	22.0	34.0	1	0.15	1.4571	2.80	111	–0.4/+0.1	±0.5	30.0	30.2	4.0	22.0	8	±0.52	±1.65	±0.015	84	0.14	12600	6.16	1.21
	25	22.0	34.0	2	0.15	1.4571	2.90	118	–0.3/+0.2	±0.5	30.0	30.2	4.0	22.0	8	±0.46	±1.55	±0.015	170	0.30	23000	6.16	2.42
	45	22.0	34.0	2	0.20	1.4571	3.50	117	–0.3/+0.2	±0.5	30.0	30.2	4.0	22.0	8	±0.38	±1.30	±0.015	390	0.66	37400	6.16	3.30
	75	22.0	34.0	3	0.20	1.4571	3.60	116	–0.3/+0.2	±0.5	30.0	30.2	4.0	22.0	8	±0.33	±1.15	±0.014	600	1.02	54500	6.16	4.90
	125	22.0	34.0	4	0.20	1.4571	4.20	96	–0.4/+0.2	±0.8	30.0	–	–	22.0	8	±0.32	±1.05	±0.015	900	1.54	60000	6.16	6.60
	150	22.0	35.0	4	0.25	1.4571	4.60	96	–0.4/+0.2	±0.8	30.0	–	–	22.0	8	±0.25	±1.00	±0.013	1415	2.50	81200	6.36	8.70
	250	22.0	35.0	4	0.30	1.4571	5.00	82	–0.4/+0.2	±0.8	30.0	–	–	22.0	8	±0.20	±0.70	±0.010	2500	4.43	121800	6.38	10.90
	320	22.0	35.0	5	0.30	1.4571	4.85	61	–0.6/+0.2	±0.8	30.0	–	–	22.0	8	±0.17	±0.60	±0.009	3400	6.02	176000	6.38	13.70
24	11	24.2	36.5	1	0.15	1.4571	3.40	81	–0.4/+0.1	±0.6	34.0	32.7	4.0	24.2	8	±0.52	±1.65	±0.018	70	0.14	8700	7.20	1.3
	25	24.2	36.5	2	0.15	1.4571	3.15	118	–0.3/+0.2	±0.6	34.0	32.2	4.0	24.2	8	±0.48	±1.50	±0.015	150	0.30	20800	7.20	2.6
	40	24.2	36.5	2	0.20	1.4571	3.20	118	–0.3/+0.2	±0.6	34.0	32.2	4.0	24.2	8	±0.38	±1.30	±0.013	360	0.72	48600	7.20	4.0
	65	24.0	36.5	2	0.25	1.4571	3.30	111	–0.3/+0.2	±0.5	34.0	32.2	3.0	24.0	8	±0.35	±1.20	±0.012	590	1.17	74400	7.20	4.8
	110	24.0	36.5	3	0.25	1.4571	4.00	98	–0.3/+0.2	±0.5	34.0	32.2	3.0	24.0	8	±0.30	±1.00	±0.012	860	1.72	73800	7.20	7.2
	180	24.0	36.5	4	0.25	1.4571	4.60	86	–0.4/+0.2	±0.8	34.0	–	–	24.0	8	±0.25	±0.90	±0.010	1200	2.40	77800	7.15	9.0
	220	24.0	36.5	5	0.25	1.4571	4.90	61	–0.4/+0.2	±0.8	33.0	–	–	24.0	8	±0.20	±0.75	±0.008	2200	4.40	126000	7.15	11.4
	320	24.0	36.5	6	0.25	1.4571	5.30	80	–0.6/+0.2	±0.8	33.0	–	–	24.0	8	±0.19	±0.60	±0.006	3700	7.39	180800	7.15	13.6
27	7	27.0	41.0	1	0.15	1.4571	3.10	99	–0.4/+0.1	±0.5	37.5	37.2	4.0	27.0	8	±0.65	±1.60	±0.019	52	0.13	9400	9.10	1.7
	20	27.0	41.0	2	0.15	1.4571	3.40	100	–0.3/+0.2	±0.5	37.5	37.2	4.0	27.0	8	±0.60	±1.50	±0.019	110	0.27	16500	9.10	3.5
	32	27.0	41.0	2	0.20	1.4571	3.70	100	–0.3/+0.2	±0.5	37.5	37.2	4.0	27.0	8	±0.46	±1.30	±0.016	260	0.65	32900	9.10	5.2
	50	27.0	41.0	2	0.25	1.4571	4.10	99	–0.3/+0.2	±0.5	37.5	36.0	4.0	27.0	8	±0.36	±1.00	±0.014	520	1.31	53600	9.10	7.0
	60	27.0	41.0	3	0.20	1.4571	4.30	100	–0.3/+0.2	±0.5	37.5	37.2	4.0	27.0	8	±0.40	±1.00	±0.013	430	1.10	40300	9.10	7.0

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

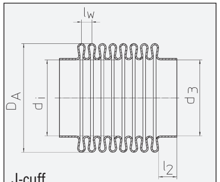
6.3 | Hydra stainless steel bellows
Preferred dimensions



B-cuff



S-cuff

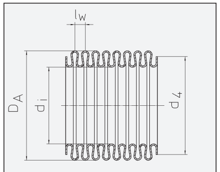


J-cuff

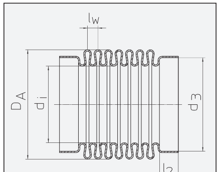
Reference diameter	Nominal pressure P_N*	Bellows profile d_i	D_A	n_L	s	Material	Corrugation length l_w	Max. number of corrugations	Ø Tolerances d_i	D_a	B-cuff Ø d_4	S-cuff Ø inside d_3	S-cuff Length l_2	J-cuff Ø inside d_3	J-cuff Length l_2	Nominal deflection per corrugation (for 10,000 load cycles) axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	Spring rate per corrugation (± 30%) axial c_δ	angular c_α	lateral c_λ	Effective cross-section A	Weight per corrugation
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	mm	mm	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
27	70	27.0 x	41.0 x	2 x	0.30	1.4571	3.55	99	–0.3/+0.2	±0.5	37.5	36.0	4.0	27.0	8	±0.30	±0.90	±0.011	900	2.26	123800	9.10	8.0
	90	27.0 x	40.0 x	4 x	0.20	1.4571	4.30	93	–0.4/+0.2	±0.8	36.5	–	–	27.0	8	±0.32	±0.80	±0.012	700	1.71	63700	8.80	8.7
	110	27.0 x	41.0 x	3 x	0.30	1.4571	4.40	90	–0.3/+0.2	±0.5	37.5	36.0	4.0	27.0	8	±0.26	±0.80	±0.011	1500	3.80	134000	9.10	12.0
	160	27.0 x	41.0 x	4 x	0.30	1.4571	5.20	76	–0.3/+0.2	±0.5	37.5	–	–	27.0	8	±0.23	±0.70	±0.011	2200	5.54	141100	9.10	16.0
29	10	29.5 x	42.0 x	1 x	0.15	1.4571	3.10	97	–0.4/+0.1	±0.5	39.0	38.5	4.0	29.5	8	±0.55	±1.50	±0.018	70	0.19	14000	10.0	2.0
	18	29.0 x	43.0 x	1 x	0.25	1.4571	3.70	73	–0.4/+0.1	±0.5	39.0	39.0	4.0	29.0	8	±0.48	±1.40	±0.018	210	0.61	29800	10.2	3.2
	36	29.0 x	43.0 x	2 x	0.20	1.4571	3.80	101	–0.3/+0.2	±0.5	39.0	39.0	4.0	29.0	8	±0.50	±1.30	±0.017	260	0.74	35000	10.2	4.9
	50	29.0 x	43.0 x	2 x	0.25	1.4571	4.20	101	–0.3/+0.2	±0.5	39.0	39.0	4.0	29.0	8	±0.44	±1.20	±0.017	510	1.44	56200	10.2	6.3
	90	29.0 x	43.0 x	3 x	0.25	1.4571	4.70	94	–0.3/+0.2	±0.5	39.0	–	–	29.0	8	±0.40	±1.10	±0.017	920	2.60	81000	10.2	9.5
	140	29.0 x	43.0 x	4 x	0.25	1.4571	5.00	88	–0.4/+0.2	±0.8	39.0	–	–	29.0	8	±0.35	±1.00	±0.016	1360	3.85	106000	10.2	12.6
	180	29.0 x	44.0 x	4 x	0.30	1.4571	5.50	73	–0.4/+0.2	±0.8	38.0	–	–	29.0	8	±0.35	±0.90	±0.015	2100	6.10	138000	10.5	17.0
	240	29.0 x	44.0 x	6 x	0.25	1.4571	6.20	70	–0.6/+0.2	±0.8	38.0	–	–	29.0	8	±0.26	±0.75	±0.014	2320	6.80	122000	10.6	19.6
	280	29.0 x	44.5 x	7 x	0.25	1.4571	6.80	61	–0.6/+0.2	±0.8	38.0	–	–	29.0	8	±0.24	±0.60	±0.031	2900	8.50	127000	10.6	23.5
	350	29.0 x	44.5 x	7 x	0.30	1.4571	6.00	50	–0.6/+0.2	±0.8	38.0	–	–	29.0	8	±0.17	±0.50	±0.011	5200	15.30	293000	10.6	29.0
30	10	30.2 x	43.5 x	1 x	0.15	1.4571	3.60	111	–0.3/+0.2	±0.5	39.0	39.0	4.0	30.2	8	±0.65	±1.60	±0.020	55	0.16	8600	10.7	2.2
	20	30.2 x	43.5 x	2 x	0.15	1.4571	3.70	101	–0.3/+0.2	±0.5	39.0	39.0	4.0	30.2	8	±0.55	±1.50	±0.018	135	0.40	20000	10.7	4.4
34	6	34.0 x	50.0 x	1 x	0.15	1.4571	3.40	74	–0.3/+0.2	±0.5	47.0	45.3	5.0	34.0	10	±0.80	±1.70	±0.022	46	0.18	10500	13.9	2.5
	11	34.0 x	50.0 x	1 x	0.20	1.4571	3.50	74	–0.3/+0.2	±0.5	47.0	45.3	5.0	34.0	10	±0.65	±1.50	±0.018	95	0.36	20500	13.9	3.4
	25	34.0 x	50.0 x	2 x	0.20	1.4571	4.20	73	–0.3/+0.2	±0.6	47.0	45.3	5.0	34.0	10	±0.63	±1.45	±0.018	200	0.77	30000	13.9	6.9
	40	34.0 x	50.0 x	2 x	0.25	1.4571	4.40	73	–0.3/+0.2	±0.6	47.0	45.3	5.0	34.0	10	±0.53	±1.25	±0.018	390	1.50	53300	13.9	8.6
	55	34.0 x	50.0 x	2 x	0.30	1.4571	4.60	73	–0.3/+0.2	±0.5	47.0	45.3	5.0	34.0	10	±0.46	±1.00	±0.016	700	2.70	87500	13.9	10.0
	100	34.0 x	50.0 x	3 x	0.30	1.4571	5.10	72	–0.3/+0.2	±0.5	46.0	–	–	34.0	10	±0.40	±1.00	±0.016	1200	4.57	122000	13.9	16.0

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

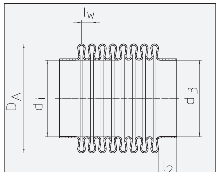
6.3 | Hydra stainless steel bellows HYDRA
Preferred dimensions



B-cuff



S-cuff

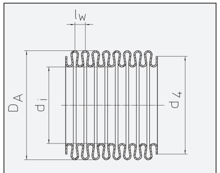


J-cuff

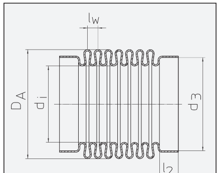
Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff Ø	S-cuff Ø inside	S-cuff Length	J-cuff Ø inside	J-cuff Length	Nominal deflection per corrugation (for 10,000 load cycles) axial	angular	lateral	Spring rate per corrugation (± 30%) axial	angular	lateral	Effective cross-section	Weight per corrugation
	P_N*	d_i	D_A	n_L	s		l_w		d_i	D_a	d_4	d_3	l_2	d_3	l_2	$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	mm	mm	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
34	130	34.0	51.0	4	0.30	1.4571	5.50	72	–0.4/+0.2	±0.8	46.0	–	–	34.0	10	±0.38	±0.95	±0.016	1500	5.90	134400	14.2	21.8
	250	34.0	48.0	5	0.30	1.4571	5.60	72	–0.4/+0.2	±0.8	46.0	–	–	34.0	10	±0.28	±0.75	±0.015	3500	12.80	281400	13.2	28.5
	260	34.0	50.0	6	0.30	1.4571	6.50	46	–0.4/+0.2	±0.8	46.0	–	–	34.0	10	±0.30	±0.75	±0.014	3300	12.70	206700	13.9	34.0
	300	34.0	51.0	7	0.30	1.4571	7.40	40	–0.6/+0.2	±0.8	45.0	–	–	34.0	10	±0.26	±0.60	±0.013	4400	17.30	217700	14.2	38.0
	370	34.0	51.0	8	0.30	1.4571	8.00	37	–0.6/+0.2	±0.8	45.0	–	–	34.0	10	±0.22	±0.50	±0.011	6000	23.60	254000	14.2	44.0
38	8	38.8	56.0	1	0.20	1.4571	4.00	68	–0.3/+0.2	±0.8	47/52.5	51.3	5.0	38.8	10	±0.80	±1.50	±0.022	80	0.39	16900	17.6	3.9
	22	38.8	56.0	2	0.20	1.4571	4.50	66	–0.3/+0.2	±0.8	47/52.5	51.3	5.0	38.8	10	±0.70	±1.40	±0.022	170	0.83	28300	17.6	7.9
	35	38.8	56.0	2	0.25	1.4571	5.00	65	–0.3/+0.2	±0.8	47/52.5	51.3	5.0	38.8	10	±0.62	±1.25	±0.020	330	1.60	44500	17.6	9.9
	50	39.0	56.0	2	0.30	1.4571	4.80	69	–0.3/+0.2	±0.8	52.5	51.3	5.0	39.0	10	±0.50	±1.05	±0.012	615	3.00	91000	17.7	11.8
	70	38.2	56.0	3	0.30	1.4571	5.00	67	–0.3/+0.2	±0.8	47/52.5	–	–	38.2	10	±0.47	±1.00	±0.016	980	4.74	130400	17.4	16.0
	120	38.2	56.0	4	0.30	1.4571	5.50	54	–0.6/+0.2	±0.8	49.0	–	–	38.2	10	±0.41	±0.90	±0.016	1400	6.80	154000	17.4	21.0
	170	38.2	56.0	5	0.30	1.4571	6.00	50	–0.6/+0.2	±0.8	49.0	–	–	38.2	10	±0.38	±0.65	±0.016	2050	9.80	189500	17.4	26.0
	215	38.2	56.0	6	0.30	1.4571	6.60	45	–0.6/+0.2	±0.8	49.0	–	–	38.2	10	±0.34	±0.58	±0.015	3100	15.00	237000	17.4	32.0
	320	38.2	54.0	7	0.30	1.4571	6.90	43	–0.6/+0.2	±0.8	49.0	–	–	38.2	10	±0.23	±0.50	±0.011	5300	24.50	355000	16.7	36.5
	360	38.2	54.0	8	0.30	1.4571	7.10	42	–0.6/+0.2	±0.8	49.0	–	–	38.2	10	±0.22	±0.45	±0.009	6300	29.20	398400	16.7	42.0
42	9	42.0	60.0	1	0.20	1.4571	4.25	61	–0.3/+0.2	±0.8	50.5/57	56.3	5.0	42.0	10	±0.75	±1.50	±0.019	90	0.52	19300	20.4	4.2
	25	42.0	60.0	2	0.20	1.4571	5.25	62	–0.3/+0.2	±0.8	50.5/57	56.0	5.0	42.0	10	±0.75	±1.40	±0.024	180	1.10	25400	20.4	8.5
	32	42.0	60.0	2	0.25	1.4571	5.00	63	–0.3/+0.2	±0.8	50.5/57	56.0	5.0	42.0	10	±0.67	±1.30	±0.021	380	2.20	59300	20.4	10.7
	40	42.0	60.0	2	0.30	1.4571	5.10	65	–0.3/+0.2	±0.5	57.0	56.3	5.0	42.0	10	±0.56	±1.05	±0.018	520	3.30	78000	20.4	12.7
	70	42.0	60.0	3	0.30	1.4571	5.70	67	–0.3/+0.2	±0.8	50.5/57	–	–	42.0	10	±0.48	±1.00	±0.017	1000	5.60	120000	20.4	20.0
	115	42.0	60.0	4	0.30	1.4571	6.20	67	–0.4/+0.2	±0.8	50.5/57	–	–	42.0	10	±0.45	±0.90	±0.018	1500	8.50	152000	20.4	26.0
	140	42.0	61.0	5	0.30	1.4571	7.00	42	–0.4/+0.2	±0.8	55.0	–	–	42.0	10	±0.42	±0.90	±0.018	2000	11.60	162400	20.8	34.0

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

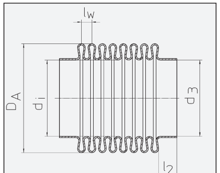
6.3 | Hydra stainless steel bellows HYDRA
Preferred dimensions



B-cuff



S-cuff

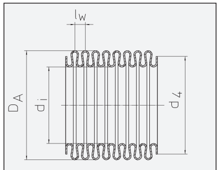


J-cuff

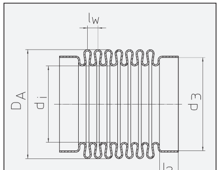
Reference diameter	Nominal pressure P_N*	Bellows profile d_i	Bellows profile D_A	Bellows profile n_L	Bellows profile s	Material	Corrugation length l_w	Max. number of corrugations	Ø Tolerances d_i	Ø Tolerances D_a	B-cuff Ø d_4	S-cuff Ø inside d_3	S-cuff Length l_2	J-cuff Ø inside d_3	J-cuff Length l_2	Nominal deflection per corrugation (for 10,000 load cycles) axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	Spring rate per corrugation (± 30%) axial c_δ	angular c_α	lateral c_λ	Effective cross-section A	Weight per corrugation
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	mm	mm	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
42	165	42.0	62.0	6	0.30	1.4571	7.60	39	–0.6/+0.2	±0.8	55.0	–	–	42.0	10	±0.40	±0.85	±0.018	2200	13.00	154500	21.2	43.0
	210	42.0	62.5	7	0.30	1.4571	8.20	36	–0.6/+0.2	±0.8	55.0	–	–	42.0	10	±0.38	±0.80	±0.016	2600	15.50	158400	21.4	51.0
	290	42.0	61.0	8	0.30	1.4571	8.40	35	–0.6/+0.2	±0.8	55.0	–	–	42.0	10	±0.30	±0.65	±0.014	4000	23.20	225500	20.8	58.0
47	8	47.6	66.0	1	0.20	1.4571	4.30	62	–0.3/+0.2	±0.8	62.5	61.3	5.0	47.6	10	±0.80	±1.50	±0.021	86	0.65	22500	25.3	4.9
	17	47.6	66.0	2	0.20	1.4571	4.70	62	–0.3/+0.2	±0.8	62.5	61.0	5.0	47.6	10	±0.77	±1.40	±0.021	178	1.40	39000	25.3	9.9
	28	47.8	66.0	2	0.25	1.4571	5.10	63	–0.3/+0.2	±0.8	62.5	61.0	5.0	47.8	10	±0.70	±1.20	±0.020	320	2.30	59800	25.4	12.5
	40	47.4	66.0	2	0.30	1.4571	5.20	63	–0.3/+0.2	±0.8	62.5	61.0	5.0	47.4	10	±0.56	±1.00	±0.017	610	4.40	108800	25.2	14.9
	65	47.4	66.0	3	0.30	1.4571	5.70	52	–0.3/+0.2	±0.8	62.5	–	–	47.4	10	±0.51	±0.90	±0.017	1240	8.60	184000	25.2	22.4
	95	47.4	66.0	4	0.30	1.4571	6.60	45	–0.6/+0.2	±0.8	62.5	–	–	47.4	10	±0.48	±0.80	±0.015	1850	12.90	204000	25.2	30.8
	130	47.4	66.0	5	0.30	1.4571	6.70	44	–0.6/+0.2	±0.8	57.0	–	–	47.4	10	±0.44	±0.70	±0.015	2550	17.80	274000	25.2	38.0
	200	47.4	64.0	6	0.30	1.4571	7.10	42	–0.6/+0.2	±0.8	57.0	–	–	47.4	10	±0.32	±0.60	±0.013	4400	29.80	406200	24.3	42.0
	270	47.4	64.0	8	0.30	1.4571	7.70	38	–0.6/+0.2	±0.8	57.0	–	–	47.4	10	±0.22	±0.40	±0.010	7000	47.00	549400	24.3	57.0
51	10	51.4	71.0	1	0.25	1.4571	4.20	59	–0.3/+0.2	±0.8	61.0	65.0	5.0	51.4	10	±0.80	±1.40	±0.018	160	1.30	51000	29.4	7.9
	22	51.4	71.0	2	0.25	1.4571	4.90	58	–0.3/+0.2	±0.8	67.5	65.0	5.0	51.4	10	±0.75	±1.20	±0.020	330	2.70	77200	29.4	15.3
	32	51.4	71.0	2	0.30	1.4571	5.20	60	–0.3/+0.2	±0.8	67.5	65.0	5.0	51.4	10	±0.66	±1.10	±0.018	530	4.30	110100	29.4	18.8
	50	51.4	71.0	3	0.30	1.4571	5.80	58	–0.3/+0.2	±0.8	65.0	65.0	5.0	51.4	10	±0.60	±1.00	±0.018	950	7.80	158500	29.4	27.6
	75	51.4	71.0	4	0.30	1.4571	6.50	61	–0.6/+0.2	±0.8	65.0	–	–	51.4	10	±0.50	±0.90	±0.017	1270	10.00	168900	29.4	31.7
	110	51.4	71.5	5	0.30	1.4571	7.30	41	–0.6/+0.2	±0.8	65.0	–	–	51.4	10	±0.47	±0.80	±0.016	1630	13.50	173300	29.6	46.5
	145	51.4	72.0	6	0.30	1.4571	7.70	38	–0.6/+0.2	±0.8	65.0	–	–	51.4	10	±0.45	±0.70	±0.014	2100	17.50	202300	29.9	56.0
56	9	56.1	77.0	1	0.25	1.4571	4.90	55	–0.6/+0.2	±0.8	68/73	72.3	5.0	56.1	10	±0.95	±1.40	±0.023	140	1.35	38800	34.8	8.5
	22	56.1	77.0	2	0.25	1.4571	5.70	53	–0.6/+0.2	±0.8	68/73	72.3	5.0	56.1	10	±0.90	±1.35	±0.025	270	2.70	55200	34.8	16.8
	30	56.1	77.0	2	0.30	1.4571	5.80	55	–0.6/+0.2	±0.8	68/73	72.3	5.0	56.2	10	±0.72	±1.20	±0.021	480	4.60	94800	34.8	20.3

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

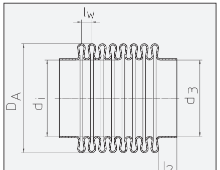
6.3 | Hydra stainless steel bellows
Preferred dimensions
HYDRA



B-cuff



S-cuff

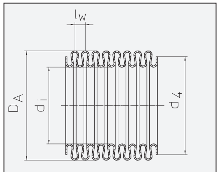


J-cuff

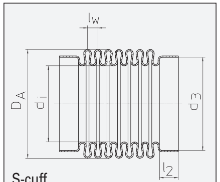
Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff Ø	S-cuff Ø inside	S-cuff Length	J-cuff Ø inside	J-cuff Length	Nominal deflection per corrugation (for 10,000 load cycles) axial	angular	lateral	Spring rate per corrugation (± 30%) axial	angular	lateral	Effective cross-section	Weight per corrugation
	P_N*	d_i	D_A	n_L	s		l_w		d_i	D_a	d_4	d_3	l_2	d_3	l_2	$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	mm	mm	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm²	g
56	50	56.1 x	77.0 x	3 x	0.30	1.4571	6.20	56	–0.6/+0.2	±0.8	68/73	–	–	56.2	10	±0.65	±1.10	±0.020	880	8.50	152300	34.7	30.5
	65	56.1 x	77.0 x	4 x	0.30	1.4571	6.70	58	–0.6/+0.2	±0.8	73.0	–	–	56.2	10	±0.62	±1.00	±0.015	1200	11.50	178000	34.7	40.6
	83	56.1 x	77.0 x	5 x	0.30	1.4571	7.20	41	–0.6/+0.2	±1.0	73.0	–	–	56.2	10	±0.57	±0.90	±0.013	1600	15.50	205000	34.7	51.5
60	8	60.0 x	82.0 x	1 x	0.25	1.4571	5.20	52	–0.6/+0.2	±0.8	78.0	77.3	5.0	60.0	10	±1.10	±1.50	±0.025	125	1.40	35000	39.6	9.1
	18	60.0 x	82.0 x	2 x	0.25	1.4571	5.90	52	–0.6/+0.2	±0.8	78.0	77.3	5.0	60.0	10	±1.00	±1.40	±0.025	250	2.80	54300	39.6	18.2
	22	60.0 x	82.0 x	2 x	0.30	1.4571	6.00	52	–0.6/+0.2	±0.8	78.0	77.3	5.0	60.0	10	±0.80	±1.10	±0.022	440	4.70	92400	39.6	22.0
	42	60.0 x	82.0 x	3 x	0.30	1.4571	6.00	54	–0.6/+0.2	±0.8	78.0	–	–	60.0	10	±0.65	±0.90	±0.018	700	7.60	147000	39.6	33.0
	65	60.0 x	82.0 x	4 x	0.30	1.4571	6.70	59	–0.6/+0.2	±0.8	78.0	–	–	60.0	10	±0.60	±0.80	±0.016	1100	12.10	185300	39.6	44.0
	110	60.0 x	82.0 x	6 x	0.30	1.4571	7.70	38	–0.6/+0.2	±0.8	76.0	–	–	60.0	10	±0.50	±0.65	±0.014	1800	19.80	229600	39.6	44.0
	220	60.8 x	79.0 x	7 x	0.30	1.4571	7.20	41	–0.6/+0.2	±0.8	73.0	–	–	60.8	10	±0.35	±0.60	±0.012	4000	42.50	565500	38.4	64.0
66	6	65.5 x	90.0 x	1 x	0.25	1.4571	5.30	47	–0.6/+0.2	±0.8	85.0	84.3	5.0	65.5	10	±1.10	±1.40	±0.024	90	1.20	29100	47.5	11.2
	15	65.5 x	90.0 x	2 x	0.25	1.4571	6.00	48	–0.6/+0.2	±0.8	85.0	84.3	5.0	65.5	10	±1.00	±1.35	±0.024	190	2.50	47900	47.5	22.4
	20	65.4 x	90.0 x	2 x	0.30	1.4571	6.10	51	–0.6/+0.2	±0.8	85.0	84.3	5.0	65.4	10	±0.95	±1.20	±0.024	330	4.50	80300	47.4	26.9
	32	65.4 x	90.0 x	3 x	0.30	1.4571	6.60	60	–0.6/+0.2	±0.8	82.0	–	–	65.4	10	±0.85	±1.10	±0.023	540	7.20	112300	47.4	40.4
	55	65.4 x	86.0 x	3 x	0.30	1.4571	6.40	63	–0.6/+0.2	±0.8	78.0	–	–	65.4	10	±0.60	±0.85	±0.016	1075	13.40	225300	44.9	35.8
	90	65.4 x	90.0 x	6 x	0.30	1.4571	8.20	36	–0.6/+0.2	±1.0	82.0	–	–	65.4	10	±0.65	±0.80	±0.018	1400	18.00	188500	47.4	81.0
	165	65.4 x	85.0 x	6 x	0.30	1.4571	7.10	36	–0.6/+0.2	±1.0	78.0	–	–	65.4	10	±0.40	±0.60	±0.012	3300	41.00	554500	44.4	65.2
70	7	72.0 x	95.0 x	1 x	0.25	1.4571	4.50	52	–0.6/+0.1	±1.0	85.0	84.3	5.0	72.0	10	±1.00	±1.35	±0.017	150	2.30	77500	54.8	19
	18	70.5 x	95.0 x	2 x	0.30	1.4571	5.90	46	–0.6/+0.2	±1.0	85.0	84.3	5.0	70.5	10	±1.00	±1.35	±0.023	360	5.40	106000	53.8	28
	45	70.5 x	92.0 x	3 x	0.30	1.4571	6.10	55	–0.5/+0.3	±1.0	85.0	–	–	70.5	10	±0.70	±0.90	±0.017	900	12.80	239500	51.8	37
	60	70.5 x	92.0 x	4 x	0.30	1.4571	7.00	53	–0.5/+0.3	±1.0	85.0	–	–	70.5	10	±0.67	±0.80	±0.012	1800	26.00	363000	51.8	50
77	7	77.5 x	101.0 x	1 x	0.25	1.4571	5.50	48	–0.6/+0.2	±1.0	95.0	95.3	5.0	77.5	10	±1.20	±1.30	±0.024	120	2.10	47400	62.5	13

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

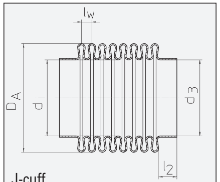
6.3 | Hydra stainless steel bellows
Preferred dimensions



B-cuff



S-cuff

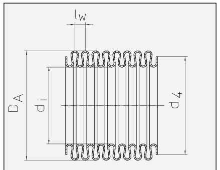


J-cuff

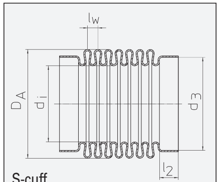
Reference diameter	Nominal pressure P_N*	Bellows profile d_i	D_A	n_L	s	Material	Corrugation length l_w	Max. number of corrugations	Ø Tolerances d_i	D_a	B-cuff Ø d_4	S-cuff Ø inside d_3	S-cuff Length l_2	J-cuff Ø inside d_3	J-cuff Length l_2	Nominal deflection per corrugation (for 10,000 load cycles) axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	Spring rate per corrugation (± 30%) axial c_δ	angular c_α	lateral c_λ	Effective cross-section A	Weight per corrugation
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	mm	mm	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm²	g
77	16	77.5	101.0	2	0.25	1.4571	6.30	49	–0.6/+0.2	±1.0	95.0	95.3	5.0	77.5	10	±1.10	±1.20	±0.025	250	4.60	75300	62.5	26
	20	77.4	101.0	2	0.30	1.4571	6.40	48	–0.6/+0.2	±1.0	95.0	95.3	5.0	77.4	10	±0.95	±1.10	±0.023	425	7.40	123800	62.5	31
	30	76.5	101.0	3	0.30	1.4571	7.20	48	–0.5/+0.3	±1.0	95.0	–	–	76.5	10	±0.90	±0.95	±0.022	610	11.50	139000	61.7	46
85	3	85.0	114.5	1	0.20	1.4571	7.00	38	–0.6/+0.2	±1.0	104.0	–	–	85.1	10	±1.90	±1.40	±0.030	45	1.00	13800	78.2	10
	8	85.0	110.0	1	0.30	1.4571	6.60	45	–0.6/+0.2	±1.0	104.0	103.5	5.0	85.0	10	±1.20	±1.20	±0.027	200	4.10	65500	74.6	10
	25	85.0	106.0	2	0.30	1.4571	6.00	54	–0.6/+0.2	±1.0	101.0	99.0	5.0	85.0	10	±0.90	±1.00	±0.021	710	14.00	268500	71.3	34
	45	85.0	106.0	3	0.30	1.4571	6.50	54	–0.5/+0.3	±1.0	101.0	–	–	85.0	10	±0.70	±0.80	±0.020	1150	22.50	370000	71.1	51
	65	85.0	106.0	4	0.30	1.4571	6.90	52	–0.5/+0.3	±1.0	101.0	–	–	85.0	10	±0.60	±0.70	±0.017	1600	32.00	460000	71.6	68
	80	85.0	108.0	5	0.30	1.4571	7.60	52	–0.5/+0.3	±1.0	101.0	–	–	85.0	10	±0.55	±0.60	±0.012	1700	34.50	411000	73.0	85
93	18	93.0	120.0	2	0.30	1.4571	9.00	40	–0.6/+0.2	±1.0	110.0	113.0	5.0	93.0	10	±1.40	±1.00	±0.035	360	9.00	75600	89.0	50
96	8	96.0	122.0	1	0.30	1.4571	7.10	43	–0.8/+0.2	±1.0	113.0	115.4	5.0	96.0	10	±1.20	±1.10	±0.026	180	4.70	63600	93.3	23
	12	96.0	122.0	2	0.25	1.4571	6.50	45	–0.8/+0.2	±1.0	113.0	115.4	5.0	96.0	10	±1.25	±1.05	±0.024	220	5.70	92800	93.3	37
	18	96.0	122.0	2	0.30	1.4571	6.70	44	–0.8/+0.2	±1.0	113.0	115.4	5.0	96.0	10	±1.00	±0.90	±0.020	385	10.00	152800	93.3	45
	30	96.0	122.0	3	0.30	1.4571	7.40	45	–0.7/+0.3	±1.0	113.0	115.4	5.0	96.0	10	±0.90	±0.80	±0.020	620	16.00	202000	93.3	66
	45	96.0	122.0	4	0.30	1.4571	7.80	43	–0.7/+0.3	±1.0	113.0	–	–	96.0	10	±0.90	±0.80	±0.019	1100	28.50	322000	93.3	86
105	5	105.3	132.0	1	0.25	1.4571	6.80	42	–0.8/+0.2	±1.0	126.0	124.0	5.0	105.3	10	±1.50	±1.30	±0.028	150	4.60	68500	111	21
	8	105.2	132.0	1	0.30	1.4571	6.30	42	–0.8/+0.2	±1.0	126.0	124.0	5.0	105.2	10	±1.20	±1.10	±0.021	240	7.40	127500	111	25
	16	104.9	132.0	2	0.30	1.4571	7.30	50	–0.8/+0.2	±1.2	126.0	124.0	5.0	104.9	10	±1.20	±1.00	±0.024	465	14.20	183600	110	50
	25	105.2	132.0	3	0.30	1.4571	8.00	46	–0.8/+0.2	±1.2	126.0	124.0	5.0	105.2	10	±1.10	±0.90	±0.024	760	23.20	250500	111	75
110	5	110.3	138.0	1	0.25	1.4571	7.20	52	–0.8/+0.2	±1.5	132.0	132.4	8.0	110.3	10	±1.70	±1.30	±0.032	140	4.70	62400	121	23
	12	110.2	130.0	1	0.30	1.4571	5.50	55	–0.8/+0.2	±1.5	125.0	124.4	8.0	110.2	10	±0.75	±0.80	±0.013	460	14.70	329000	113	18
	25	110.2	130.0	2	0.30	1.4571	6.20	50	–0.8/+0.2	±1.5	125.0	124.4	8.0	110.2	10	±0.75	±0.70	±0.012	950	30.00	535000	113	37

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

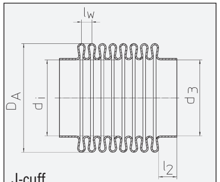
6.3 | **Hydra stainless steel bellows** HYDRA
Preferred dimensions



B-cuff



S-cuff



J-cuff

Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff ØØ	S-cuff ØØ inside	S-cuff Length	J-cuff ØØ inside	J-cuff Length	Nominal deflection per corrugation (for 10,000 load cycles) axial	angular	lateral	Spring rate per corrugation (± 30%) axial	angular	lateral	Effective cross-section	Weight per corrugation
	P_N*	d_i	D_A	n_L	s		l_w		d_i	D_a	d_4	d_3	l_2	d_3	l_2	$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	mm	mm	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
110	40	110.2	130.0	3	0.30	1.4571	7.00	48	–0.7/+0.3	±1.5	125.0	–	–	110.2	10	±0.70	±0.60	±0.012	1600	50.00	706000	113	55
	60	110.2	132.0	4	0.30	1.4571	7.50	42	–0.7/+0.3	±1.5	125.0	–	–	110.2	10	±0.65	±0.55	±0.010	2050	65.00	802000	115	72
	70	110.2	134.0	5	0.30	1.4571	8.00	40	–0.7/+0.3	±1.5	125.0	–	–	110.2	10	±0.60	±0.50	±0.008	2200	71.00	769000	117	90
115	10	115.0	140.0	1	0.30	1.4571	6.80	38	–0.5/+1.5	–1.5/+0.5	132.0	–	–	115.0	10	±1.00	±0.80	±0.017	330	11.70	174000	128	26.0
	18	115.0	133.0	1	0.30	1.4571	5.10	52	–0.5/+1.5	–1.5/+0.5	127.5	–	–	115.0	10	±0.50	±0.40	±0.006	780	26.20	692000	121	19.0
	40	115.0	133.0	2	0.30	1.4571	5.30	40	–0.5/+1.5	–1.5/+0.5	127.5	–	–	115.0	10	±0.45	±0.40	±0.006	1550	52.00	1273000	121	37.4
135	10	135.0	174.0	2	0.30	1.4571	13.00	42	–0.5/+1.5	–1.5/+0.5	158.0	–	–	135.0	16.5	±3.00	±2.00	±0.080	210	11.00	44500	188	95
	18	135.0	171.0	3	0.30	1.4571	14.00	39	–0.5/+1.5	–1.5/+0.5	157.0	–	–	135.0	16.5	±2.20	±1.50	±0.065	440	22.50	78800	184	131
	32	135.0	172.0	5	0.30	1.4571	14.00	39	–0.5/+1.5	–1.5/+0.5	157.0	–	–	135.0	16.5	±2.00	±1.40	±0.060	725	37.30	131000	185	222
	55	135.0	174.0	8	0.30	1.4571	16.00	34	–0.5/+1.5	–1.5/+0.5	158.0	–	–	135.0	16.5	±1.70	±1.20	±0.055	2500	130.00	350000	188	366
164	10	164.0	203.0	2	0.30	1.4571	13.00	42	–0.5/+1.5	–1.5/+0.5	–	–	–	164.0	16.4	±3.00	±1.80	±0.070	250	18.40	74700	265	114
	16	164.0	202.0	3	0.30	1.4571	14.00	39	–0.5/+1.5	–1.5/+0.5	–	–	–	164.0	16.7	±2.60	±1.60	±0.065	425	31.00	109000	263	167
	25	164.0	203.0	5	0.30	1.4571	15.00	36	–0.5/+1.5	–1.5/+0.5	–	–	–	164.0	16.6	±2.40	±1.40	±0.065	750	33.00	168000	265	282
	40	164.0	205.0	8	0.30	1.4571	16.00	34	–0.5/+1.5	–1.5/+0.5	–	–	–	164.0	16.3	±2.10	±1.30	±0.060	1210	90.00	241000	267	466
214	8	214.0	255.0	2	0.30	1.4571	15.00	36	–0.5/+1.5	–1.5/+0.5	–	–	–	214.0	17	±3.30	±1.60	±0.070	275	33.00	100800	432	158
	12	214.0	256.0	3	0.30	1.4571	16.00	34	–0.5/+1.5	–1.5/+0.5	–	–	–	214.0	17.2	±3.10	±1.50	±0.070	415	50.00	134000	434	241
	20	214.0	257.0	5	0.30	1.4571	17.00	32	–0.5/+1.5	–1.5/+0.5	–	–	–	214.0	17.2	±3.00	±1.40	±0.070	685	83.00	197000	436	407
	32	214.0	260.0	8	0.30	1.4571	18.00	30	–0.5/+1.5	–1.5/+0.5	–	–	–	214.0	16.8	±2.80	±1.30	±0.070	1075	132.00	280000	441	685

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

Optimised for ANSI valves

The correction factors for pressure and load cycles have already been taken into account, so that the number of corrugations can be determined pursuant to

$$n_W = \frac{2\delta}{2\delta_n} \qquad (6.1.5.a)$$

BAO: Bellows without connecting pieces
BAT: Bellows with connecting pieces

Bellows description (example):

BAT	60.0	x	82.0	x	6	x	0.3	15W	1.4571
BAT: Bellows with connecting pieces	Inside diameter d_i = 60 mm		Outside diameter D_A = 82 mm		Number of single layers n_L = 6		Individual layers thickness s = 0.3 mm	15 corrugations acc. to Section 6.1.5.a	Material 1.4571

6.4 | HYDRA metal bellows for ANSI valves

Pressure ranges as per ANSI B16.34

Pressure range (ANSI Class)	Design pressure p_{RT} [bar]	Test pressure p_T [bar]
150	25	37.5
300	50	75
600	100	150
800	134	200
900	150	225
1500	250	375

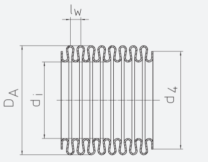
Table 6.4.1.

Load cycle numbers as per MSS SP-117

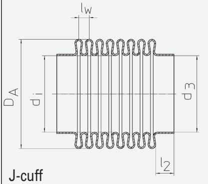
Nominal valve diameter	ANSI pressure range Class 800 and below		ANSI pressure range above Class 800	
	GATE valve	GLOBE valve	GATE valve	GLOBE valve
smaller than 2½"	2,000	5,000	2,000	2,000
2½" to 4"	2,000	5,000	1,000	2,000
larger than 4"	1,000	2,000	1,000	1,000

Table 6.4.2.

6.4 | HYDRA metal bellows for ANSI valves HYDRA



B-cuff

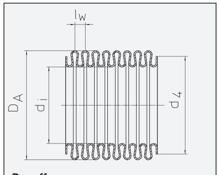


J-cuff

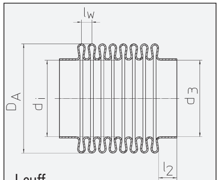
Reference diameter	Max. shaft diam.	ANSI Class	Nominal pressure	Bellows profile				Material	Corru-gation length	Max. no. of corruga-tions	Ø Tolerances		B-cuff Ø	J-cuff Ø inside	J-cuff Length	Nominal deflection per corrugation 1,000 Load cycles	2,000 Load cycles	5,000 Load cycles	Axial spring rate per cor-rugation (± 30%)
			P_N*	d_i	D_A	n_L	s		l_w		d_i	D_a	d_4	d_3	l_2	$2\delta_{n,1000}$	$2\delta_{n,2000}$	$2\delta_{n,5000}$	
mm	mm	–	bar	mm	mm	–	mm		mm	–				mm	mm	mm	mm	mm	N/mm
9	7.5	150	25	9.0	14.0	1	0.10	1.4541 / 1.4571	1.30	235	-0.4/+0.1	±0.3	12.5	9.0	5	±0.26	±0.23	±0.19	115
		300	50	9.0	14.5	2	0.10	1.4541 / 1.4571	1.75	214	-0.4/+0.1	±0.4	13.0	9.0	5	±0.32	±0.28	±0.23	160
		600	100	9.0	14.0	3	0.10	1.4541 / 1.4571	1.75	220	-0.4/+0.1	±0.5	12.5	9.0	5	±0.22	±0.19	±0.16	450
		800/900	150	9.0	14.0	4	0.10	1.4541 / 1.4571	2.00	191	-0.4/+0.1	±0.5	12.5	9.0	5	±0.22	±0.19	±0.16	760
		1500	250	9.0	13.0	4	0.10	1.4541 / 1.4571	1.50	258	-0.5/+0.1	±0.5	11.7	9.0	5	±0.13	±0.11	±0.09	1230
16	14.5	150	25	16.6	24.0	2	0.10	1.4541 / 1.4571	2.00	104	-0.4/+0.1	±0.5	21.5	16.6	6	±0.47	±0.41	±0.34	126
		300	50	16.8	24.0	2	0.15	1.4541 / 1.4571	2.30	106	-0.4/+0.1	±0.5	21.5	16.8	6	±0.35	±0.30	±0.25	420
		600	100	16.4	24.0	3	0.15	1.4541 / 1.4571	2.50	104	-0.5/+0.1	±0.5	21.5	16.4	6	±0.35	±0.30	±0.25	680
		800/900	150	16.4	24.0	4	0.15	1.4541 / 1.4571	3.00	103	-0.5/+0.1	±0.5	21.5	16.4	6	±0.31	±0.27	±0.22	1000
		1500	250	16.0	24.5	4	0.20	1.4541 / 1.4571	3.80	89	-0.5/+0.1	±0.5	21.5	16.0	6	±0.22	±0.19	±0.16	2150
18	16.5	150	25	18.2	26.0	2	0.10	1.4541 / 1.4571	2.70	97	-0.4/+0.2	±0.5	24.0	18.2	6	±0.61	±0.54	±0.44	154
		300	50	18.0	26.0	2	0.15	1.4541 / 1.4571	2.60	93	-0.4/+0.2	±0.5	24.0	18.0	6	±0.43	±0.38	±0.31	405
		600	100	18.0	28.0	3	0.20	1.4541 / 1.4571	3.50	75	-0.4/+0.2	±0.5	25.0	18.0	6	±0.40	±0.35	±0.29	1000
		800/900	150	18.0	28.0	3	0.25	1.4541 / 1.4571	3.80	75	-0.4/+0.2	±0.5	25.0	18.0	6	±0.35	±0.30	±0.25	1700
		1500	250	18.0	28.0	4	0.25	1.4541 / 1.4571	3.50	82	-0.4/+0.2	±0.5	25.0	18.0	6	±0.25	±0.22	±0.18	2840
22	20.5	150	25	22.0	32.5	2	0.15	1.4541 / 1.4571	2.80	73	-0.4/+0.2	±0.5	28.0	22.0	8	±0.63	±0.55	±0.45	217
		300	50	22.0	32.0	2	0.20	1.4541 / 1.4571	3.20	77	-0.4/+0.2	±0.5	28.0	22.0	8	±0.45	±0.39	±0.32	660
		600	100	22.0	32.0	3	0.20	1.4541 / 1.4571	3.30	77	-0.4/+0.2	±0.5	28.0	22.0	8	±0.38	±0.33	±0.27	1020
		800/900	150	22.0	34.0	4	0.25	1.4541 / 1.4571	4.30	59	-0.4/+0.2	±0.8	30.0	22.0	8	±0.38	±0.33	±0.27	1900
		1500	250	22.0	34.0	4	0.30	1.4541 / 1.4571	4.50	65	-0.4/+0.2	±0.8	30.0	22.0	8	±0.29	±0.26	±0.21	3600
24	22.5	150	25	24.2	35.5	2	0.15	1.4541 / 1.4571	3.10	71	-0.4/+0.2	±0.5	34.0	24.2	8	±0.75	±0.66	±0.54	200
		300	50	24.2	36.5	2	0.25	1.4541 / 1.4571	3.30	63	-0.4/+0.2	±0.5	34.0	24.2	8	±0.51	±0.45	±0.37	590

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.4 | HYDRA metal bellows for ANSI valves HYDRA



B-cuff

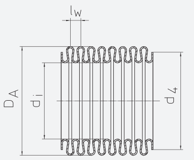


J-cuff

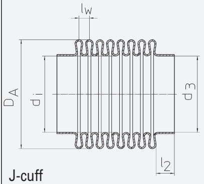
Reference diameter	Max. shaft diam.	ANSI Class	Nominal pressure	Bellows profile				Material	Corru-gation length	Max. no. of corruga-tions	Ø Tolerances		B-cuff	J-cuff		Nominal deflection per corrugation			Axial spring rate per cor-rugation
													Ø	Ø inside	Length	1,000 Load cycles	2,000 Load cycles	5,000 Load cycles	(± 30%)
			P_N*	d_i	D_A	n_L	s		l_w		d_i	D_a	d_4	d_3	l_2	$2\delta_{n,\,1000}$	$2\delta_{n,\,2000}$	$2\delta_{n,\,5000}$	
mm	mm	–	bar	mm	mm	–	mm		mm	–				mm	mm	mm	mm	mm	N/mm
24		600	100	24.0 x	36.5 x	3 x	0.25	1.4541 / 1.4571	4.00	62	-0.4/+0.2	±0.5	34.0	24.0	8	±0.49	±0.43	±0.35	860
		800/900	150	24.0 x	36.0 x	4 x	0.25	1.4541 / 1.4571	4.60	64	-0.4/+0.2	±0.8	34.0	24.0	8	±0.39	±0.34	±0.28	2060
		1500	250	24.0 x	35.5 x	5 x	0.25	1.4541 / 1.4571	4.80	66	-0.6/+0.2	±0.8	34.0	24.0	8	±0.31	±0.27	±0.22	3650
27	25.0	150	25	27.0 x	38.0 x	2 x	0.15	1.4541 / 1.4571	2.80	111	-0.4/+0.2	±0.8	34.5	27.0	8	±0.67	±0.58	±0.48	220
		300	50	27.0 x	40.0 x	2 x	0.25	1.4541 / 1.4571	4.00	88	-0.4/+0.2	±0.8	37.5	27.0	8	±0.56	±0.49	±0.40	660
		600	100	27.0 x	39.5 x	3 x	0.25	1.4541 / 1.4571	4.00	93	-0.4/+0.2	±0.8	36.5	27.0	8	±0.45	±0.39	±0.32	1250
		800/900	150	27.0 x	41.0 x	4 x	0.30	1.4541 / 1.4571	5.20	87	-0.6/+0.2	±0.8	37.5	27.0	8	±0.36	±0.32	±0.26	2200
29	27.0	150	25	29.0 x	43.0 x	2 x	0.20	1.4541 / 1.4571	3.80	83	-0.4/+0.2	±0.8	39.0	29.0	8	±0.83	±0.73	±0.60	260
		300	50	29.0 x	42.0 x	2 x	0.25	1.4541 / 1.4571	3.80	88	-0.4/+0.2	±0.8	39.0	29.0	8	±0.63	±0.55	±0.45	690
		600	100	29.0 x	43.0 x	4 x	0.25	1.4541 / 1.4571	5.00	82	-0.6/+0.2	±0.8	39.0	29.0	8	±0.56	±0.49	±0.40	1360
		800/900	150	29.0 x	41.5 x	4 x	0.25	1.4541 / 1.4571	4.80	88	-0.6/+0.2	±0.8	39.0	29.0	8	±0.49	±0.43	±0.35	2100
		1500	250	29.0 x	43.0 x	5 x	0.30	1.4541 / 1.4571	5.80	70	-0.6/+0.2	±0.8	39.0	29.0	8	±0.42	±0.37	±0.30	4020
34	32.0	150	25	34.0 x	49.0 x	2 x	0.20	1.4541 / 1.4571	4.20	73	-0.4/+0.2	±0.8	47.0	34.0	10	±1.00	±0.88	±0.72	270
		300	50	34.0 x	50.0 x	2 x	0.30	1.4541 / 1.4571	4.60	73	-0.4/+0.2	±0.8	47.0	34.0	10	±0.74	±0.65	±0.53	700
		600	100	34.0 x	49.0 x	3 x	0.30	1.4541 / 1.4571	5.10	75	-0.6/+0.2	±0.8	47.0	34.0	10	±0.61	±0.54	±0.44	1560
		800/900	150	34.0 x	48.0 x	4 x	0.30	1.4541 / 1.4571	5.20	78	-0.6/+0.2	±0.8	45.0	34.0	10	±0.49	±0.43	±0.35	2850
		1500	250	34.0 x	48.0 x	5 x	0.30	1.4541 / 1.4571	5.60	70	-0.6/+0.2	±0.8	45.0	34.0	10	±0.40	±0.35	±0.29	3500
38	36.2	150	25	38.8 x	53.5 x	2 x	0.20	1.4541 / 1.4571	4.50	83	-0.4/+0.2	±0.8	47.0	38.8	10	±0.97	±0.85	±0.70	310
		300	50	39.0 x	54.0 x	2 x	0.30	1.4541 / 1.4571	4.40	73	-0.4/+0.2	±0.8	47.0	39.0	10	±0.67	±0.58	±0.48	1000
		600	100	38.2 x	56.0 x	4 x	0.30	1.4541 / 1.4571	5.50	70	-0.6/+0.2	±0.8	47.0	38.2	10	±0.65	±0.57	±0.47	1400
		800/900	150	38.2 x	55.0 x	5 x	0.30	1.4541 / 1.4571	6.00	67	-0.6/+0.2	±0.8	47.0	38.2	10	±0.58	±0.51	±0.42	2050
		1500	250	38.2 x	54.0 x	6 x	0.30	1.4541 / 1.4571	6.40	54	-0.6/+0.2	±0.8	47.0	38.2	10	±0.45	±0.39	±0.32	4550

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.4 | HYDRA metal bellows for ANSI valves



B-cuff

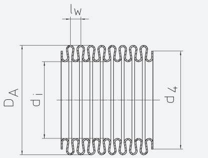


J-cuff

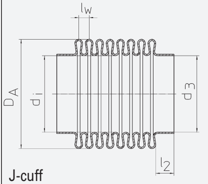
Reference diameter	Max. shaft diam.	ANSI Class	Nominal pressure	Bellows profile				Material	Corrugation length	Max. no. of corrugations	Ø Tolerances		B-cuff	J-cuff		Nominal deflection per corrugation			Axial spring rate per corrugation (± 30%)
			P_N*	d_i	D_A	n_L	s		l_w		d_i	D_a	Ø d_4	Ø inside d_3	Length l_2	1,000 Load cycles $2\delta_{n,1000}$	2,000 Load cycles $2\delta_{n,2000}$	5,000 Load cycles $2\delta_{n,5000}$	
mm	mm	–	bar	mm	mm	–	mm		mm	–				mm	mm	mm	mm	mm	N/mm
42	40.0	150	25	42.0 x	60.0 x	2 x	0.25	1.4541 / 1.4571	5.00	63	-0.4/+0.2	±0.8	57.0	42.0	10	±1.14	±1.00	±0.82	380
		300	50	42.0 x	58.0 x	2 x	0.30	1.4541 / 1.4571	4.80	73	-0.4/+0.2	±0.8	50.5	42.0	10	±0.75	±0.66	±0.54	880
		600	100	42.0 x	60.0 x	4 x	0.30	1.4541 / 1.4571	6.20	67	-0.4/+0.2	±0.8	50.5	42.0	10	±0.72	±0.63	±0.52	1500
		800/900	150	42.0 x	61.0 x	6 x	0.30	1.4541 / 1.4571	7.40	59	-0.6/+0.2	±0.8	55.0	42.0	10	±0.61	±0.54	±0.44	2900
		1500	250	42.0 x	60.0 x	7 x	0.30	1.4541 / 1.4571	8.00	53	-0.6/+0.2	±0.8	55.0	42.0	10	±0.46	±0.40	±0.33	4830
47	45.4	150	25	47.8 x	66.0 x	2 x	0.25	1.4541 / 1.4571	5.10	63	-0.4/+0.2	±0.8	62.5	47.8	10	±1.21	±1.06	±0.87	320
		300	50	47.4 x	63.0 x	2 x	0.30	1.4541 / 1.4571	5.00	78	-0.4/+0.2	±0.8	56.5	47.4	10	±0.72	±0.63	±0.52	1025
		600	100	47.4 x	65.0 x	4 x	0.30	1.4541 / 1.4571	6.30	61	-0.6/+0.2	±0.8	57.0	47.4	10	±0.70	±0.61	±0.50	1850
		800/900	150	47.4 x	64.0 x	6 x	0.30	1.4541 / 1.4571	7.10	58	-0.6/+0.2	±0.8	57.0	47.4	10	±0.51	±0.45	±0.37	4400
		1500	250	47.4 x	64.0 x	8 x	0.30	1.4541 / 1.4571	7.70	51	-0.6/+0.2	±0.8	57.0	47.7	10	±0.36	±0.32	±0.26	7000
53	51.0	1500	250	53.0 x	70.0 x	8 x	0.30	1.4541 / 1.4571	7.70	51	-0.6/+0.2	±0.8	64.0	53.0	10	±0.45	±0.39	±0.32	7700
56	54.0	150	25	56.1 x	74.5 x	2 x	0.25	1.4541 / 1.4571	5.40	60	-0.6/+0.2	±0.8	68.0	56.1	10	±1.25	±1.10	±0.90	425
		300	50	56.2 x	76.0 x	3 x	0.30	1.4541 / 1.4571	6.10	56	-0.6/+0.2	±0.8	68.0	56.2	10	±1.00	±0.88	±0.72	990
		600	100	56.2 x	77.0 x	5 x	0.30	1.4541 / 1.4571	7.20	55	-0.6/+0.2	±0.8	73.0	56.2	10	±0.90	±0.79	±0.65	1600
60	58.0	800/900	150	60.0 x	79.0 x	6 x	0.30	1.4541 / 1.4571	7.50	52	-0.6/+0.2	±0.8	73.0	60.0	10	±0.58	±0.51	±0.42	3300
66	63.4	150	25	65.4 x	87.0 x	2 x	0.30	1.4541 / 1.4571	5.80	52	-0.6/+0.2	±0.8	75.0	65.4	10	±1.25	±1.10	±0.90	530
		300	50	65.4 x	86.0 x	3 x	0.30	1.4541 / 1.4571	6.40	56	-0.6/+0.2	±0.8	82.0	65.4	10	±0.97	±0.85	±0.70	985
		600	100	65.4 x	88.0 x	6 x	0.30	1.4541 / 1.4571	8.10	53	-0.6/+0.2	±1.0	82.0	65.4	10	±1.04	±0.91	±0.75	2010
		800/900	150	65.4 x	85.0 x	6 x	0.30	1.4541 / 1.4571	7.10	54	-0.6/+0.2	±1.0	80.0	65.4	10	±0.63	±0.55	±0.45	3300
70	68.5	150	25	70.5 x	92.0 x	2 x	0.30	1.4541 / 1.4571	6.00	53	-0.6/+0.2	±1.0	85.0	70.5	10	±1.25	±1.10	±0.90	565
		300	50	70.5 x	90.0 x	3 x	0.30	1.4541 / 1.4571	5.50	61	-0.6/+0.2	±1.0	85.0	70.5	10	±0.97	±0.85	±0.70	1220
85	83.0	150	25	85.0 x	106.0 x	2 x	0.30	1.4541 / 1.4571	6.00	54	-0.6/+0.2	±1.0	101.0	85.0	10	±1.39	±1.22	±1.00	710

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.4 | **HYDRA metal bellows for ANSI valves** HYDRA



B-cuff

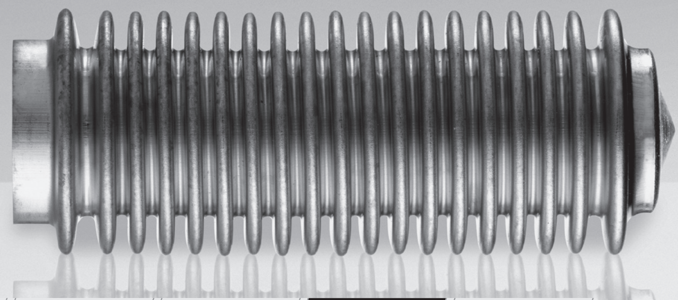


J-cuff

Reference diameter	Max. shaft diam.	ANSI Class	Nominal pressure	Bellows profile				Material	Corrugation length	Max. no. of corrugations		Ø Tolerances		B-cuff Ø	J-cuff Ø inside	J-cuff Length	Nominal deflection per corrugation 1,000 Load cycles	2,000 Load cycles	5,000 Load cycles	Axial spring rate per corrugation
			P_N*	d_i	D_A	n_L	s		l_w			d_i	D_a	d_4	d_3	l_2	$2\delta_{n,1000}$	$2\delta_{n,2000}$	$2\delta_{n,5000}$	(± 30%)
mm	mm	–	bar	mm	mm	–	mm		mm	–					mm	mm	mm	mm	mm	N/mm
85	83.0	300	50	85.0	105.0	3	0.30	1.4541 / 1.4571	6.20	58		-0.6/+0.2	±1.0	101.0	85.0	10	±1.04	±0.91	±0.75	1300
		600	100	85.0	105.0	5	0.30	1.4541 / 1.4571	7.20	51		-0.6/+0.2	±1.0	101.0	85.0	10	±0.92	±0.80	±0.66	2590
96	94.0	800/900	150	96.0	116.0	8	0.30	1.4541 / 1.4571	8.20	44		-0.6/+0.2	±1.0	108.0	96.0	10	±0.68	±0.60	±0.49	6100
110	108.2	150	25	110.2	130.0	2	0.30	1.4541 / 1.4571	6.20	50		-0.8/+0.2	±1.5	125.0	110.2	10	±1.20	±1.05	±0.86	950
		300	30	110.2	129.0	3	0.30	1.4541 / 1.4571	7.00	58		-0.8/+0.2	±1.5	125.0	110.2	10	±0.99	±0.86	±0.71	1875

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.5 | HYDRA bronze bellows



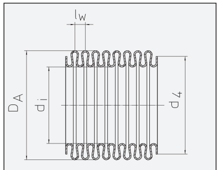
Bronze bellows for measurement and control technology
Based on their small spring rates, bronze bellows are especially suited for measurement and control technology applications. They are manufactured with seamless sleeves made of materials 2.1020 (CuSn6) or 2.1030 (CuSn8).

BAO: Bellows without connecting parts
BAT: Bellows with connecting parts

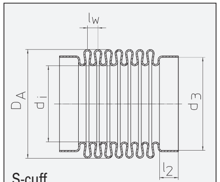
Bellows description (example):

BAO		6.3	x	9.7	x	1	x	0.1		8W		2.1020
BAO: Bellows without connecting part		Inside diameter d_i = 6,3 mm		Outside diameter D_A = 9,7 mm		Number of single layers n_L = 1		Individual layers thickness s = 0.1 mm		8 corrugations acc. to Section 6.1		Material 2.1020

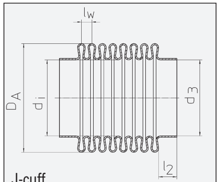
6.5 | HYDRA bronze bellows HYDRA
Preferred dimensions



B-cuff



S-cuff

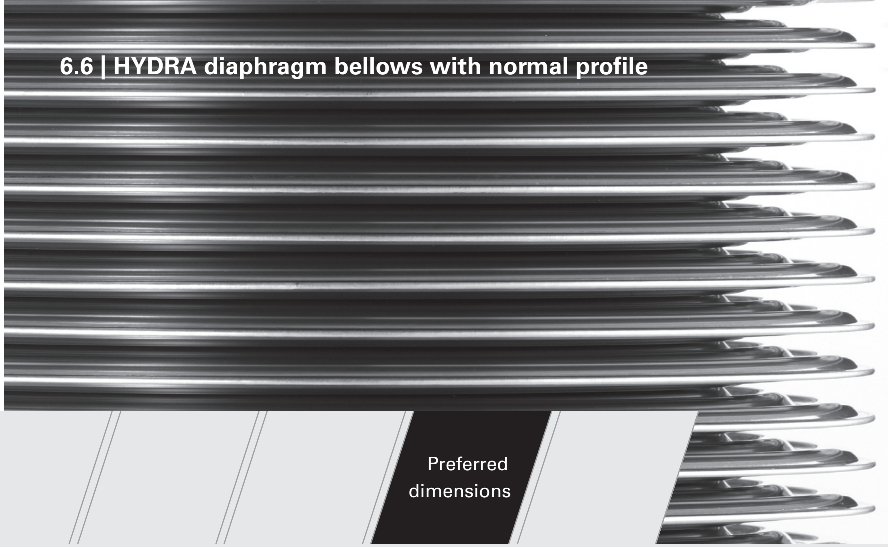


J-cuff

Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	∅Tolerances		B-cuff ∅	S-cuff		J-cuff		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (± 30%)			Effective	Weight per corrugation
												∅ inside	Length	∅ inside	Length	Axial	angular	lateral	Axial	angular	lateral		
	P_N*	d_i	D_A	n_L	s		l_w		d_i	D_a	d_4	d_3	l_2	d_3	l_2	$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	mm	mm	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
4	30	4.06 x	6.0 x	1 x	0.070	2.1020 / 2.1030	0.70	57	±0.2	±0.3	5.5	–	–	4.06	5.0	±0.06	±1.00	±2	207	0.011	32000	0.20	0.02
5	20	5.34 x	8.0 x	1 x	0.080	2.1020 / 2.1030	0.95	53	±0.2	±0.3	7.0	–	–	5.34	5.0	±0.10	±1.25	±4	120	0.012	17700	0.35	0.04
6	12	6.24 x	10.0 x	1 x	0.080	2.1020 / 2.1030	1.25	48	±0.2	±0.3	8.5	–	–	6.24	5.0	±0.15	±1.75	±8	51	0.007	6500	0.53	0.06
	20	6.30 x	9.7 x	1 x	0.10	2.1020 / 2.1030	1.25	48	±0.2	±0.3	8.5	–	–	6.30	5.0	±0.10	±1.20	±4	105	0.015	12900	0.51	0.08
8	8	8.0 x	12.5 x	1 x	0.080	2.1020 / 2.1030	1.30	231	-0.3/+0.2	±0.3	11.7	–	–	8.0	6.0	±0.20	±1.75	±8	47	0.011	8800	0.85	0.10
9	6	9.0 x	14.0 x	1 x	0.080	2.1020 / 2.1030	1.45	207	-0.3/+0.2	±0.3	13.0	12.3	2	9.0	6.0	±0.25	±2.10	±11	40	0.012	7500	1.04	0.13
12	5	12.0 x	19.0 x	1 x	0.090	2.1020 / 2.1030	1.80	167	-0.3/+0.2	±0.4	18.0	16.8	2.5	12.0	6.0	±0.35	±2.10	±14	28	0.015	6200	1.92	0.24
14	5	14.0 x	22.0 x	1 x	0.10	2.1020 / 2.1030	2.20	136	-0.3/+0.2	±0.5	18.5	19.3	3.5	14.0	6.0	±0.35	±2.00	±14	52	0.037	10400	2.63	0.38
16	5	16.0 x	24.0 x	1 x	0.11	2.1020 / 2.1030	1.95	154	-0.3/+0.2	±0.5	21.5	21.1	4.0	16.0	6.0	±0.35	±1.60	±11	49	0.043	15400	3.18	0.45
18	4	18.0 x	28.0 x	1 x	0.11	2.1020 / 2.1030	2.20	136	-0.3/+0.2	±0.5	25.0	25.2	3.0	18.0	6.0	±0.35	±2.10	±11	27	0.031	8800	4.34	0.62
22	3	22.0 x	34.0 x	1 x	0.12	2.1020 / 2.1030	2.80	125	-0.3/+0.2	±0.5	30.0	30.2	4.0	22.0	8.0	±0.60	±2.00	±20	25	0.064	7500	6.20	1.00
27	3	27.0 x	39.0 x	1 x	0.13	2.1020 / 2.1030	2.90	138	-0.3/+0.2	±0.5	37.5	37.2	4.0	27.0	8.0	±0.65	±1.90	±19	41	0.097	16000	8.60	1.32
34	2	34.0 x	50.0 x	1 x	0.15	2.1020 / 2.1030	3.60	111	-0.3/+0.2	±0.5	47.0	45.3	5.0	34.0	10.0	±0.80	±2.00	±22	34	0.131	13800	14.2	2.53

* outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.6 | HYDRA diaphragm bellows with normal profile



Preferred dimensions

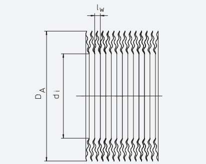
Flexibility for small installation spaces
HYDRA diaphragm bellows with normal profiles have a very high range of movement.
They are particularly suited for applications in which large movements must be implemented in very little installation space. Standard material is 1.4571. Bellows which are subject to high loads can also be made of the hardening material AM 350. Axial loads require a movement distribution of 80% compression and 20% stretching.

MO: Bellows without connecting parts
MM: Bellows with connecting parts

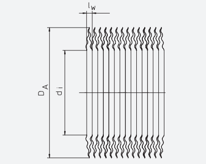
Bellows description (example):

MO	26.0	x	57.0	x	1	x	0.1	8MP	1.4571
MO: Diaphragm bellows without connecting parts	Inside diameter d_i = 26 mm		Outside diameter D_A = 57 mm		Number of single layers n_L = 1		Individual layers thickness s = 0.1 mm	8 diaphragm pairs	Material 1.4571

6.6 | HYDRA diaphragm bellows with standard profile HYDRA
Preferred dimensions



Connection - outside of bellows



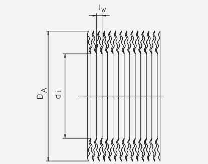
Connection - bellows interior

Reference diameter	Nominal pressure	Bellows profile				Material	Length per diaphragm pair	Max. number of diaphragm pairs*	∅Tolerances		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (± 30%)			Effective cross section	Weight per diaphragm pair
	P_N**	d_i	D_A	n_L	s		l_w		d_i	D_a	axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	axial c_δ	angular c_α	lateral c_λ	A	
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm²	g
11	5.0	11.0 x	22.0 x	1 x	0.10	1.4571	1.2	120	±0.3	±0.3	0.80 = + 0.16 / − 0.64	±1.11	±0.0038	100	0.06	28000	2.2	0.46
	8.0	11.0 x	22.0 x	1 x	0.15	1.4571	1.2	120	±0.3	±0.3	0.70 = + 0.14 / − 0.56	±0.97	±0.0033	210	0.12	59000	2.2	0.68
	4.0	11.0 x	27.0 x	1 x	0.10	1.4571	1.4	100	±0.3	±0.3	1.00 = + 0.20 / − 0.80	±1.21	±0.0049	77	0.06	21000	3.0	0.76
	6.0	11.0 x	27.0 x	1 x	0.15	1.4571	1.5	95	±0.3	±0.3	0.80 = + 0.16 / − 0.64	±0.96	±0.0042	160	0.13	38000	3.0	1.15
	2.5	11.0 x	31.0 x	1 x	0.10	1.4571	2.2	65	±0.3	±0.3	1.20 = + 0.24 / − 0.96	±1.31	±0.0083	52	0.05	7100	3.7	1.06
	5.2	11.0 x	31.0 x	1 x	0.15	1.4571	2.2	65	±0.3	±0.3	1.00 = + 0.20 / − 0.80	±1.09	±0.0069	107	0.10	15000	3.7	1.58
12	8.0	12.0 x	22.0 x	1 x	0.10	1.4571	1.0	145	±0.3	±0.3	0.70 = + 0.14 / − 0.56	±0.94	±0.0027	180	0.11	78000	2.0	0.32
	12.0	12.0 x	22.0 x	1 x	0.15	1.4571	1.0	145	±0.3	±0.3	0.60 = + 0.12 / − 0.48	±0.81	±0.0023	390	0.25	169000	2.0	0.48
17	2.1	17.0 x	37.0 x	1 x	0.10	1.4571	2.1	67	±0.3	±0.3	1.70 = + 0.34 / − 1.36	±1.44	±0.0088	60	0.10	15000	6.0	1.36
	3.6	17.0 x	37.0 x	1 x	0.15	1.4571	2.1	67	±0.3	±0.3	1.40 = + 0.28 / − 1.12	±1.19	±0.0072	110	0.17	27000	6.0	2.04
21	1.3	21.0 x	42.5 x	1 x	0.10	1.4571	2.0	140	±0.3	±0.3	1.60 = + 0.32 / − 1.28	±1.15	±0.0067	50	0.11	19000	8.1	1.72
	2.8	21.0 x	42.5 x	1 x	0.15	1.4571	2.0	140	±0.3	±0.3	1.50 = + 0.30 / − 1.20	±1.08	±0.0062	90	0.20	34000	8.1	2.57
	5.2	21.0 x	42.5 x	1 x	0.20	1.4571	2.0	140	±0.3	±0.3	1.40 = + 0.28 / − 1.12	±1.01	±0.0058	136	0.30	51400	8.1	3.43
	1.0	21.0 x	49.0 x	1 x	0.10	1.4571	3.2	45	±0.3	±0.3	2.40 = + 0.48 / − 1.92	±1.57	±0.0146	35	0.09	6300	10.1	2.46
	2.2	21.0 x	49.0 x	1 x	0.15	1.4571	3.1	45	±0.3	±0.3	2.20 = + 0.44 / − 1.76	±1.44	±0.0129	64	0.17	12200	10.1	3.69
	4.0	21.0 x	49.0 x	1 x	0.20	1.4571	3.1	45	±0.3	±0.3	2.00 = + 0.40 / − 1.60	±1.31	±0.0118	106	0.28	20300	10.1	4.93
26	2.0	25.5 x	50.0 x	1 x	0.10	1.4571	1.9	145	±0.3	±0.3	1.00 = + 0.20 / − 0.80	±0.61	±0.0033	40	0.12	23700	11.6	2.32
	3.0	25.5 x	50.0 x	1 x	0.15	1.4571	1.9	145	±0.3	±0.3	0.90 = + 0.18 / − 0.72	±0.55	±0.0030	95	0.30	56000	11.6	3.49
	0.8	26.0 x	57.0 x	1 x	0.10	1.4571	3.6	75	±0.3	±0.3	2.70 = + 0.54 / − 2.16	±1.49	±0.0156	34	0.13	6800	14.2	3.23
	1.8	26.0 x	57.0 x	1 x	0.15	1.4571	3.7	75	±0.3	±0.3	2.50 = + 0.50 / − 2.00	±1.38	±0.0148	66	0.25	12400	14.2	4.85
	3.2	26.0 x	57.0 x	1 x	0.20	1.4571	3.5	80	±0.3	±0.3	2.30 = + 0.46 / − 1.84	±1.27	±0.0129	101	0.38	21300	14.2	6.47

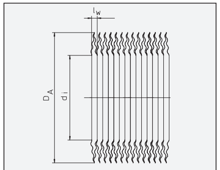
*for connection lengths < 20 mm, the maximum number of diaphragm pairs is reduced for longer connection pieces
** outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.6 | HYDRA diaphragm bellows with standard profile

Preferred dimensions



Connection - outside of bellows



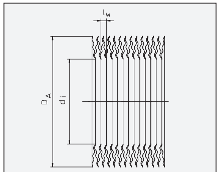
Connection - bellows interior

Reference diameter	Nominal pressure P_N**	Bellows profile d_i	D_A	n_L	s	Material	Length per diaphragm pair l_w	Max. number of diaphragm pairs*	∅Tolerances d_i	D_a	Nominal deflection per corrugation (for 10,000 load cycles) axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	Spring rate per corrugation (± 30%) axial c_δ	angular c_α	lateral c_λ	Effective cross section A	Weight per diaphragm pair
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm²	g
29	0.7	29.0	x 61.0	x 1	x 0.10	1.4571	3.8	72	±0.3	±0.3	2.90 = + 0.58 / – 2.32	±1.48	±0.0163	32	0.14	6700	16.6	3.62
	1.6	29.0	x 61.0	x 1	x 0.15	1.4571	3.7	75	±0.3	±0.3	2.70 = + 0.54 / – 2.16	±1.38	±0.0148	58	0.26	12900	16.6	5.43
	2.9	29.0	x 61.0	x 1	x 0.20	1.4571	3.6	75	±0.3	±0.3	2.50 = + 0.50 / – 2.00	±1.27	±0.0133	95	0.42	22300	16.6	7.24
33	0.6	33.0	x 67.0	x 1	x 0.10	1.4571	3.7	75	±0.3	±0.3	3.10 = + 0.62 / – 2.48	±1.42	±0.0152	30	0.16	8200	20.4	4.27
	1.4	33.0	x 67.0	x 1	x 0.15	1.4571	3.7	75	±0.3	±0.3	2.90 = + 0.58 / – 2.32	±1.33	±0.0143	55	0.30	15100	20.4	6.41
	2.6	33.0	x 67.0	x 1	x 0.20	1.4571	3.7	75	±0.3	±0.3	2.70 = + 0.54 / – 2.16	±1.24	±0.0133	94	0.51	25700	20.4	8.55
36	0.5	36.0	x 72.0	x 1	x 0.10	1.4571	3.8	72	±0.3	±0.3	3.30 = + 0.66 / – 2.64	±1.40	±0.0154	29	0.18	8800	23.8	4.89
	1.3	36.0	x 72.0	x 1	x 0.15	1.4571	3.8	72	±0.3	±0.3	3.10 = + 0.62 / – 2.48	±1.32	±0.0145	51	0.32	15500	23.8	7.33
	2.4	36.0	x 72.0	x 1	x 0.20	1.4571	4.0	70	±0.3	±0.3	2.90 = + 0.58 / – 2.32	±1.23	±0.0143	89	0.57	24300	23.8	9.77
38	0.7	38.0	x 66.0	x 1	x 0.10	1.4571	2.5	110	±0.3	±0.3	2.70 = + 0.54 / – 2.16	±1.19	±0.0086	35	0.21	22700	21.8	3.66
	1.6	38.0	x 66.0	x 1	x 0.15	1.4571	2.6	105	±0.3	±0.3	2.50 = + 0.50 / – 2.00	±1.10	±0.0083	60	0.35	36000	21.8	5.49
	3.0	38.0	x 66.0	x 1	x 0.20	1.4571	2.7	100	±0.3	±0.3	2.30 = + 0.46 / – 1.84	±1.01	±0.0079	100	0.59	55600	21.8	7.32
42	0.5	42.0	x 81.0	x 1	x 0.10	1.4571	4.1	42	±0.3	±0.3	3.60 = + 0.72 / – 2.88	±1.34	±0.0160	27	0.22	9100	30.7	6.03
	1.1	42.0	x 81.0	x 1	x 0.15	1.4571	4.0	45	±0.3	±0.3	3.40 = + 0.68 / – 2.72	±1.27	±0.0147	48	0.40	17000	30.7	9.04
	1.9	42.0	x 81.0	x 1	x 0.20	1.4571	4.4	40	±0.3	±0.3	3.20 = + 0.64 / – 2.56	±1.19	±0.0152	75	0.62	22000	30.7	12.1
44	0.4	44.0	x 84.0	x 1	x 0.10	1.4571	4.2	35	±0.3	±0.3	3.70 = + 0.74 / – 2.96	±1.32	±0.0161	26	0.23	9100	33.2	6.43
	1.0	44.0	x 84.0	x 1	x 0.15	1.4571	4.2	35	±0.3	±0.3	3.50 = + 0.70 / – 2.80	±1.25	±0.0153	47	0.42	16400	33.2	9.65
	1.8	44.0	x 84.0	x 1	x 0.20	1.4571	4.2	35	±0.3	±0.3	3.20 = + 0.64 / – 2.56	±1.15	±0.0140	75	0.67	26000	33.2	12.9
47	0.4	47.0	x 88.0	x 1	x 0.10	1.4571	4.4	32	±0.3	±0.3	3.80 = + 0.76 / – 3.04	±1.29	±0.0165	26	0.26	9200	36.9	6.96
	1.0	47.0	x 88.0	x 1	x 0.15	1.4571	4.4	32	±0.3	±0.3	3.60 = + 0.72 / – 2.88	±1.22	±0.0156	47	0.47	16600	36.9	10.4
	1.8	47.0	x 88.0	x 1	x 0.20	1.4571	4.3	34	±0.3	±0.3	3.30 = + 0.66 / – 2.64	±1.12	±0.0140	78	0.78	28800	36.9	13.9

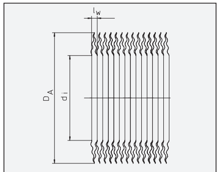
*for connection lengths < 20 mm, the maximum number of diaphragm pairs is reduced for longer connection pieces

** outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.6 | HYDRA diaphragm bellows with standard profile HYDRA
Preferred dimensions



Connection - outside of bellows

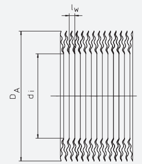


Connection - bellows interior

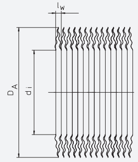
Reference diameter	Nominal pressure P_N**	Bellows profile d_i	D_A	n_L	s	Material	Length per diaphragm pair l_w	Max. number of diaphragm pairs*	∅Tolerances d_i	D_a		Nominal deflection per corrugation (for 10,000 load cycles) axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	Spring rate per corrugation (± 30%) axial c_δ	angular c_α	lateral c_λ	Effective cross section A	Weight per diaphragm pair
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm		mm	Degree	mm	N/mm	Nm/degree	N/mm	cm²	g
52	1.0	52.0	80.0	1	0.10	1.4571	3.2	45	±0.3	±0.3		2.40 = + 0.48 / − 1.92	±0.83	±0.0077	70	0.67	44700	34.0	4.64
	2.1	52.0	80.0	1	0.15	1.4571	3.2	45	±0.3	±0.3		2.20 = + 0.44 / − 1.76	±0.76	±0.0071	128	1.22	82000	34.0	6.97
	4.0	52.0	80.0	1	0.20	1.4571	3.2	45	±0.3	±0.3		2.00 = + 0.40 / − 1.60	±0.69	±0.0064	212	2.01	135000	34.0	9.29
	0.4	52.0	95.0	1	0.10	1.4571	4.6	38	±0.3	±0.3		4.00 = + 0.80 / − 3.20	±1.25	±0.0166	24	0.28	9200	43.6	7.94
	0.9	52.0	95.0	1	0.15	1.4571	4.5	40	±0.3	±0.3		3.80 = + 0.76 / − 3.04	±1.18	±0.0155	50	0.59	20000	43.6	11.9
	1.5	52.0	95.0	1	0.20	1.4571	4.6	38	±0.3	±0.3		3.50 = + 0.70 / − 2.80	±1.09	±0.0146	70	0.83	26800	43.6	15.9
57	0.7	57.0	102	1	0.15	1.4571	4.8	32	±0.3	±0.3		4.10 = + 0.82 / − 3.28	±1.18	±0.0165	42	0.58	17300	51.0	13.5
	1.4	57.0	102	1	0.20	1.4571	4.8	32	±0.3	±0.3		3.90 = + 0.78 / − 3.12	±1.12	±0.0156	65	0.90	26700	51.0	18.0
	2.1	57.0	102	1	0.25	1.4571	5.0	32	±0.3	±0.3		3.60 = + 0.72 / − 2.88	±1.04	±0.0150	91	1.25	34500	51.0	22.5
	4.2	57.0	102	2	0.25	1.4571	5.3	30	±0.3	±0.3		3.30 = + 0.66 / − 2.64	±0.95	±0.0146	196	2.70	662000	51.0	45.0
62	0.7	62.0	109	1	0.15	1.4571	4.9	32	±0.3	±0.3		4.30 = + 0.86 / − 3.44	±1.15	±0.0164	43	0.69	19700	58.9	15.1
	1.2	62.0	109	1	0.20	1.4571	4.9	32	±0.3	±0.3		4.10 = + 0.82 / − 3.28	±1.10	±0.0156	61	0.97	27900	58.9	20.2
	1.9	62.0	109	1	0.25	1.4571	4.9	32	±0.3	±0.3		3.80 = + 0.76 / − 3.04	±1.02	±0.0145	89	1.42	40600	58.9	25.2
67	1.0	67.0	102	1	0.15	1.4571	4.5	36	±0.3	±0.3		3.00 = + 0.60 / − 2.40	±0.81	±0.0106	69	1.07	36500	56.9	11.1
	1.8	67.0	102	1	0.20	1.4571	4.5	36	±0.3	±0.3		2.50 = + 0.50 / − 2.00	±0.68	±0.0088	123	1.92	65000	56.9	14.9
	3.0	67.0	102	1	0.25	1.4571	4.5	36	±0.3	±0.3		2.10 = + 0.42 / − 1.68	±0.57	±0.0074	192	2.99	101500	56.9	18.6
	0.6	67.0	116	1	0.15	1.4571	4.9	32	±0.3	±0.3		4.50 = + 0.90 / − 3.60	±1.13	±0.0160	40	0.73	21000	67.3	16.9
	1.1	67.0	116	1	0.20	1.4571	4.7	32	±0.3	±0.3		4.30 = + 0.86 / − 3.44	±1.08	±0.0147	59	1.08	33500	67.3	22.5
	1.8	67.0	116	1	0.25	1.4571	5.1	30	±0.3	±0.3		4.00 = + 0.80 / − 3.20	±1.00	±0.0148	88	1.61	42500	67.3	28.2
	3.6	67.0	116	2	0.25	1.4571	5.4	29	±0.3	±0.3		3.70 = + 0.74 / − 2.96	±0.93	±0.0145	190	3.47	82000	67.3	56.3
72	0.6	72.0	123	1	0.15	1.4571	5.3	250	±0.3	±0.3		4.70 = + 0.94 / − 3.76	±1.10	±0.0170	43	0.89	22000	76.4	18.7
	1.0	72.0	123	1	0.20	1.4571	5.3	250	±0.3	±0.3		4.50 = + 0.90 / − 3.60	±1.06	±0.0163	54	1.12	27400	76.4	25.0

*for connection lengths < 20 mm, the maximum number of diaphragm pairs is reduced for longer connection pieces
** outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.6 | HYDRA diaphragm bellows with standard profile HYDRA
Preferred dimensions



Connection - outside of bellows



Connection - bellows interior

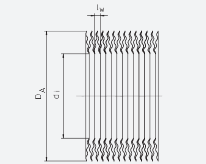
Reference diameter	Nominal pressure P_N**	Bellows profile d_i	D_A	n_L	s	Material	Length per diaphragm pair l_w	Max. number of diaphragm pairs*	∅Tolerances d_i	D_a	Nominal deflection per corrugation (for 10,000 load cycles) axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	Spring rate per corrugation (± 30%) axial c_δ	angular c_α	lateral c_λ	Effective cross section A	Weight per diaphragm pair
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
72	1.6	72.0 x	123 x	1 x	0.25	1.4571	5.2	250	±0.3	±0.3	4.20 = + 0.84 / – 3.36	±0.99	±0.0149	76	1.58	40000	76.4	31.2
	0.7	77.0 x	107 x	1 x	0.10	1.4571	3.4	250	±0.3	±0.3	2.70 = + 0.54 / – 2.16	±0.67	±0.0066	52	0.96	57000	67.1	6.9
	0.5	77.0 x	130 x	1 x	0.15	1.4571	5.2	250	±0.3	±0.3	4.90 = + 0.98 / – 3.92	±1.09	±0.0164	38	0.89	22500	86.0	20.7
	1.0	77.0 x	130 x	1 x	0.20	1.4571	5.3	250	±0.3	±0.3	4.70 = + 0.94 / – 3.76	±1.04	±0.0160	52	1.22	30000	86.0	27.6
	1.5	77.0 x	130 x	1 x	0.25	1.4571	5.4	250	±0.3	±0.3	4.40 = + 0.88 / – 3.52	±0.97	±0.0153	75	1.75	41300	86.0	34.5
82	0.5	82.0 x	136 x	1 x	0.15	1.4571	5.4	250	±0.3	±0.3	5.00 = + 1.00 / – 4.00	±1.05	±0.0165	38	0.98	23200	95.2	22.2
	0.9	82.0 x	136 x	1 x	0.20	1.4571	5.6	250	±0.3	±0.3	4.80 = + 0.96 / – 3.84	±1.01	±0.0164	52	1.35	30000	95.2	29.6
	1.4	82.0 x	136 x	1 x	0.25	1.4571	5.7	250	±0.3	±0.3	4.50 = + 0.90 / – 3.60	±0.95	±0.0156	74	1.92	40600	95.2	37.0
87	0.8	87.0 x	143 x	1 x	0.20	1.4571	5.7	250	±0.3	±0.3	5.20 = + 1.04 / – 4.16	±1.04	±0.0171	54	1.56	33000	106	32.4
	1.3	87.0 x	143 x	1 x	0.25	1.4571	5.8	250	±0.3	±0.3	5.00 = + 1.00 / – 4.00	±1.00	±0.0168	75	2.16	44200	106	40.5
	1.9	87.0 x	143 x	1 x	0.30	1.4571	5.9	250	±0.3	±0.3	4.70 = + 0.94 / – 3.76	±0.94	±0.0160	101	2.91	57600	106	48.6
92	0.6	92.0 x	134 x	1 x	0.15	1.4571	4.0	250	±0.3	±0.3	3.90 = + 0.78 / – 3.12	±0.79	±0.0092	46	1.28	55000	101	17.9
	0.8	92.0 x	134 x	1 x	0.20	1.4571	4.1	250	±0.3	±0.3	3.20 = + 0.64 / – 2.56	±0.65	±0.0077	32	0.89	36400	101	23.9
	1.3	92.0 x	134 x	1 x	0.25	1.4571	4.1	250	±0.3	±0.3	3.00 = + 0.60 / – 2.40	±0.61	±0.0072	45	1.25	51200	101	29.8
	1.9	92.0 x	134 x	1 x	0.30	1.4571	4.2	250	±0.3	±0.3	2.80 = + 0.56 / – 2.24	±0.57	±0.0069	62	1.73	67300	101	35.8
	0.8	92.0 x	149 x	1 x	0.20	1.4571	6.0	250	±0.3	±0.3	5.30 = + 1.06 / – 4.24	±1.01	±0.0175	56	1.77	33900	116	34.5
	1.2	92.0 x	149 x	1 x	0.25	1.4571	6.2	250	±0.3	±0.3	5.10 = + 1.02 / – 4.08	±0.97	±0.0174	77	2.44	43600	116	43.2
	1.8	92.0 x	149 x	1 x	0.30	1.4571	6.2	250	±0.3	±0.3	4.80 = + 0.96 / – 3.84	±0.91	±0.0164	102	3.23	57800	116	51.8
97	1.7	97.0 x	134 x	1 x	0.20	1.4571	4.0	250	±0.3	±0.3	2.80 = + 0.56 / – 2.24	±0.56	±0.0064	142	4.13	178000	106	21.5
	2.7	97.0 x	134 x	1 x	0.25	1.4571	4.2	250	±0.3	±0.3	2.40 = + 0.48 / – 1.92	±0.48	±0.0058	221	6.43	251000	106	26.9
	3.9	97.0 x	134 x	1 x	0.30	1.4571	4.2	250	±0.3	±0.3	2.20 = + 0.44 / – 1.76	±0.44	±0.0053	318	9.26	361000	106	32.2
	0.8	97.0 x	156 x	1 x	0.20	1.4571	6.0	250	±0.3	±0.3	5.50 = + 1.10 / – 4.40	±1.00	±0.0173	59	2.06	39300	128	37.5

*for connection lengths < 20 mm, the maximum number of diaphragm pairs is reduced for longer connection pieces
** outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

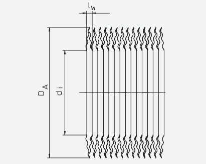
6.6 | HYDRA diaphragm bellows with standard profile

HYDRA

Preferred dimensions



Connection - outside of bellows

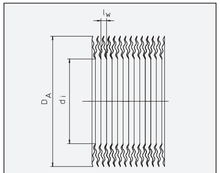


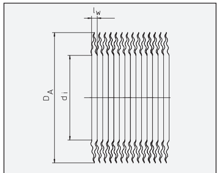
Connection - bellows interior

Reference diameter	Nominal pressure P_N**	Bellows profile d_i	D_A	n_L	s	Material	Length per diaphragm pair l_w	Max. number of diaphragm pairs*	∅Tolerances d_i	D_a	Nominal deflection per corrugation (for 10,000 load cycles) axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	Spring rate per corrugation (± 30%) axial c_δ	angular c_α	lateral c_λ	Effective cross section A	Weight per diaphragm pair
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm²	g
97	1.1	97.0	156	1	0.25	1.4571	6.2	250	±0.3	±0.3	5.30 = + 1.06 / – 4.24	±0.96	±0.0173	76	2.65	47500	128	46.9
	1.7	97.0	156	1	0.30	1.4571	6.2	250	±0.3	±0.3	5.00 = + 1.00 / – 4.00	±0.91	±0.0163	103	3.60	64300	128	56.3
102	0.7	102	163	1	0.20	1.4571	6.0	250	±0.3	±0.3	5.70 = + 1.14 / – 4.56	±0.99	±0.0172	50	1.92	36500	140	40.6
	1.1	102	163	1	0.25	1.4571	6.5	250	±0.3	±0.3	5.50 = + 1.10 / – 4.40	±0.95	±0.0179	77	2.95	48000	140	50.8
	1.6	102	163	1	0.30	1.4571	6.5	250	±0.3	±0.3	5.20 = + 1.04 / – 4.16	±0.90	±0.0170	103	3.95	64200	140	60.9
112	0.6	112	173	1	0.20	1.4571	6.2	250	±0.3	±0.3	5.60 = + 1.12 / – 4.48	±0.90	±0.0162	40	1.77	31600	162	43.7
	1.0	112	173	1	0.25	1.4571	6.4	250	±0.3	±0.3	5.30 = + 1.06 / – 4.24	±0.85	±0.0158	61	2.70	45400	162	54.6
	1.4	112	173	1	0.30	1.4571	6.4	250	±0.3	±0.3	5.00 = + 1.00 / – 4.00	±0.80	±0.0149	81	3.59	60200	162	65.5
121	0.9	121	173	1	0.20	1.4571	6.0	250	±0.3	±0.3	5.20 = + 1.04 / – 4.16	±0.81	±0.0141	65	3.06	58000	172	38.4
	1.4	121	173	1	0.25	1.4571	6.2	250	±0.3	±0.3	4.80 = + 0.96 / – 3.84	±0.75	±0.0134	101	4.76	85200	172	48.0
	2.0	121	173	1	0.30	1.4571	6.2	250	±0.3	±0.3	4.50 = + 0.90 / – 3.60	±0.70	±0.0126	146	6.88	123000	172	57.6
127	0.7	127	185	1	0.15	1.4571	5.6	250	±0.3	±0.3	4.90 = + 0.98 / – 3.92	±0.72	±0.0117	40	2.12	46500	192	34.1
	0.9	127	185	1	0.20	1.4571	5.6	250	±0.3	±0.3	4.80 = + 0.96 / – 3.84	±0.71	±0.0114	60	3.19	70000	192	45.5
	1.3	127	185	1	0.25	1.4571	5.6	250	±0.3	±0.3	4.60 = + 0.92 / – 3.68	±0.68	±0.0110	78	4.14	91000	192	56.9
	1.6	127	185	1	0.30	1.4571	6.0	250	±0.3	±0.3	4.40 = + 0.88 / – 3.52	±0.65	±0.0112	96	5.10	97000	192	68.2
	0.5	127	195	1	0.20	1.4571	6.7	250	±0.3	±0.3	6.10 = + 1.22 / – 4.88	±0.87	±0.0169	42	2.38	36400	207	55.0
	0.9	127	195	1	0.25	1.4571	6.8	250	±0.3	±0.3	5.80 = + 1.16 / – 4.64	±0.83	±0.0163	64	3.62	54000	207	68.8
	1.2	127	195	1	0.30	1.4571	6.9	250	±0.3	±0.3	5.40 = + 1.08 / – 4.32	±0.77	±0.0154	90	5.09	73500	207	82.5
152	0.5	152	226	1	0.20	1.4571	6.8	250	±0.3	±0.3	6.70 = + 1.34 / – 5.36	±0.81	±0.0160	38	2.96	44000	284	70.3
	0.7	152	226	1	0.25	1.4571	6.5	250	±0.3	±0.3	6.40 = + 1.28 / – 5.12	±0.78	±0.0146	60	4.68	76000	284	87.9
	1.0	152	226	1	0.30	1.4571	7.9	250	±0.3	±0.3	6.10 = + 1.22 / – 4.88	±0.74	±0.0169	80	6.23	67000	284	105

*for connection lengths < 20 mm, the maximum number of diaphragm pairs is reduced for longer connection pieces
** outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

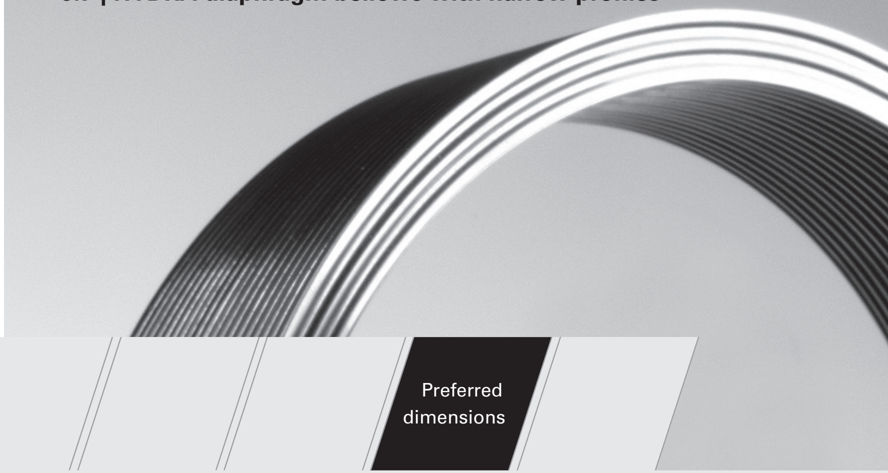
6.6 | **HYDRA diaphragm bellows with standard profile** HYDRA
Preferred dimensions


Normal profile 1


Normal profile 2

Reference diameter	Nominal pressure	Bellows profile				Material	Length per diaphragm pair	Max. number of diaphragm pairs*	∅Tolerances			Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (± 30%)			Effective cross section	Weight per diaphragm pair
	P_N**	d_i	D_A	n_L	s		l_w		d_i	D_a								A	
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm		mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
177	0.4	177 x	257 x	1 x	0.20	1.4571	8.9	250	±0.3	±0.3		7.20 = + 1.44 / – 5.76	±0.76	±0.0196	34	3.49	30300	374	87.3
	0.6	177 x	257 x	1 x	0.25	1.4571	8.9	250	±0.3	±0.3		6.80 = + 1.36 / – 5.44	±0.72	±0.0185	56	5.75	50000	374	109
	0.9	177 x	257 x	1 x	0.30	1.4571	7.5	250	±0.3	±0.3		6.30 = + 1.26 / – 5.04	±0.67	±0.0145	75	7.70	94000	374	131
202	0.4	202 x	287 x	1 x	0.20	1.4571	8.5	250	±0.3	±0.3		7.80 = + 1.56 / – 6.24	±0.73	±0.0180	30	3.91	37200	474	104
	0.5	202 x	287 x	1 x	0.25	1.4571	8.6	250	±0.3	±0.3		7.40 = + 1.48 / – 5.92	±0.69	±0.0173	52	6.78	63000	474	131
	0.8	202 x	287 x	1 x	0.30	1.4571	8.6	250	±0.3	±0.3		6.90 = + 1.38 / – 5.52	±0.65	±0.0161	70	9.13	85000	474	157

*for connection lengths < 20 mm, the maximum number of diaphragm pairs is reduced for longer connection pieces
** outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)



Diaphragm bellows with increased pressure resistance

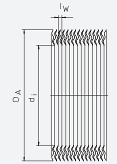
HYDRA diaphragm bellows with narrow profiles are more pressure resistant and also have a higher spring rate than diaphragm bellows with standard profiles. The range of movement is somewhat smaller. For this reason they are well suited for static applications, such as sliding ring seals, for example. The standard material is of 1.4571.
Bellows which are subject to high loads can also be made of the hardening material AM 350. Axial loads require a movement distribution of 80% compression and 20% expansion.

MO: Bellows without connecting parts
MM: Bellows with connecting parts

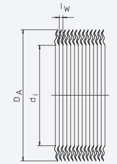
Bellows description (example):

MO	25.5	x	36.5	x	1	x	0.1	8MP	1.4571
MO: Diaphragm bellows without connecting parts	Inside diameter d_i = 25.5 mm		Outside diameter D_A = 36.5 mm		Number of single layers n_L = 1		Individual layers thickness s = 0.1 mm	8 diaphragm pairs	Material 1.4571

6.7 | HYDRA diaphragm bellows with narrow profiles HYDRA
Preferred dimensions



Connection - outside of bellows

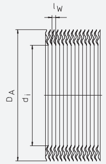


Connection - bellows interior

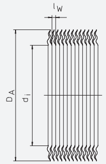
Reference diameter	Nominal pressure	Bellows profile				Material	Length per diaphragm pair	Max. number of diaphragm pairs*	ØTolerances		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (± 30%)			Effective cross section	Weight per diaphragm pair
	P_N**	d_i	D_A	n_L	s		l_w		d_i	D_a	axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	axial c_δ	angular c_α	lateral c_λ	A	
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm²	g
12	8.0	12.0	20.0	1	0.10	1.4571	1.0	145	±0.3	±0.3	0.50 = + 0.10 / – 0.40	±0.72	±0.0021	200	0.11	76800	2.1	0.42
	12.0	12.0	20.0	1	0.15	1.4571	1.0	145	±0.3	±0.3	0.40 = + 0.08 / – 0.32	±0.57	±0.0017	500	0.28	192000	2.1	0.63
17	3.5	17.0	31.0	1	0.10	1.4571	1.5	95	±0.3	±0.3	0.90 = + 0.18 / – 0.72	±0.86	±0.0038	100	0.13	38400	4.65	0.84
	6.0	17.0	31.0	1	0.15	1.4571	1.5	95	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.76	±0.0033	190	0.24	72900	4.65	1.27
25	8.0	25.5	36.5	1	0.10	1.4571	1.2	230	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.44	±0.0015	105	0.22	105000	7.6	0.85
	12.0	25.5	36.5	1	0.15	1.4571	1.2	230	±0.3	±0.3	0.50 = + 0.10 / – 0.40	±0.37	±0.0013	280	0.59	280000	7.6	1.27
29	6.0	29.5	42.5	1	0.10	1.4571	1.4	200	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.45	±0.0018	110	0.31	109000	10.3	1.16
	9.0	29.5	42.5	1	0.15	1.4571	1.4	200	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.38	±0.0016	265	0.75	263000	10.3	1.74
34	6.0	33.5	46.5	1	0.10	1.4571	1.4	200	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.40	±0.0016	105	0.37	129000	12.7	1.29
	9.0	33.5	46.5	1	0.15	1.4571	1.5	185	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.34	±0.0015	247	0.86	263000	12.7	1.94
	6.0	34.5	47.5	1	0.10	1.4571	1.3	215	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.39	±0.0015	100	0.37	149000	13.3	1.32
	9.0	34.5	47.5	1	0.15	1.4571	1.4	200	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.34	±0.0014	250	0.92	322000	13.3	1.98
36	4.0	36.0	53.0	1	0.10	1.4571	1.9	145	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.41	±0.0023	70	0.30	57600	15.6	1.88
	6.0	36.0	53.0	1	0.15	1.4571	1.9	145	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.36	±0.0020	150	0.65	123000	15.6	2.82
37	6.0	37.0	50.0	1	0.10	1.4571	1.5	185	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.37	±0.0016	103	0.43	130000	15.0	1.40
	9.0	37.0	50.0	1	0.15	1.4571	1.5	185	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.32	±0.0014	310	1.28	391000	15.0	2.11
39	6.0	39.5	52.5	1	0.10	1.4571	1.5	185	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.35	±0.0015	97	0.45	137000	16.7	1.48
	9.0	39.5	52.5	1	0.15	1.4571	1.5	185	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.30	±0.0013	300	1.38	423000	16.7	2.23
42	6.0	42.5	55.5	1	0.10	1.4571	1.5	185	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.33	±0.0014	92	0.48	147000	19.0	1.58
	9.0	42.5	55.5	1	0.15	1.4571	1.5	185	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.28	±0.0012	310	1.62	497000	19.0	2.37
44	6.0	44.5	57.5	1	0.10	1.4571	1.5	185	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.31	±0.0014	100	0.57	173000	20.5	1.65
	9.0	44.5	57.5	1	0.15	1.4571	1.6	175	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.27	±0.0013	250	1.42	381000	20.5	2.47

*for connection lengths < 20 mm, the maximum number of diaphragm pairs is reduced for longer connection pieces
** outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.7 | HYDRA diaphragm bellows with narrow profiles HYDRA
Preferred dimensions



Connection - outside of bellows



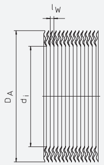
Connection - bellows interior

Reference diameter	Nominal pressure	Bellows profile				Material	Length per diaphragm pair	Max. number of diaphragm pairs*	ØTolerances		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (± 30%)			Effective cross section	Weight per diaphragm pair
	P_N**	d_i	D_A	n_L	s		l_w		d_i	D_a	axial $2\delta_{n,0}$	angular $2\alpha_{n,0}$	lateral $2\lambda_{n,0}$	axial c_δ	angular c_α	lateral c_λ	A	
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm²	g
47	6.0	47.0	60.0	1	0.10	1.4571	1.6	175	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.30	±0.0014	100	0.62	168000	22.6	1.73
	9.0	47.0	60.0	1	0.15	1.4571	1.7	160	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.26	±0.0013	250	1.56	371000	22.6	2.59
52	6.0	52.5	65.5	1	0.10	1.4571	1.6	175	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.27	±0.0013	108	0.82	220000	27.4	1.90
	9.0	52.5	65.5	1	0.15	1.4571	1.7	160	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.23	±0.0012	286	2.17	517000	27.4	2.86
57	6.0	57.0	70.0	1	0.10	1.4571	1.6	165	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.25	±0.0012	102	0.90	241000	31.8	2.05
	9.0	57.0	70.0	1	0.15	1.4571	1.7	145	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.22	±0.0011	270	2.38	565000	31.8	3.07
62	6.0	62.5	75.5	1	0.10	1.4571	1.5	95	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.23	±0.0010	100	1.04	318000	37.5	2.23
	9.0	62.5	75.5	1	0.15	1.4571	1.5	95	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.20	±0.0009	260	2.70	825000	37.5	3.34
	1.0	62.0	88.0	1	0.15	1.4571	1.9	75	±0.3	±0.3	1.50 = + 0.3 / – 1.2	±0.46	±0.0025	148	1.82	346000	44.0	7.35
	2.0	62.0	88.0	1	0.20	1.4571	1.9	75	±0.3	±0.3	1.40 = + 0.28 / – 1.12	±0.43	±0.0024	248	3.04	579000	44.0	9.80
	2.5	62.0	88.0	1	0.25	1.4571	1.9	95	±0.3	±0.3	1.30 = + 0.26 / – 1.04	±0.40	±0.0022	380	4.66	888000	44.0	12.25
67	9.0	67.0	80.0	1	0.15	1.4571	1.5	90	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.22	±0.0010	200	2.36	720000	42.0	3.56
	12.0	67.0	80.0	1	0.20	1.4571	1.6	90	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.19	±0.0009	500	5.89	1583000	42.0	4.74
	7.0	67.0	83.0	1	0.15	1.4571	1.6	90	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.24	±0.0011	225	2.76	74000	44.3	4.47
	10.0	67.0	83.0	1	0.20	1.4571	1.7	85	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.21	±0.0011	560	6.87	1635000	44.3	5.96
72	7.0	72.0	88.0	1	0.15	1.4571	1.6	110	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.23	±0.0011	190	2.65	712500	50.4	4.77
	10.0	72.0	88.0	1	0.20	1.4571	1.7	105	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.20	±0.0010	530	7.40	1760000	50.4	6.35
77	7.0	77.0	93.0	1	0.15	1.4571	1.6	110	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.22	±0.0010	200	3.15	847000	56.9	5.06
	10.0	77.0	93.0	1	0.20	1.4571	1.7	105	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.19	±0.0009	540	8.51	2025000	56.9	6.75
82	7.0	82.0	98.0	1	0.15	1.4571	1.6	95	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.20	±0.0009	213	3.76	1011000	63.8	5.36
	10.0	82.0	98.0	1	0.20	1.4571	1.7	90	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.18	±0.0009	550	9.72	2312000	63.8	7.15
84	7.0	84.0	100	1	0.15	1.4571	1.6	95	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.20	±0.0009	220	4.06	1091000	66.6	5.48

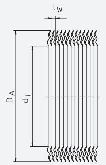
*for connection lengths < 20 mm, the maximum number of diaphragm pairs is reduced for longer connection pieces
** outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.7 | HYDRA diaphragm bellows with narrow profiles
Preferred dimensions

6.7 | HYDRA diaphragm bellows with narrow profiles
Preferred dimensions



Connection - outside of bellows

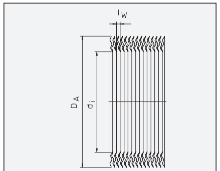


Connection - bellows interior

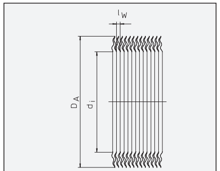
Reference diameter	Nominal pressure	Bellows profile				Material	Length per diaphragm pair	Max. number of diaphragm pairs*	∅Tolerances		Nominal deflection per corrugation (for 10,000 load cycles) axial	angular	lateral	Spring rate per corrugation (± 30%) axial	angular	lateral	Effective cross section	Weight per diaphragm pair
	P_N**	d_i	D_A	n_L	s		l_w		d_i	D_a	$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm²	g
84	10.0	84.0 x	100 x	1 x	0.20	1.4571	1.7	90	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.17	±0.0009	560	10.3	2460000	66.6	7.31
87	7.0	87.0 x	103 x	1 x	0.15	1.4571	1.6	95	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.19	±0.0009	245	4.82	1300000	71.0	5.66
	10.0	87.0 x	103 x	1 x	0.20	1.4571	1.7	90	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.17	±0.0008	710	13.98	3325000	71.0	7.55
92	7.0	92.0 x	108 x	1 x	0.15	1.4571	1.4	110	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.18	±0.0007	315	6.87	2410000	78.1	5.96
	10.0	92.0 x	108 x	1 x	0.20	1.4571	1.6	95	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.16	±0.0007	730	15.9	4277000	78.1	7.94
97	7.0	97.0 x	113 x	1 x	0.15	1.4571	1.6	95	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.17	±0.0008	320	7.70	2070000	86.8	6.25
	10.0	97.0 x	113 x	1 x	0.20	1.4571	1.7	90	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.15	±0.0008	740	17.8	4234000	86.8	8.34
102	7.0	102 x	118 x	1 x	0.15	1.4571	1.5	100	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.17	±0.0007	330	8.71	2660000	95.2	6.55
	10.0	102 x	118 x	1 x	0.20	1.4571	1.7	90	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.15	±0.0007	750	19.8	4710000	95.2	8.74
106	7.0	106 x	122 x	1 x	0.15	1.4571	1.5	100	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.16	±0.0007	330	9.36	2859000	102.2	6.79
	10.0	106 x	122 x	1 x	0.20	1.4571	1.6	95	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.14	±0.0007	750	21.3	5710000	102.2	9.05
112	7.0	112 x	128 x	1 x	0.15	1.4571	1.6	95	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.15	±0.0007	340	10.7	2870000	110.0	7.15
	10.0	112 x	128 x	1 x	0.20	1.4571	1.7	90	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.13	±0.0007	760	23.9	5680000	110.0	9.53
127	7.0	127 x	143 x	1 x	0.15	1.4571	1.6	95	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.14	±0.0006	350	13.9	3740000	143.0	8.04
	10.0	127 x	143 x	1 x	0.20	1.4571	1.7	90	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.12	±0.0006	770	30.6	7280000	143.0	10.72
142	7.0	142 x	158 x	1 x	0.15	1.4571	1.8	20	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.12	±0.0006	350	17.2	3650000	177.0	8.94
	10.0	142 x	158 x	1 x	0.20	1.4571	1.9	20	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.11	±0.0006	770	37.8	7200000	177.0	11.91
	4.0	142 x	168 x	1 x	0.15	1.4571	2.8	20	±0.3	±0.3	1.00 = + 0.2 / – 0.8	±0.15	±0.0012	220	11.5	1010000	189.0	15.00
	6.0	142 x	168 x	1 x	0.20	1.4571	3.0	20	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.12	±0.0010	570	29.9	2280000	189.0	20.00
147	6.0	147 x	167 x	1 x	0.15	1.4571	1.8	20	±0.3	±0.3	0.90 = + 0.18 / – 0.72	±0.13	±0.0007	450	24.2	5130000	192.0	11.69
	8.0	147 x	167 x	1 x	0.20	1.4571	2.0	20	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.12	±0.0007	850	45.7	7860000	192.0	15.59
158	8.0	158 x	178 x	1 x	0.20	1.4571	1.8	20	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.11	±0.0006	870	53.3	11300000	221.0	16.63

*for connection lengths < 20 mm, the maximum number of diaphragm pairs is reduced for longer connection pieces
** outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

6.7 | HYDRA diaphragm bellows with narrow profiles HYDRA
Preferred dimensions



Connection - outside of bellows



Connection - bellows interior

Reference diameter	Nominal pressure P_N**	Bellows profile d_i	D_A	n_L	s	Material	Length per diaphragm pair l_w	Max. number of diaphragm pairs*	∅Tolerances d_i	D_a	Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (± 30%)			Effective cross section A	Weight per diaphragm pair
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm	Degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
158	12.0	158	178	1	0.25	1.4571	2.0	20	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.10	±0.0006	1370	83.9	14400000	221.0	20.79
168	6.0	168	188	1	0.15	1.4571	2.1	20	±0.3	±0.3	0.90 = + 0.18 / – 0.72	±0.12	±0.0007	520	35.9	5600000	249.0	13.25
	8.0	168	188	1	0.20	1.4571	2.2	20	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.10	±0.0007	930	64.3	9130000	249.0	17.67
176	9.0	176	196	1	0.25	1.4571	2.1	20	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.09	±0.0005	1530	115	18000000	272.0	23.08
	12.0	176	196	1	0.30	1.4571	2.2	20	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.07	±0.0005	2200	166	23600000	272.0	27.70
186	3.0	186	212	1	0.15	1.4571	3.0	20	±0.3	±0.3	1.20 = + 0.24 / – 0.96	±0.14	±0.0012	280	24.2	1850000	311.0	19.26
191	7.0	191	211	1	0.20	1.4571	2.0	20	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.09	±0.0005	1050	92.5	15900000	315.0	19.96
	10.0	191	211	1	0.25	1.4571	2.1	20	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.08	±0.0005	1650	145	22600000	315.0	24.94
205	10.0	205	225	1	0.25	1.4571	2.1	20	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.07	±0.0005	1800	182	28300000	363.0	26.68
	12.0	205	225	1	0.30	1.4571	2.2	20	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.06	±0.0004	2900	292	41500000	363.0	32.02
223	10.0	223	243	1	0.25	1.4571	2.1	20	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.07	±0.0004	1850	219	34160000	427.0	28.92
	12.0	223	243	1	0.30	1.4571	2.2	20	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.06	±0.0004	2950	349	49630000	427.0	34.70
240	10.0	240	260	1	0.25	1.4571	2.1	20	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.06	±0.0004	1900	259	40390000	488.0	31.03
	12.0	240	260	1	0.30	1.4571	2.2	20	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.06	±0.0004	3000	409	58100000	488.0	37.23
250	6.0	250	275	1	0.25	1.4571	2.6	20	±0.3	±0.3	0.90 = + 0.18 / – 0.72	±0.08	±0.0006	1400	210	21400000	537.0	40.72
	8.0	250	275	1	0.30	1.4571	2.7	20	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.07	±0.0005	2200	331	31200000	537.0	48.86
268	6.0	268	292	1	0.25	1.4571	2.6	20	±0.3	±0.3	0.90 = + 0.18 / – 0.72	±0.07	±0.0006	1600	274	27800000	611.0	41.70
	8.0	268	292	1	0.30	1.4571	2.7	20	±0.3	±0.3	0.80 = + 0.16 / – 0.64	±0.07	±0.0005	2500	428	40300000	611.0	50.04
280	5.0	280	300	1	0.25	1.4571	2.6	20	±0.3	±0.3	0.70 = + 0.14 / – 0.56	±0.06	±0.0004	2000	367	37300000	656.0	35.99
	7.0	280	300	1	0.30	1.4571	2.7	20	±0.3	±0.3	0.60 = + 0.12 / – 0.48	±0.05	±0.0004	3100	569	53600000	656.0	43.19

*for connection lengths < 20 mm, the maximum number of diaphragm pairs is reduced for longer connection pieces
** outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

Overview

6.8 | Geometry of connecting parts for metal and diaphragm bellows

Metal bellows with B-cuff

The design of the weld area for the connecting parts and the selection of the welding method are determined by the total wall thickness of the bellows, i.e. multiply wall thickness by the number of layers. The dimensions for d_4, n_L and s can be found in the bellows tables 6.3 or 6.4.

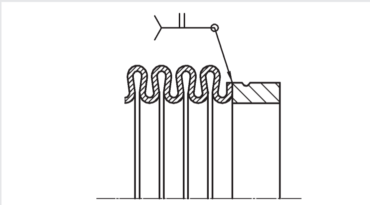


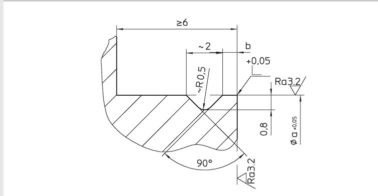
Figure 6.8.1.

Total wall thickness	Welding method	Geometry of weld lip	Weld diameter	Width of weld lip
mm	–	–	mm	mm
n_L x s ≤ 0.10	Laser	B III	$a = d_4^{\pm 0.05}$	–
0.10 < n_L x s ≤ 0.20	Laser	B III	$a = d_4^{\pm 0.05}$	–
0.10 < n_L x s ≤ 0.20	Laser / Microplasma	B I, B IV	$a = d_4^{\pm 0.05}$	$b = 0,4^{+0,1/-0}$
0.20 < n_L x s ≤ 0.30	Laser / Microplasma	B I, B IV	$a = d_4^{\pm 0.05}$	$b = (2 x s)^{+0,1/-0}$
0.30 < n_L x s ≤ 0.45	Laser / Microplasma / TIG	B I, B IV	$a = d_4^{\pm 0.05}$	$b = (2 x s)^{+0,1/-0}$
0.45 < n_L x s ≤ 0.90	Microplasma / TIG	B I, B IV	$a = d_4^{\pm 0.05}$	$b = (2 x s)^{\pm 0,1}$
0.90 < n_L x s ≤ 1.20	TIG with weld accessory	B II, B V	$a = d_4^{\pm 0.05}$	$b = (2 x s)^{\pm 0,1}$
0.90 < n_L x s ≤ 1.20	TIG with weld accessory	B II, B V	$a = d_4^{\pm 0.05}$	$b = 2,5^{\pm 0,1}$

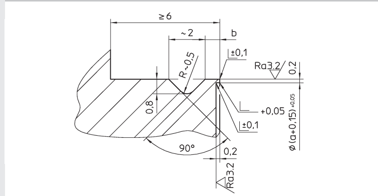
Table 6.8.1.

Geometry designs in the weld seam area

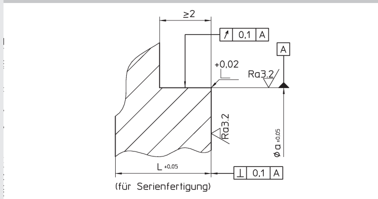
Design B I



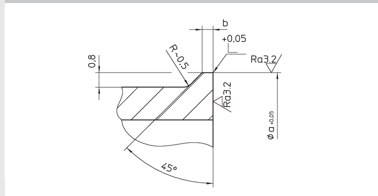
Design B II (also for intermediate rings)



Design B III



Design B IV



Design B V

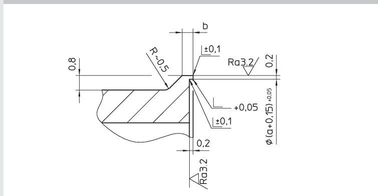


Figure 6.8.2. (values a and b in accordance with Table 6.8.1.)

6.8 | Geometry of connecting pieces for metal and diaphragm bellows

Metal bellows with S-cuff

S-cuffs can be made for bellows with a maximum of 3 layers and a total wall thickness that is less than or equal to 0.9 mm. The design of the connecting piece is mainly determined by the welding method. The dimensions for d_3, l_2, n_L and s can be found in the bellows tables 6.3 or 6.4.

Welded through

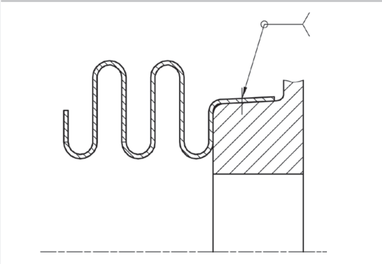


Figure 6.8.3.a

Welded on edge

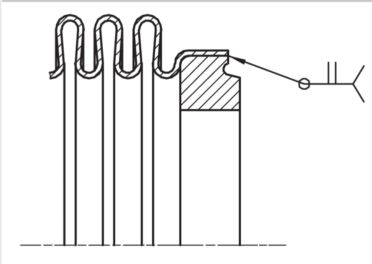


Figure 6.8.3.b

Total wall thickness	Welding method and position	Process	Cuff diameter	Weld diameter	Width of weld lip	Edge radius
mm	–	–	mm	mm	mm	mm
n_L x s ≤ 0.4	Laser pressed on and welded through (6.8.3.a)	S I	35 m d_3 ≤ 75 *	$a = (d_3 + 0.3)^{\pm 0.05}$	–	R = 1.0
n_L x s ≤ 0.45	Laser welded on edge (6.8.3.b)	S II	$d_3 \le 32$ $32 < d_3 \le 115$ $115 < d_3$	$a = (d_3 + 0.1)^{\pm 0.05}$ $a = (d_3 + 0.3)^{\pm 0.05}$ $a = (d_3 + 0.5)^{\pm 0.05}$	–	R = 0.5 R = 1.0 R = 1.5
0.1 < n_L x s ≤ 0.3	Microplasma welded on edge (6.8.3.b)	S III	$d_3 \le 32$ $32 < d_3 \le 115$ $115 < d_3$	$a = (d_3 + 0.1)^{\pm 0.05}$ $a = (d_3 + 0.3)^{\pm 0.05}$ $a = (d_3 + 0.5)^{\pm 0.05}$	$b = (2 \times n_L \times s)^{+0.1/-0}$	R = 0.5 R = 1.0 R = 1.5
0.3 < n_L x s ≤ 0.9	Microplasma or TIG welded on edge (6.8.3.b)	S III	$d_3 \le 32$ $32 < d_3 \le 115$ $115 < d_3$	$a = (d_3 + 0.1)^{\pm 0.05}$ $a = (d_3 + 0.3)^{\pm 0.05}$ $a = (d_3 + 0.5)^{\pm 0.05}$	$b = (2 \times n_L \times s)^{+0.1/-0}$	R = 0.5 R = 1.0 R = 1.5

Table 6.8.2.

** Other dimensions with special tools*

Design S I

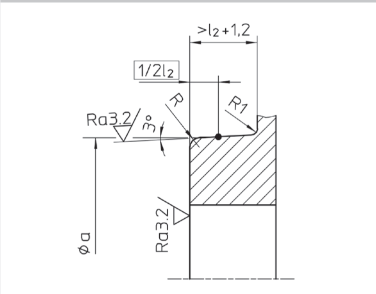
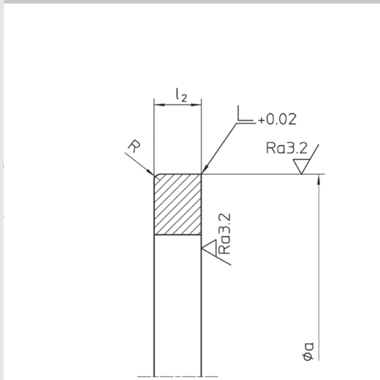
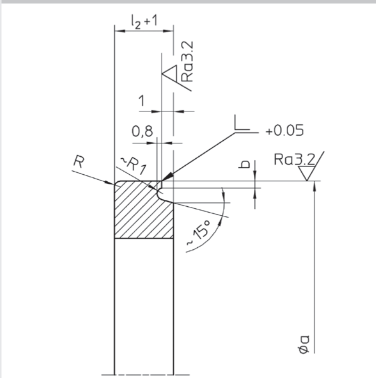


Figure 6.8.4. (values a, b and R in accordance with Table 6.8.2., l_2 in accordance with Tables 6.3. or 6.4.)

Design S II



Design S III



6.8 | Geometry of connecting pieces for metal and diaphragm bellows

Metal bellows with J-cuff

The welding method determines the connection geometry for J-cuffs (with or without weld lip). The dimensions for d_3, l_2, n_L and s can be found in the bellows tables 6.3 or 6.4.

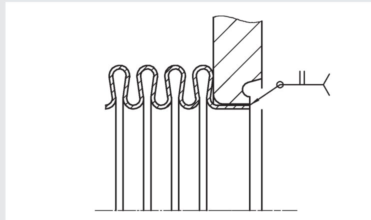


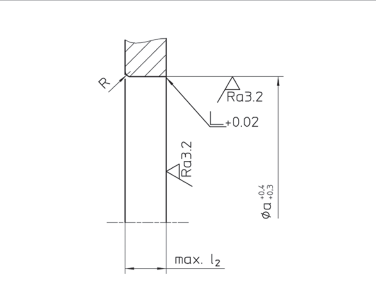
Figure 6.8.5.

Total wall thickness	Welding method and position	Process	Cuff diameter	Weld diameter	Width of weld lip	Edge radius
mm	–	–	mm	mm	mm	mm
n_L x s ≤ 0.45	Laser	J I	$d_3 \le 10$ $10 < d_3 \le 50$ $50 < d_3$	$a = (d_3 + 2 \times n_L \times s)^{+0.2/+0.3}$	–	R = 0.35 R = 1.0 R = 1.5
0.1 < n_L x s ≤ 0.3	Microplasma	J II	$d_3 \le 10$ $10 < d_3 \le 50$ $50 < d_3$	$a = (d_3 + 2 \times n_L \times s)^{+0.3/+0.4}$	–	R = 0.35 R = 1.0 R = 1.5
0.3 < n_Lx s ≤ 0.9	Microplasma or TIG	J II	$d_3 \le 10$ $10 < d_3 \le 50$ $50 < d_3$	$a = (d_3 + 2 \times n_L \times s)^{+0.3/+0.4}$	$b = (2 \times n_L \times s)^{+0.1/-0}$	R = 0.35 R = 1.0 R = 1.5
0.9 < n_Lx s ≤ 2.4	TIG with additional work material	J II	$d_3 \le 10$ $10 < d_3 \le 50$ $50 < d_3$	$a = (d_3 + 2 \times n_L \times s)^{+0.3/+0.4}$	$b = (2 \times n_L \times s)^{+0.1/-0}$	R = 0.35 R = 1.0 R = 1.5

Table 6.8.3.

6.8 | Geometry of connecting pieces for metal and diaphragm bellows

Design J I



Design J II

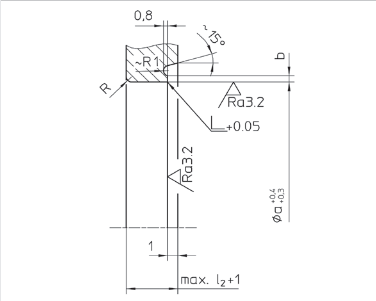


Figure 6.8.6. (values a, b and R in accordance with Table 6.8.3., l_2 in accordance with Tables 6.3. or 6.4.)

Metal bellows

Connecting pieces for diaphragm bellows may be welded at the outside or inside diameter with the microplasma welding method. The dimensions for D_A, d_i, and l_W are indicated in diaphragm bellows tables 6.6 or 6.7.

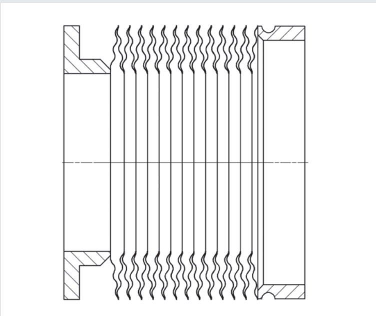


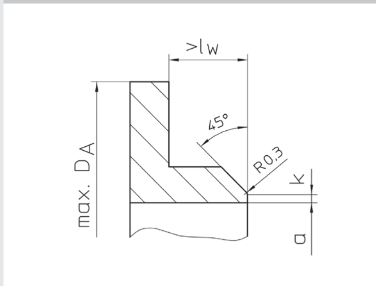
Figure 6.8.7.

6.8 | Geometry of connecting pieces for metal and diaphragm bellows

Welding position	Bellows inside diameter	Weld diameter	Width of weld lip	Edge dimensions
–	mm	mm	mm	mm
at inside diameter	$d_i \leq 60$ $60 < d_i \leq 100$ $100 < d_i$	$a = d_i^{+0.1/-0}$ $a = d_i^{+0.15/-0}$ $a = d_i^{+0.2/-0}$	$b = 0.4^{+0.1/-0}$ $b = 0.5^{+0.1/-0}$ $b = 0.6^{+0.1/-0}$	$k = \max\begin{cases}0.9\\ \frac{D_A - d_i}{24} - 0.2\end{cases}$
at outside diameter	$D_A \leq 80$ $80 < D_A \leq 140$ $140 < D_A$	$a = (D_A - 0.15)^{+0.1/-0}$ $a = (D_A - 0.15)^{+0.15/-0}$ $a = (D_A - 0.15)^{+0.15/-0.05}$	$b = 0.4^{+0.1/-0}$ $b = 0.5^{+0.1/-0}$ $b = 0.6^{+0.1/-0}$	$k = \max\begin{cases}0.9\\ \frac{D_A - d_i}{24} - 0.2\end{cases}$

Table 6.8.4.

Connecting piece for inside diameter



Connecting piece for outside diameter

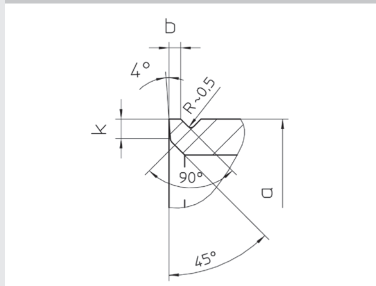
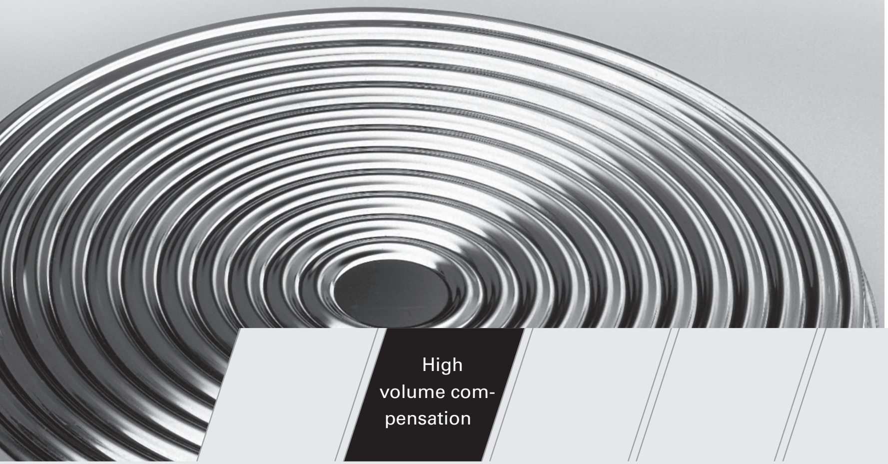


Figure 6.8.8. (values a, b and k in accordance with Table 6.8.2., D_A in accordance with Tables 6.6. or 6.7.)



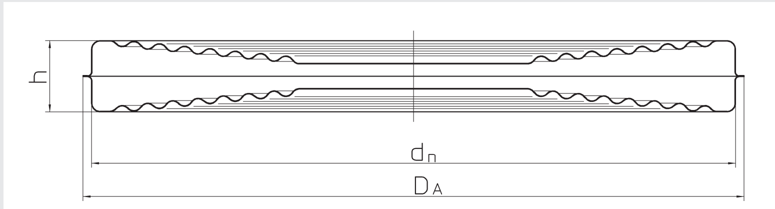
High volume compensation

Compensating for volume changes
HYDRA load cells are described on the basis of their installation dimensions, volume compensation and differential pressures at which the minimum or maximum load cell volume is obtained. Negative differential pressure means outside positive pressure.

1.4541 is the standard work material used for load cells; other materials are available on request.

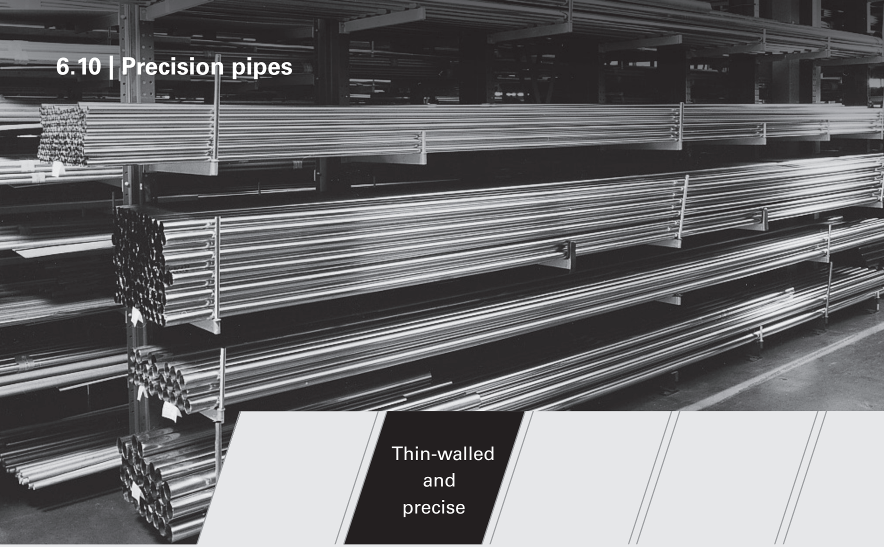
Bellows description (example):

DZ		500	x	515	x	0.5		1.4541
DZ: Load cell		Nominal diameter d_n = 500 mm		Outside diameter D_A = 515 mm		Wall thickness 0.5 mm		Material 1.4571



Load cells: Dimensions and Performance

Nominal diameter d_n	Outside diameter D_A	Height h	Volume compensation ΔV (± 5%)	Differential pressure min. / max.
mm	mm	mm	l	mbar
260	275	40	1.9	-100 / 240
330	342	36	4.5	-100 / 550
380	390	42	7.5	-350 / 1000
440	450	42	10.0	-350 / 1000
500	515	56	12.5	-100 / 510



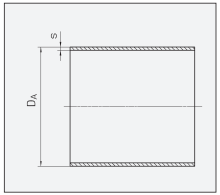
HYDRA precision pipes are sorted by diameter and wall thickness. The maximum delivery length per pipe is 6,500 m; any number of shorter lengths are also available. Tolerances for pipe diameter and length are in the range of ±0.1 mm. Standard material is 1.4571; other materials available on request.

Bellows description (example):

HWE		35.8	x	0.2	x	300		1.4571
HWE: Precision pipe		Outside diameter D_A = 35.8 mm		Wall thickness 0.2 mm		Length 300 mm		Material: 1.4571

HYDRA

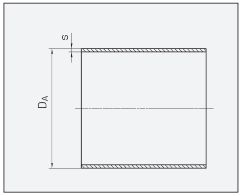
Thin-walled stainless steel pipes
Standard material: 1.4571



Outer diam. D_A	Wall thickness s
[mm]	[mm]
7.30	**0.10**
8.00	0.10
8.20	0.10
8.50	0.10
8.80	0.10
9.10	0.10
9.20	0.10
9.50	0.10
9.80	0.10
10.10	0.10
10.20	0.10
10.40	0.10
10.50	0.10
10.80	0.10
11.10	0.10
11.40	0.10
11.90	0.10
12.00	0.10
12.20	0.10
12.30	0.10
12.40	0.10
12.50	0.10
12.60	0.10
12.80	0.10
13.00	0.10
13.20	0.10
13.50	0.10
14.20	0.10
14.40	0.10
14.80	0.10
14.90	0.10

Outer diam. D_A	Wall thickness s
[mm]	[mm]
15.00	0.10
15.05	0.10
15.10	0.10
15.50	0.10
15.90	0.10
16.00	0.10
16.30	0.10
16.40	0.10
16.50	0.10
16.80	0.10
17.10	0.10
17.70	0.10
17.90	0.10
18.20	0.10
18.30	0.10
18.40	0.10
18.70	0.10
19.90	0.10
20.00	0.10
20.35	0.10
20.40	0.10
22.20	0.10
22.40	0.10
22.80	0.10
22.90	0.10
24.20	0.10
25.70	0.10
27.20	0.10
30.50	0.10
32.00	0.10

Outer diam. D_A	Wall thickness s
[mm]	[mm]
8.30	**0.15**
8.70	0.15
9.30	0.15
9.70	0.15
10.00	0.15
10.10	0.15
10.30	0.15
10.40	0.15
10.90	0.15
12.00	0.15
12.10	0.15
12.30	0.15
12.40	0.15
12.50	0.15
12.70	0.15
13.10	0.15
13.50	0.15
13.80	0.15
13.90	0.15
14.30	0.15
14.50	0.15
14.70	0.15
14.90	0.15
15.30	0.15
15.50	0.15
15.70	0.15
15.90	0.15
16.00	0.15
16.10	0.15
16.30	0.15
16.50	0.15



Outer diam. D_A	Wall thickness s
[mm]	[mm]
16.70	0.15
16.90	0.15
17.10	0.15
17.50	0.15
17.90	0.15
18.00	0.15
18.30	0.15
18.50	0.15
18.70	0.15
18.90	0.15
19.10	0.15
19.30	0.15
19.50	0.15
19.70	0.15
20.00	0.15
20.10	0.15
20.50	0.15
20.90	0.15
21.30	0.15
21.70	0.15
22.10	0.15
22.30	0.15
22.50	0.15
22.70	0.15
22.80	0.15
22.90	0.15
23.00	0.15
23.30	0.15
23.50	0.15
24.20	0.15
24.40	0.15

Outer diam. D_A	Wall thickness s
[mm]	[mm]
24.50	0.15
24.60	0.15
24.90	0.15
25.40	0.15
25.70	0.15
25.80	0.15
26.00	0.15
26.30	0.15
26.50	0.15
27.00	0.15
27.30	0.15
27.70	0.15
28.30	0.15
28.80	0.15
30.00	0.15
30.50	0.15
30.80	0.15
31.00	0.15
32.00	0.15
32.50	0.15
33.00	0.15
33.50	0.15
34.50	0.15
35.00	0.15
35.80	0.15
36.20	0.15
37.50	0.15
39.20	0.15
41.00	0.15
44.20	0.15
45.30	0.15

Outer diam. D_A	Wall thickness s
[mm]	[mm]
45.80	0.15
46.50	0.15
47.00	0.15
47.50	0.15
47.90	0.15
50.40	0.15
51.00	0.15
51.70	0.15
54.20	0.15
8.40	**0.20**
9.10	0.20
9.40	0.20
10.00	0.20
10.10	0.20
10.40	0.20
12.40	0.20
13.60	0.20
14.10	0.20
15.00	0.20
15.60	0.20
16.00	0.20
16.10	0.20
16.40	0.20
16.70	0.20
16.95	0.20
17.50	0.20
18.05	0.20
18.10	0.20
18.20	0.20
18.40	0.20

Outer diam. D_A	Wall thickness s
[mm]	[mm]
18.60	0.20
18.70	0.20
18.90	0.20
19.40	0.20
19.90	0.20
20.10	0.20
20.20	0.20
20.40	0.20
20.70	0.20
20.90	0.20
21.00	0.20
22.40	0.20
22.60	0.20
22.90	0.20
23.10	0.20
23.20	0.20
23.40	0.20
23.90	0.20
24.00	0.20
24.40	0.20
24.50	0.20
24.60	0.20
24.90	0.20
25.10	0.20
25.40	0.20
26.10	0.20
26.70	0.20
27.20	0.20
27.40	0.20
27.90	0.20
28.40	0.20

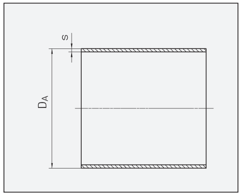
Outer diam. D_A	Wall thickness s
[mm]	[mm]
28.90	0.20
29.40	0.20
29.90	0.20
30.10	0.20
30.40	0.20
30.70	0.20
30.90	0.20
31.30	0.20
32.00	0.20
33.10	0.20
33.60	0.20
33.70	0.20
34.40	0.20
34.60	0.20
34.90	0.20
35.20	0.20
35.60	0.20
35.80	0.20
35.90	0.20
36.10	0.20
36.40	0.20
37.30	0.20
37.50	0.20
39.20	0.20
39.75	0.20
41.00	0.20
41.60	0.20
42.20	0.20
42.40	0.20
42.80	0.20
43.20	0.20

Outer diam. D_A	Wall thickness s
[mm]	[mm]
43.40	0.20
43.75	0.20
44.30	0.20
45.60	0.20
45.80	0.20
46.20	0.20
46.50	0.20
46.80	0.20
46.90	0.20
47.10	0.20
47.60	0.20
48.00	0.20
48.60	0.20
51.00	0.20
51.60	0.20
51.80	0.20
52.40	0.20
52.60	0.20
53.50	0.20
53.65	0.20
54.30	0.20
56.50	0.20
57.10	0.20
10.50	**0.25**
11.20	0.25
12.50	0.25
13.10	0.25
13.80	0.25
14.70	0.25
15.90	0.25

HYDRA

Thin-walled stainless steel pipes

Standard material: 1.4571



Outer diam. D_A	Wall thickness s
[mm]	[mm]
16.20	0.25
16.90	0.25
17.00	0.25
17.60	0.25
18.50	0.25
19.15	0.25
19.80	0.25
20.45	0.25
21.10	0.25
21.75	0.25
22.40	0.25
22.50	0.25
22.70	0.25
23.10	0.25
23.70	0.25
24.30	0.25
24.50	0.25
25.10	0.25
25.40	0.25
25.70	0.25
26.30	0.25
26.90	0.25
27.50	0.25
28.00	0.25
28.15	0.25
28.30	0.25
28.80	0.25
29.50	0.25
30.10	0.25
30.70	0.25
31.30	0.25

Outer diam. D_A	Wall thickness s
[mm]	[mm]
31.90	0.25
32.50	0.25
33.20	0.25
33.90	0.25
34.50	0.25
35.00	0.25
35.10	0.25
35.70	0.25
36.30	0.25
36.90	0.25
37.50	0.25
38.20	0.25
38.90	0.25
39.30	0.25
39.95	0.25
41.10	0.25
41.80	0.25
42.50	0.25
43.20	0.25
43.30	0.25
43.50	0.25
43.95	0.25
44.50	0.25
45.20	0.25
45.70	0.25
45.80	0.25
46.40	0.25
46.60	0.25
46.90	0.25
47.05	0.25
47.30	0.25

Outer diam. D_A	Wall thickness s
[mm]	[mm]
47.60	0.25
47.70	0.25
48.30	0.25
49.00	0.25
49.70	0.25
50.00	0.25
50.05	0.25
50.40	0.25
50.70	0.25
51.10	0.25
51.50	0.25
51.80	0.25
51.90	0.25
52.20	0.25
52.60	0.25
53.30	0.25
54.00	0.25
54.10	0.25
54.70	0.25
54.80	0.25
54.90	0.25
55.50	0.25
56.60	0.25
57.30	0.25
59.10	0.25
59.40	0.25
59.80	0.25
60.10	0.25
60.40	0.25
60.50	0.25
61.20	0.25

HYDRA

Thin-walled stainless steel pipes

Standard material: 1.4571

Outer diam. D_A	Wall thickness s
[mm]	[mm]
61.60	0.25
65.90	0.25
66.00	0.25
66.70	0.25
68.90	0.25
69.60	0.25
69.70	0.25
70.50	0.25
70.90	0.25
71.00	0.25
71.70	0.25
72.50	0.25
72.60	0.25
77.90	0.25
78.00	0.25
78.70	0.25
78.80	0.25
87.90	0.25
88.00	0.25
88.80	0.25
89.70	0.25
96.50	0.25
97.20	0.25
99.90	0.25
100.00	0.25
100.80	0.25
103.40	0.25
105.80	0.25
107.90	0.25
108.00	0.25
108.70	0.25

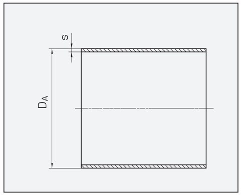
Outer diam. D_A	Wall thickness s
[mm]	[mm]
108.80	0.25
9.60	**0.30**
10.00	0.30
12.00	0.30
12.30	0.30
13.40	0.30
14.80	0.30
15.20	0.30
16.30	0.30
16.70	0.30
17.00	0.30
19.30	0.30
21.00	0.30
22.60	0.30
23.00	0.30
23.40	0.30
24.20	0.30
24.60	0.30
25.00	0.30
25.20	0.30
25.40	0.30
25.80	0.30
27.60	0.30
28.30	0.30
28.35	0.30
29.10	0.30
29.60	0.30
30.30	0.30
31.00	0.30
31.70	0.30

Outer diam. D_A	Wall thickness s
[mm]	[mm]
32.40	0.30
33.10	0.30
33.60	0.30
34.60	0.30
35.30	0.30
36.00	0.30
36.10	0.30
36.70	0.30
37.40	0.30
37.60	0.30
38.10	0.30
38.85	0.30
39.15	0.30
39.60	0.30
39.95	0.30
40.35	0.30
41.10	0.30
41.20	0.30
41.85	0.30
42.00	0.30
42.60	0.30
43.35	0.30
43.40	0.30
44.10	0.30
44.85	0.30
45.60	0.30
46.35	0.30
46.70	0.30
47.10	0.30
47.50	0.30
47.85	0.30

6.10 | Precision pipes

Thin-walled stainless steel pipes

Standard material: 1.4571

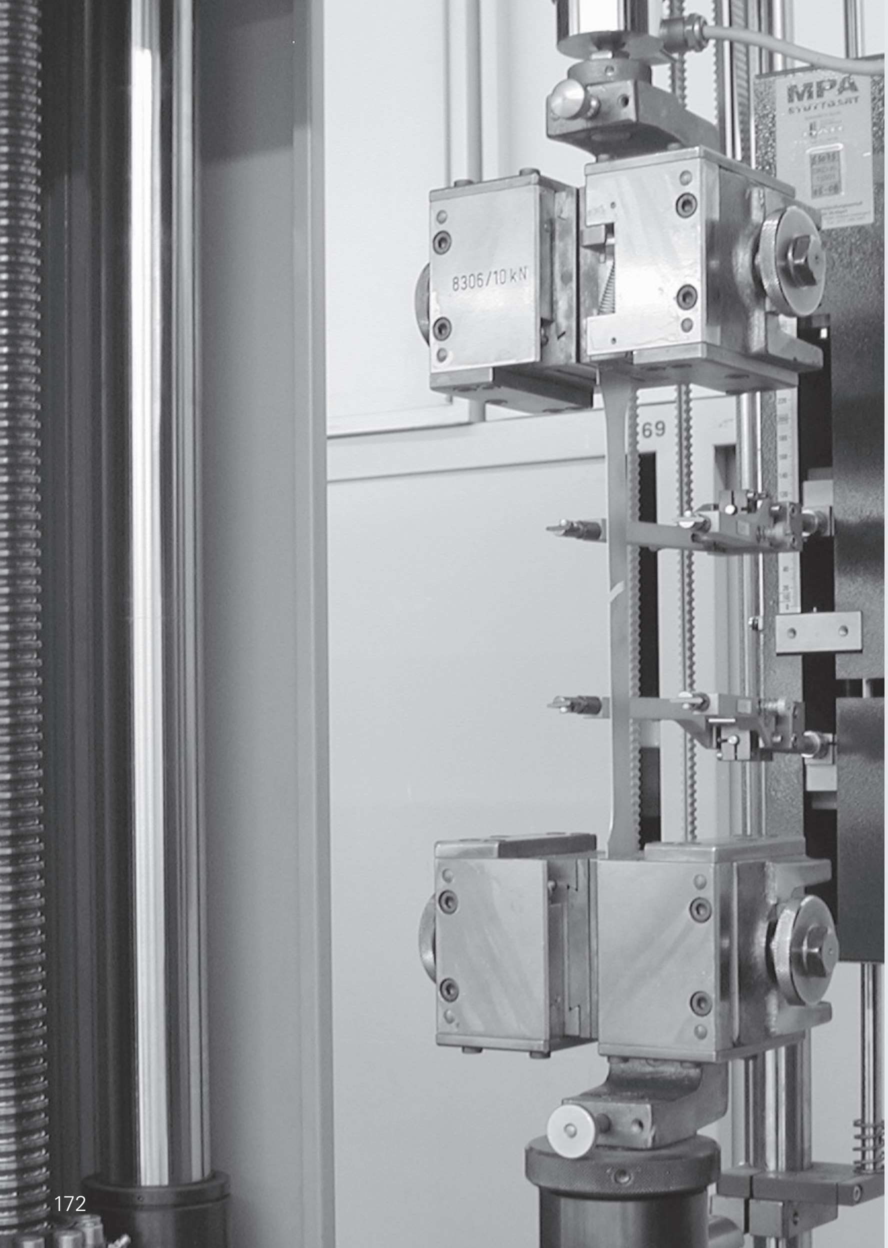


Outer diam. D_A	Wall thickness s
[mm]	[mm]
48.00	0.30
48.80	0.30
49.40	0.30
49.60	0.30
50.40	0.30
51.20	0.30
52.00	0.30
52.36	0.30
52.80	0.30
53.60	0.30
54.20	0.30
54.40	0.30
55.00	0.30
55.20	0.30
56.00	0.30
56.70	0.30
56.80	0.30
57.50	0.30
57.60	0.30
58.40	0.30
59.20	0.30
60.00	0.30
60.60	0.30
61.40	0.30
62.20	0.30
63.00	0.30
63.80	0.30
64.60	0.30
65.40	0.30
66.00	0.30
66.10	0.30

Outer diam. D_A	Wall thickness s
[mm]	[mm]
66.90	0.30
67.80	0.30
68.70	0.30
69.55	0.30
69.70	0.30
70.40	0.30
71.00	0.30
71.10	0.30
71.25	0.30
71.90	0.30
72.10	0.30
72.95	0.30
73.80	0.30
74.65	0.30
77.10	0.30
77.90	0.30
78.00	0.30
78.10	0.30
78.90	0.30
85.60	0.30
86.50	0.30
87.40	0.30
88.00	0.30
88.10	0.30
88.20	0.30
88.30	0.30
88.90	0.30
89.20	0.30
89.70	0.30
93.60	0.30
94.50	0.30

Outer diam. D_A	Wall thickness s
[mm]	[mm]
95.40	0.30
96.30	0.30
96.60	0.30
97.50	0.30
98.40	0.30
99.30	0.30
100.00	0.30
100.10	0.30
100.20	0.30
100.90	0.30
101.10	0.30
101.30	0.30
102.00	0.30
102.80	0.30
102.90	0.30
103.60	0.30
105.80	0.30
106.70	0.30
108.00	0.30
108.10	0.30
108.90	0.30
109.00	0.30
109.70	0.30
109.90	0.30
110.80	0.30
111.70	0.30

Tools are available for the pipe sizes listed in the tables. Other sizes, wall thickness and materials are available on request.



7 | Data Sheets

Designations, available types, temperature limits

Material group	Material no. to DIN EN 10 027	Short name to DIN EN 10 027	Short name to DIN (old)	Semi-finished product	Documentation	Documentation on old	Upper temp. limit °C
Unalloyed steel	1.0254	P235TR1	St 37.0	Welded tube	DIN EN 10217-1	DIN 1626	300
				Seamless tube	DIN EN 10216-1	DIN 1629	
	1.0255	P235TR2	St 37.4	Welded tube	DIN EN 10217-1		
				Seamless tube	DIN EN 10216-1		
	1.0427	C22G1	C 22.3	Flanges	VdTÜV-W 364		350
Common structural steel	1.0038	S235JRG2	RSt 37-2	Steel bar, flat	DIN EN 10025		300
	1.0050	E295	St 50-2	products, wire rod,			
	1.0570	S355J2G3	St 52-3	profiles	AD W1		
Heat resistant unalloyed steel	1.0460	C22G2	C 22.8	Flanges	VdTÜV W 350		450
Heat resistant steel	1.0345	P235GH	HI	Sheet	DIN EN 10028	DIN 17155	480
				Seamless tube	DIN EN 10216		450
	1.0425	P265GH	HII	Sheet	DIN EN 10028	DIN 17155	480
	1.0481	P295GH	17 Mn 4	Sheet	DIN EN 10028	DIN 17155	500
				Seamless tube	DIN 17175		
	1.5415	16Mo3	15 Mo 3	Sheet	DIN EN 10028	DIN 17155	530
				Seamless tube	DIN 17175		
	1.7335	13CrMo4-5	13 CrMo 4 4	Sheet	DIN EN 10028	DIN 17155	570
				Seamless tube	DIN 17175		
	1.7380	10CrMo9-10	10 CrMo 9 10	Sheet	DIN EN 10028	DIN 17155	600
				Seamless tube	DIN 17175		
	1.0305	P235G1TH	St 35.8	Seamless tube	DIN 17175		480
Fine-grained structural steel Standard	1.0562	P355N	StE 355	Sheet	DIN EN 10028	DIN 17102	
heat resist.	1.0565	P355NH	WStE 355	Strip			400
cold resist.	1.0566	P355NL1	TStE 355	Steel bar			(-50) [1]
special	1.1106	P355NL2	EStE 355				(-60) [1]

1) Cold resistant limit

Strength values at room temperature (RT) (guaranteed values [1])

Material no. to DIN EN 10 027	Yield point min. R_{eH} N/mm²	Tensile strength R_m N/mm²	Breaking elongation, min. A_5 %	A_{80} %	Notched bar impact strength min. A_V (KV [2]) J	Remarks
1.0254	235	360-500	23			s ≤ 16
1.0255	235	360-500	23		at 0 °C: 27	s ≤ 16
1.0427	240	410-540	20 (transverse)		at RT: 31	s ≤ 70
1.0038	235	340-470	21-26 [1]	17-21 [3]	at RT: 27	3 ≤ s ≤ 100 (R_m)
1.0050	295	470-610	16-20 [1]	12-16 [3]		10 ≤ s ≤ 150 (KV)
1.0570	355	490-630	18-22 [1]	14-18 [3]	at -20 °C: 27	s < 16 (R_{eH})
1.0460	240	410-540	20		at RT: 31	s ≤ 70
1.0345	235	360-480	25		at 0 °C: 27	s ≤ 16
	235	360-500	23		at 0 °C: 27	s ≤ 16
1.0425	265	410-530	23		at 0 °C: 27	s ≤ 16
1.0481	295	460-580	22		at 0 °C: 27	s ≤ 16
	270					
1.5415	275	440-590	24		at RT: 31	s ≤ 16
	270					
1.7335	300	440-600	20		at RT: 31	s ≤ 16
	290					
1.7380	310	480-630	18		at RT: 31	s ≤16
	280					
1.0305	235	360-480	23		at RT: 34	s ≤ 16
1.0562	355	490-630	22		at 0 °C: 47	s ≤ 16
1.0565					at 0 °C: 47	s ≤ 16
1.0566					at 0 °C: 55	s ≤ 16
1.1106					at 0 °C: 90	s ≤ 16

1) Smallest value of longitudinal or transverse test
2) New designation to DIN EN 10045; average of 3 specimens in DIN EN standards
3) Dependent on product thickness

Designations, available types, temperature limits

Material group	Material no. to DIN EN 10 027	Short name to DIN EN 10 027	Semi-finished product	Documentation	Documentation old	Upper temp. limit °C
Stainless ferritic steel	1.4511	X3CrNb17	Strip	DIN EN 10088 VdTÜV-W422	DIN 17441 2)	200 nach VdTÜV
	1.4512	X2CrTi12	Strip	DIN EN 10088 SEW 400		350
Stainless austenitic steel	1.4301	X5CrNi18-10	Strip Strip Sheet	DIN EN 10088	DIN 17441/97 DIN 17440/96	550 / 300 1)
	1.4306	X2CrNi19-11	Strip Strip Sheet	DIN EN 10088	DIN 17441/97 DIN 17440/96	550 / 350 1)
	1.4541	X6CrNiTi18-10	Strip Strip Sheet	DIN EN 10088	DIN 17441/97 DIN 17440/96	550 / 400 1)
	1.4571	X6CrNiMoTi17-12-2	Strip Strip Sheet	DIN EN 10088	DIN 17441/97 DIN 17440/96	550 / 400 1)
	1.4404	X2CrNiMo17-12-2	Strip Strip Sheet	DIN EN 10088	DIN 17441/97 DIN 17440/96	550 / 400 1)
	1.4435	X2CrNiMo18-14-3	Strip Strip Sheet	DIN EN 10088	DIN 17441/97 DIN 17440/96	550 / 400 1)
	1.4565	X2CrNiMnMoNbN25-18-5-4	Strip, Strip Sheet	SEW 400 / 97	SEW 400 / 91	550 / 400 1)
	1.4539	X1NiCrMoCu25-20-5	Strip Sheet, Strip	DIN EN 10088		550 / 400 1)
			Seamless tube	VdTÜV-W421		400
	1.4529	X1NiCrMoCuN25-20-7	Strip Sheet, Strip Seamless tube	DIN EN 10088 VdTÜV-W 502		400
Austenitic steel of high heat resistance	1.4948	X6CrNi18-10	Strip Sheet	DIN EN 10028-7	DIN 17460	600
			strip Forgin	DIN EN 10222-5	DIN 17460	600
			Seamless tube	DIN 17459		600
	1.4919	X6CrNiMo17-13	Sheet, strip, bar	DIN 17460		600
			Forging			
			Seamless tube	DIN 17459		600
	1.4958	X5NiCrAlTi31-20	Sheet, strip, bar Forging	DIN 17460		600
			Seamless tube	DIN 17459		600

1) Temperature limit where risk of intercrystalline corrosion
2) Earlier standard DIN 17441 7/85

Strength values at room temperature (RT) (guaranteed values 3))

Material no. to DIN EN 10 027		Yield points min. $R_{p0,2}$ N/mm²	Yield points min. $R_{p1,0}$ N/mm²	Tensile strength R_m N/mm²	Breaking elongation, min. > 3 mm Thickness A_5 %	Breaking elongation, min. < 3 mm Thickness A_{80} %	Notched bar impact strength > 10 mm thickness, transverse min. KV in J	Remarks
1.4511		230		420-600		23		s ≤ 6
1.4512		210		380-560		25		s ≤ 6
1.4301	q	230	260	540-750	45	45	at RT: 60	s ≤ 6
	l	215	245		43	40		
1.4306	q	220	250	520-670	45	45	at RT: 60	s ≤ 6
	l	205	235		43	40		
1.4541	q	220	250	520-720	40	40	at RT: 60	s ≤ 6
	l	205	235		38	35		
1.4571	q	240	270	540-690	40	40	at RT: 60	s ≤ 6
	l	225	255		38	35		
1.4404	q	240	270	530-680	40	40	at RT: 60	s ≤ 6
	l	225	255		38	35		
1.4435	q	240	270	550-700	40	40	at RT: 60	s ≤ 6
	l	225	255		38	35		
1.4565	q	420	460	800-1000	30	25	at RT: 55	s ≤ 30
1.4539	q	240	270	530-730	35	35	at RT: 60	s ≤ 6
	l	225	255		33	30		
		220	250	520-720	40	40		
1.4529	q	300	340	650-850	40	40	at RT: 60	
	l	285	325		38	35		s ≤ 75
		300	340	600-800	40	40	at RT: 84	
1.4948	q	230	260	530-740	45	45	at RT: 60	s ≤ 6
	q	195	230	490-690	35		at RT: 60	s ≤ 250
	q	185	225	500-700	30		at RT: 60	
1.4919		205	245	490-690	35	30	at RT: 60	
		205	245	490-690	30		at RT: 60	
1.4958		170	200	500-750	35	30	at RT: 80	
		170	200	500-750	35		at RT: 80	s ≤ 50

3) Smallest value of longitudinal or transverse test, q = tensile test, transverse, l = tensile test, longitudinal

Designations, available types, temperature limits

Material group	Material no. to DIN EN 10 027 [1]	Short name to DIN EN 10 027	Trade name	Semi-finished product	Documentation	Upper temp. limit °C
Heat resistant steel	1.4828	X15CrNiSi20-12		Strip Sheet, Strip,	DIN EN 10095 (SEW470)	900
	1.4876	X10NiCrAlTi32-21	INCOLOY 800	Strip Sheet, Strip all	SEW470 VdTÜV-W412	 600
		X10NiCrAlTi32-21 H	INCOLOY 800 H	Strip Sheet, Strip all	VdTÜV-W434 DIN EN 10095	950 900
Nickel-based alloys	2.4858	NICr21Mo	INCOLOY 825	all Strip Sheet, Strip	DIN 17750/02 VdTüV-W432 DIN 17744 [2]	 450
	2.4816	NiCR15Fe	INCONEL 600 INCONEL 600 H	 Strip Sheet, Strip	DIN EN 10095 DIN 17750/02 VdTÜV-W305 DIN 17742 [2]	1000 450
	2.4819	NiMo16Cr15W	HASTELLOY C-276	Strip Sheet, Strip	DIN 17750/02 VdTÜV-W400 DIN 17744 [2]	 450
	2.4856	NiCr22Mo9Nb	INCONEL 625 INCONEL 625 H	Flat products Strip Sheet, Strip	DIN EN 10095 DIN 17750/02 (VdTÜV-W499) DIN 17744 [2]	900 450
	2.4610	NiMo16Cr16Ti	HASTELLOY-C4	Strip Sheet, Strip Strip Sheet, Strip	DIN 17750/02 VdTÜV-W424 DIN 17744 [2]	 400
	2.4360	NiCu30Fe	MONEL	Strip, Strip Sheet Seamless tube Forging	DIN 17750/02 VdTÜV-W 263 DIN 17743 [2]	 425

1) In the case of nickel-based alloys, DIN 17007 governs the material number
2) Chemical composition

Strength values at room temperature (RT) (guaranteed values [3])

Material no. to DIN EN 10 027 [1]	Yield points min. $R_{p0,2}$ N/mm²	$R_{p1,0}$ N/mm²	Tensile strength R_m N/mm²	Breaking elongation, min. A_5 %	A_{80} %	Notched bar impact strength min. KV J	Remarks
1.4828	230	270	500-750				s ≤ 3 mm solution annealed
1.4876	170	210	450-680	22			Soft annealed
INCOLOY 800	210	240	500-750	30		at RT: 150 [4]	
(1.4876 H)	170	200	450 -700	30			solution annealed (AT)
INCOLOY 800H	170	210	450-680		28		
2.4858	240	270	≥ 550	30			Soft annealed
INCOLOY 825	235	265	550-750			at RT: 80	s ≤ 30 mm
2.4816	240		500-850				Annealed (+A)
	180	210	≥ 550		28		solution annealed (F50)
INCONEL 600	200	230	550-750	30		at RT: 150 [4]	Soft annealed
INCONEL 600 H	180	210	500-700	35	30	at RT: 150 [4]	solution annealed
2.4819	310	330	≥ 690	30			s ≤ 5 mm, solution anne-
HASTELLOY C-276	310	330	730-1000	30	30	at RT: 96	aled (F69)
					30		
2.4856	415		820-1050				s ≤ 3 mm, Annealed (+A)
INCONEL 625 H	275	305	≥ 690			at RT: 100	solution annealed (F69)
INCONEL 625	400	440	830-1000	30			s ≤ 3 mm; Soft annealed
2.4610	305	340	≥ 690	40		at RT: 96	s ≤ 5, solution annealed
HASTELLOY-C4	280	315	700-900	40	30	at RT: 96	5 < s ≤ 30
					30		
2.4360	175	205	≥ 450	30			s ≤ 50, Soft annealed
MONEL	175		450-600	30		at RT: 120	Soft annealed

3) Smallest value of longitudinal or transverse test
4) Value a_k in J/cm²

Designations, available types, temperature limits

Material group	Material designation DIN EN 1652 (new) Number	Short name	DIN 17670 (old Number	Short name	Semi-finished product	Documentation	Documentation old	Upper temp. limit °C
Copper-based alloy	CW354H	CuNi30Mn1Fe	2.0882	CuNi30Mn1Fe CUNIFER 30 [1]	Strip, Strip Sheet	DIN-EN 1652 AD-W 6/2	DIN 17664 DIN 17670	350
Copper	CW024A	Cu-DHP	2.0090	SF-Cu	Strip, Strip Sheet	DIN-EN 1652 AD-W 6/2	DIN 1787 DIN 17670	250
Copper-tin alloy	CW452K	CuSn6	2.1020	CuSn6 Bronze	Strip, Strip Sheet	DIN-EN 1652	DIN 17662 DIN 17670	
Copper-zinc alloy	CW503L	CuZn20	2.0250	CuZn 20	Strip, Strip Sheet	DIN-EN 1652	DIN 17660 DIN 17670	
	CW508L	CuZn37	2.0321	CuZn 37 Brass	Strip, Strip Sheet	DIN-EN 1652	DIN 17660 DIN 17670	
			2.0402	CuZn40Pb2	Strip, Strip Sheet	DIN 17670 DIN 17660		
	DIN EN 485-2 (new) Number	Short Name	DIN 1745-1 (old) Number	Short Name	Semi-finished product	Documentation	Documentation old	Upper temp. limit °C
Wrought aluminium alloy	EN AW-5754	EN AW-Al Mg3	3.3535	AlMg 3	Strip, Strip Sheet	DIN EN 485-2 DIN EN 575-3 AD-W 6/1	DIN 1745 DIN 1725	150 (AD-W)
	EN AW-6082	EN AW-AlSi1MgMn	3.2315	AlMgSi 1	Strip, Strip Sheet	DIN-EN 485-2 DIN-EN 573-3	DIN 1745 DIN 1725	
Pure nickel	2.4068	LC-Ni 99		LC-Ni 99	Strip, Strip	VdTÜV-W 345		600
Titanium	3.7025	Ti 1		Ti 1	Sheet Strip, Strip Sheet	DIN 17 850 DIN 17 860 VdTÜV-W 230		250
Tantalum		Ta		Ta	Strip, Strip Sheet	VdTÜV-W382		250

1) Trade name

Strength values at room temperature (RT) (guaranteed values [2])

Material no.	Yield points min. $R_{p0,2}$ N/mm²	$R_{p1,0}$ N/mm²	Tensile strength R_m N/mm²	Breaking elongation, min. A_5 %	Notched bar impact strength min. KV J	Remarks
CW354H 2.0882	≥ 120		350-420	35 [6]		R350 (F35) [4] 0.3 ≤ s ≤ 15
CW024A 2.0090	≤ 100 ≤ 140		200-250 220-260	42 [6] 33 [7] / 42 [6]		R200 (F20) [4] s > 5 mm R220 (F22) [4] 0.2 ≤ s ≤ 5 mm
CW452K 2.1020	≤ 300		350-420	45 [7] 55 [6]		R350 (F35) [4] 0.1 ≤ s ≤ 5 mm
CW503L 2.0250	≤ 150		270-320	38 [7] 48 [6]		R270 (F27) [4] 0.2 ≤ s ≤ 5 mm
CW508L 2.0321	≤ 180		300-370	38 [7] 48 [6]		R300 (F30) [4] 0.2 ≤ s ≤ 5 mm
2.0402	≤ 300		≥ 380	35		(F38) [5] 0.3 ≤ s ≤ 5 mm
Material no.	Yield points min. $R_{p0,2}$ N/mm²	$R_{p1,0}$ N/mm²	Tensile strength Rm N/mm²	Breaking elongation, min. A_5 %	Notched bar impact strength-min. KV J	Remarks
EN AW-5754 3.3535	≥ 80		190-240	14 (A50)		0.5 < s ≤ 1.5 mm State: 0 / H111 DIN EN-values
EN AW-6082 3.2315	≤ 85		≤ 150	14 (A50)		0.4 ≤ s ≤ 1.5 mm State: 0 ; DIN EN values
2.4068	≥ 80	≥ 105	340-540	40		
3.7025	≥ 180	≥ 200	290-410	30 / 24 [8]	62	0.4 < s ≤ 8 mm
TANTAL - ES	≥ 140		≥ 225	35 [3]		0.1 ≤ s ≤ 5.0 Electron beam melted Sintered in vacuum
TANTAL - GS	≥ 200		≥ 280	30 [3]		

2) Smallest value of longitudinal or transverse test
3) Measured length lo = 25 mm
4) State designation to DIN EN 1652 or (--) to DIN
5) To DIN, material not contained in the DIN EN
6) Specification in DIN EN for s > 2.5 mm
7) Breaking elongation A50, specification in DIN EN for s ≤ 2.5 mm
8) A50 for thicknesses ≤ 5 mm

Chemical composition (percentage by mass)

Material group	Material no.	Short name	C[1]	Si max.	Mn	P max.	S max.	Cr	Mo	Ni	Other elements
Unalloyed steel	1.0254	P235TR1	≤ 0.16	0.35	≤ 1.20	0.025	0.020	≤ 0.30	≤ 0.08	≤ 0.30	Cu ≤ 0.30 Cr+Cu+Mo+Ni ≤ 0.70
	1.0255	P235TR2	≤ 0.16	0.35	≤ 1.20	0.025	0.020	≤ 0.30	≤ 0.08	≤ 0.30	Cu ≤ 0.30 Cr+Cu+Mo+Ni ≤ 0.70 Al_{ges} ≥ 0.02
	1.0427	C22G1	0.18 - 0.23	0.15 - 0.35	0.4 - 0.9	0.035	0.03	≤ 0.30			Al_{ges} ≥ 0.015
Common structural steel	1.0038	S235JRG2	≤ 0.17		≤ 1.40	0.045	0.045				N ≤ 0.009
	1.0050	E295				0.045	0.045				N ≤ 0.009
	1.0570	S355J2G3	≤ 0.20	0.55	1.6	0.035	0.035				Al_{ges} ≥ 0.015
Heat resist. unalloyed steel	1.0460	C22G2	0.18 - 0.23	0.15 -0.35	0.40 -0.90	0.035	0.030	≤ 0.30			
Heat resistant steel	1.0345	P235GH	≤ 0.16	0.35	0.4 - 1.20	0.03	0.025	≤ 0.30	≤ 0.08	≤ 0.30	Nb,Ti,V Al_{ges} ≥ 0.020 Cu ≤ 0.30 Cr+Cu+Mo+Ni ≤ 0.70
	1.0425	P265GH	≤ 0.20	0.4	0.50	0.03	0.025	≤ 0.30	≤ 0.08	≤ 0.30	
	1.0481	P295GH	0.08 - 0.20	0.40	0.9 - 1.50	0.03	0.025	≤ 0.30	≤ 0.08	≤ 0.30	
	1.5415	16Mo3	0.12 - 0.20	0.35	0.4 - 0.90	0.03	0.025	≤ 0.30	0.25 - 0.35	≤ 0.30	Cu ≤ 0.3
	1.7335	13CrMo4-5	0.08 - 0.18	0.35	0.4 - 1.00	0.030	0.025	0.7 - 1.15	0.4 - 0.6		Cu ≤ 0.3
	1.7380	10 CrMo9-10	0.08 - 0.14	0.5	0.4 - 0.80	0.03	0.025	2 - 2.50	0.9 - 1.10		Cu ≤ 0.3
	1.0305	P235G1TH	≤ 0.17	0.1 - 0.35	0.4 - 0.80	0.040	0.040				

1) Carbon content dependent on thickness. Values are for a thickness of ≤ 16mm.

Chemical composition (percentage by mass)

Material group	Material no.	Short name	C max.	Si max.	Mn	P max.	S max.	Cr	Mo	Ni	Other elements
Fine-grained structural steel	1.0562	P355N	0.2	0.50	0.9 - 1.70	0.03	0.025	≤ 0.3	≤ 0.8	≤ 0.5	Al_{ges} ≥ 0.020 (s. DIN EN 10028-3)
	1.0565	P355NH	0.2	0.50	0.9 - 1.70	0.03	0.025	≤ 0.3	≤ 0.8	≤ 0.5	Cu, N, Nb, Ti, V Nb + Ti + V ≤ 0.12
	1.0566	P355NL1	0.18	0.50	0.90 -1.70	0.030	0.020	≤ 0.3	≤ 0.8	≤ 0.5	
	1.1106	P355NL2	0.18	0.50	0.9 - 1.70	0.025	0.015	≤ 0.3	≤ 0.8	≤ 0.5	
Stainless ferritic steel	1.4511	X3CrNb17	0.05	1.00	≤ 1.0	0.040	0.015	16.0 - 18.0			Nb: 12 x % C -1,00
	1.4512	X2CrTi12	0.03	1.00	≤ 1.0	0.04	0.015	10.5 - 12.5			Ti: 6 x (C+N) - 0.65
Stainless austenitic steel	1.4301	X5CrNi18-10	0.07	1.00	≤ 2.0	0.045	0.015	17.0 - 19.5		8.00 -10.50	
	1.4306	X2CrNi19-11	0.03	1.00	≤ 2.0	0.045	0.015	18.0 -20.0		10.0 -12.0	
	1.4541	X6CrNiTi18-10	0.08	1.00	≤ 2.0	0.045	0.015	17.0 -19.0		9.0 -12.0	Ti: 5 x % C - 0.7
	1.4571	X6CrNiMoTi 17 12 2	0.08	1.00	≤ 2.0	0.045	0.015	16.5 -18.5	2- 2.5	10.5 -13.5	Ti: 5 x % C - 0.7
	1.4404	X2CrNiMo 17 12 2	0.03	1.00	≤ 2.0	0.045	0.015	16.5 -18.5	2.0 -2.5	10.0 -13.0	N ≤ 0.11
	1.4435	X2CrNiMo 18 14 3	0.03	1.00	≤ 2.0	0.045	0.015	17.0 -19.0	2.5 -3.0	12.5 -15.0	
	1.4565	X2CrNiMuMo NbN2518-5-4	0.04	1.00	4.50 - 6.5	0.030	0.015	21.0 - 25.0	3.0 - 4.5	15.0 - 18.0	Nb ≤ 0.30, N: 0.04 - 0.15
	1.4539	X1NiCrMoCu 25-20-5	0.02	0.70	≤ 2.0	0.030	0.010	19.00 -21	4.0 -5.0	24.0 -26.0	Cu, N: ≤ 0.15
	1.4529	X2NiCrMoCuN 25-20-7	0.02	0.50	≤1.0	0.03	0.01	19.0 -21.0	6.0 -7.0	24 -26	Cu: 0.5 - 1 N: 0.15 - 0.25

Chemical composition (percentage by mass)

Material group	Material no.	Short name Trade name	C	Si	Mn	P max.	S max.	Cr	Mo	Ni	Other elements
Austenitic steel of high heat resistance	1.4948	X6CrNi18-10	0.04 -0.08	≤ 1.00	≤ 2.0	0.035	0.015	17.0 -19.0		8.0 -11.0	
	1.4919	X6CrNiMo 17-13	0.04 -0.08	≤ 0.75	≤ 2.0	0.035	0.015	16.0 -18.0	2.0 -2.5	12.0 -14.0	
Heat resistant steel	1.4828	X15CrNiSi 20-12	≤ 0.2	1.50 -2.00	≤ 2.0	0.045	0.015	19.0 -21.0		11.0 -13.0	N: max 0.11
	1.4876 (DIN EN 10095)	X10NiCrAlTi32-21 INCOLOY 800H	≤ 0.12	≤ 1.0	≤ 2.0	0.030	0.015	19.0 -23.0		30.0 -34.0	Al: 0.15 - 0.60 Ti: 0.15 - 0.60
Nickel-based alloy	2.4858	NiCr21Mo INCOLOY 825	≤ 0.025	≤ 0.5	≤ 1.0	0.02	0.015	19.5 -23.5	2.5 -3.5	38.0 -46.0	Ti, Cu, Al, Co ≤ 1.0
	2.4816	NiCr15Fe INCONEL 600 INCONEL 600 H	0.05 -0.1	≤ 0.5	≤ 1.0	0.02	0.015	14.0 -17.0		> 72	Ti, Cu, Al
	2.4819	NiMo16Cr15W HASTELLOY C-276	≤ 0.01	0.08	≤ 1.0	0.02	0.015	14.5 16.5	15 -17	Re-mainder	V, Co, Cu, Fe
	2.4856	NiCr22Mo9Nb INCONEL 625 INCONEL 625 H	0.03 -0.1	≤ 0.5	≤ 0.5	0.02	0.015	20.0 -23.0	8.0 -10.0	> 58	Ti, Cu, Al Nb/Ta: 3.15 - 4.15 Co ≤ 1,0
	2.4610	NiMo16Cr16Ti HASTELLOY C4	≤ 0.015	≤ 0.08	≤ 1.0	0.025	0.015	14.0 -18.0	14.0 -17.0	Re-mainder	Ti, Cu, Co ≤ 2,0
	2.4360	NiCu30Fe MONEL	≤ 0.15	≤ 0.5	≤ 2.0		0.02			> 63	Cu: 28 - 34% Ti, Al, Co ≤ 1.0
Copper-based alloy	2.0882	CuNi 30 Mn1 Fe CUNIFER 30	≤ 0.05		0.5 -1.50		0.050			30.0 -32.0	Cu: Rest, Pb, Zn

Chemical composition (percentage by mass)

Material group	Material no.	Short name	Cu	Al	Zn	Sn	Pb	Ni	Ti	Ta	Other elements
Copper	CW024A (2.0090)	Cu DHP (SF-Cu)	≥ 99.9								P: 0.015 - 0.04
Copper-tin alloy	CW452K (2.1020)	CuSn 6 Bronze	Rest		≤ 0,2	5.5 -7.0	≤ 0.2	≤ 0.2			P: 0.01 - 0.4 Fe: ≤ 0.1
Copper-zinc alloy	CW503L 2.0250	CuZn 20	79.0 -81.0	≤ 0.02	Re-mainder	≤ 0.1	≤ 0.05				
	CW508L (2.0321)	CuZn 37 Brass	62.0 -64.0	≤ 0.05	Re-mainder	≤ 0.1	≤ 0.1	≤ 0.3			
	2.0402	CuZn 40 Pb 2	57.0 -59.0	≤ 0.1	Re-mainder	≤ 0.3	1.5 -2.5	≤ 0.4			
Wrought aluminium alloy	EN AW-5754 (3.3535)	EN AW-Al Mg3	≤ 0.1	Re-mainder	≤ 0.1				≤ 0.15		Si, Mn, Mg
	EN AW-6082 (3.2315)	EN AW-Al Si1MgMn	≤ 0.1	Re-mainder	≤ 0.2				≤ 0.1		Si, Mn, Mg
Pure nickel	2.4068	LC-Ni 99	≤ 0.025					≥ 99	≤ 0.1		C ≤ 0.02 Mg ≤ 0.15 S ≤ 0.01 Si ≤ 0.2
Titanium	3.7025	Ti							Re-mainder		N ≤ 0.05 H ≤ 0.013 C ≤ 0.06 Fe ≤ 0.15
Tantalum	-	Ta						≤ 0.01	≤ 0.01	Rem.	

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Material no. to DIN	Type of value	Material strength values in N/mm²													
		Temperatures in °C													
		RT[1)]	100	150	200	250	300	350	400	450	500	550	600	700	800
1.0254	$R_{p\,0,2}$	235													
1.0255	$R_{p\,0,2}$	235													
1.0427	$R_{p\,0,2}$	220	210	190	170	150	130	110							
1.0038	$R_{p\,0,2}$	205	187		161	143	122	(values to AD W1)							
1.0570	$R_{p\,0,2}$	315	254		226	206	186								
1.0460	$R_{p\,0,2}$	240	230	210	185	165	145	125	100	80					
	$R_{p\,1/10000}$								136	80	(53)				
	$R_{p\,1/100000}$								95	49	(30)	() = values at 480 °C			
	$R_{m\,10000}$								191	113	(75)				
	$R_{m\,100000}$								132	69	(42)				
1.0345	$R_{p\,0,2}$	206	190	180	170	150	130	120	110						
	$R_{p\,1/10000}$								136	80	(53)				
	$R_{p\,1/100000}$								95	49	(30)	() = values at 480 °C			
	$R_{m\,10000}$								191	113	(75)				
	$R_{m\,100000}$								132	69	(42)				
	$R_{m\,200000}$								115	57	(33)				
1.0425	$R_{p\,0,2}$	234	215	205	195	175	155	140	130						
	$R_{p\,1/10000}$								136	80	(53)				
	$R_{p\,1/100000}$								95	49	(30)	() = values at 480 °C			
	$R_{m\,10000}$								191	113	(75)				
	$R_{m\,100000}$								132	69	(42)				
	$R_{m\,200000}$								115	57	(33)				
1.0481	$R_{p\,0,2}$	272	250	235	225	205	185	170	155						
	$R_{p\,1/10000}$								167	93	49				
	$R_{p\,1/100000}$								118	59	29				
	$R_{m\,10000}$								243	143	74				
	$R_{m\,100000}$								179	85	41				
	$R_{m\,200000}$								157	70	30				
1.5415	$R_{p\,0,2}$	275			215	200	170	160	150	145	140				
	$R_{p\,1/10000}$									216	132	(84)			
	$R_{p\,1/100000}$									167	73	(36)	() = values at		
	$R_{m\,10000}$									298	171	(102)	530 °C		
	$R_{m\,100000}$									239	101	(53)			
	$R_{m\,200000}$									217	84	(45)			
1.7335	$R_{p\,0,2}$				230	220	205	190	180	170	165				
	$R_{p\,1/10000}$									245	157	(53)			
	$R_{p\,1/100000}$									191	98	(24)	() = values at		
	$R_{m\,10000}$									370	239	(76)	570 °C		
	$R_{m\,100000}$									285	137	(33)			
	$R_{m\,200000}$									260	115	(26)			

1) Room temperature values valid up to 50 °C

7.1 | Material data sheets
Strength values at elevated temperatures

HYDRA

Material no. to DIN	Type of value	Material strength values in N/mm²													
		Temperatures in °C													
		RT[1)]	100	150	200	250	300	350	400	450	500	550	600	700	800
1.7380	$R_{p\,0,2}$				245	230	220	210	200	190	180				
	$R_{p\,1/10000}$									240	147	83	44		
	$R_{p\,1/100000}$									166	103	49	22		
	$R_{m\,10000}$									306	196	108	61		
	$R_{m\,100000}$									221	135	68	34		
	$R_{m\,200000}$									201	120	58	28		
1.0305	$R_{p\,0,2}$	235			185	165	140	120	110	105					
	$R_{p\,1/10000}$								136	80	(53)				
	$R_{p\,1/100000}$								95	49	(30)	() = values at 480 °C			
	$R_{m\,10000}$								191	113	(75)				
	$R_{m\,100000}$								132	69	(42)				
	$R_{m\,200000}$								115	57	(33)				
1.0565	$R_{p\,0,2}$	336	304	284	245	226	216	196	167						
1.4511	$R_{p\,0,2}$	230	230	220	205	190	180	165							
1.4512	$R_{p\,0,2}$	210	200	195	190	186	180	160							
1.4301	$R_{p\,0,2}$	215	157	142	127	118	110	104	98	95	92	90			
	$R_{p\,1}$		191	172	157	145	135	129	125	122	120	120			
	$R_{m\,10000}$							(approx. values to DIN 17441)					122	48	(17)
	$R_{m\,100000}$												74	23	(5)
1.4306	$R_{p\,0,2}$	205	147	132	118	108	100	94	89	85	81	80			
	$R_{p\,1}$		181	162	147	137	127	121	116	112	109	108			
1.4541	$R_{p\,0,2}$	205	176	167	157	147	136	130	125	121	119	118			
	$R_{p\,1}$		208	196	186	177	167	161	156	152	149	147			
	$R_{m\,10000}$							(approx. values to DIN 17441)					115	45	(17)
	$R_{m\,100000}$												65	22	(8)
1.4571	$R_{p\,0,2}$	225	185	177	167	157	145	140	135	131	129	127			
	$R_{p\,1}$		218	206	196	186	175	169	164	160	158	157			
1.4404	$R_{p\,0,2}$	225	166	152	137	127	118	113	108	103	100	98			
	$R_{p\,1}$		199	181	167	157	145	139	135	130	128	127			
1.4435	$R_{p\,0,2}$	225	165	150	137	127	119	113	108	103	100	98			
	$R_{p\,1}$		200	180	165	153	145	139	135	130	128	127			
1.4565	$R_{p\,0,2}$	420	350	310	270	255	240	225	210	210	210	200			
	$R_{p\,1}$	460	400	355	310	290	270	255	240	240	240	230			
1.4539	$R_{p\,0,2}$	220	205	190	175	160	145	135	125	115	110	105			
	$R_{p\,1}$		235	220	205	190	175	165	155	145	140	135			
	R_{m} (VdTÜV)	520	440	420	400	390	380	370	360						
1.4529	$R_{p\,0,2}$	300	230	210	190	180	170	165	160						
	$R_{p\,1}$	340	270	245	225	215	205	195	190						

1) Room temperature values valid up to 50 °C

Material no. to DIN	Type of value	RT[1]	100	150	200	250	300	350	400	450	500	550	600	700	800	900
		Material strength values in N/mm² – Temperatures in °C														
1.4948	$R_{p\,0,2}$	230	157	142	127	117	108	103	98	93	88	83	78			
	$R_{p\,1}$	260	191	172	157	147	137	132	127	122	118	113	108			
	R_m	530	440	410	390	385	375	375	375	370	360	330	300			
	$R_{p\,1/10000}$										147	121	94	35		
	$R_{p\,1/100000}$										114	96	74	22		
	$R_{m\,10000}$										250	191	132	55		
	$R_{m\,100000}$										192	140	89	28		
	$R_{m\,200000}$										176	125	78	22		
1.4919	$R_{p\,0,2}$	205	177		147		127		118		108	103	98			
	$R_{p\,1}$	245	211		177		157		147		137	132	128			
	$R_{p\,1/10000}$											180	125	46		
	$R_{p\,1/100000}$											125	85	25		
	$R_{m\,10000}$											250	175	65		
	$R_{m\,100000}$											175	120	34		
1.4828 DIN EN 10095	$R_{p\,0,2}$	230	332		318		300		279		253		218	(Manufacturer's figures)		
	R_m	550	653		632		600		550		489		421			
	$R_{p\,1/1000}$												120	50	20	8
	$R_{p\,1/10000}$												80	25	10	4
	$R_{m\,1000}$												190	75	35	15
	$R_{m\,10000}$												120	36	18	8.5
	$R_{m\,100000}$												65	16	7,5	3.0
1.4876 DIN EN 10095 Incoloy 800H	$R_{p\,0,2}$	170	185	170	160	150	145		130		125	120	115	(Manufacturer's figures)		
	$R_{p\,1}$	210	205	190	180	170	165		150		145	140	135			
	R_m	450	425		400		390		380		360		300			
	$R_{p\,1/1000}$												130	70	30	13
	$R_{p\,1/10000}$												90	40	15	5
	$R_{m\,1000}$												200	90	45	20
	$R_{m\,10000}$												152	68	30	10
	$R_{m\,100000}$												114	48	21	8
2.4858	$R_{p\,0,2}$	235	205	190	180	175	170	165	160	155						
	$R_{p\,1}$	265	235	220	205	200	195	190	185	180						
	R_m	550	530		515		500		490	485						
2.4816 DIN EN 10095	$R_{p\,0,2}$	200	180		165		155		150	145			(Soft annealed)			
	R_m	550 -750	520		500		485		480	475						
	$R_{p\,0,2}$	180	170		160		150		150	145			(solution annealed)			
	R_m	500 -700	480		460		445		440	435						
	$R_{p\,1/10000}$										153		91	43	18	8
	$R_{p\,1/100000}$										126		66	28	12	4
	$R_{m\,1000}$												160	96	38	22
	$R_{m\,10000}$										297		138	63	29	13
	$R_{m\,100000}$										215		97	42	17	7

1) Room temperature values valid up to 50 °C

Material no. to DIN	Type of value	RT	100	150	200	250	300	350	400	450	500	550	600	700	800	900
		Material strength values in N/mm² – Temperatures in °C														
2.4819 VdTÜV-W 400	$R_{p0,2}$	310	280		240		220		195							
	R_{p1}	330	305		275		215		200							
2.4856 DIN EN 10095	$R_{p\,0,2}$	410	350		320		300		280		170					
	$R_{p\,1/100000}$						Manufacturer's figures for Inconel 625 H						250	90	30	10
	$R_{m\,100000}$												290	135	45	18
	$R_{m\,1000}$													260	107	34
	$R_{m\,10000}$													190	63	20
2.4610	$R_{p\,0,2}$	305	285		255		245		225					(S <= 5)		
	$R_{p\,1}$	340	315		285		270		260							
2.4360	$R_{p\,0,2}$	175	150	140	135	132	130	130	130	(130)	() = values at 425 °C					
	R_m	450	420	400	390	385	380	375	370	(360)						
	$R_{p\,1/10000}$				107	99	92	84								
	$R_{p\,1/100000}$				102	94	86	78								
	K/S	93	87	84	82	80	78	75								
CW354H 2.0882	$R_{p\,1}$	140	130	126	123	120	117	112								
	$R_{p\,1/10000}$				107	99	92	84								
	$R_{p\,1/100000}$				102	94	86	78		Permissible tension to AD-W 6/2 für 10^5 h						
	K/S		93	87	84	82	80	78	75							
CW024A 2.0090	$R_{p\,1}$	65	58	58												
	R_m	220	220	195	170	145										
	$R_{p\,2/10000}$		58	53	46	37										
	$R_{p\,2/100000}$		56	49	40	30										
	K/S	57	57	50	43	36	Permissible tension to AD-W 6/2 für 10^5 h								(F 20)	
	K/S	67	63	56	49	41									(F 22)	
3.3535 EN-AW 5754	$R_{p\,0,2}$	80	70		Permissible tension to AD-W6/1											
	$R_{m\,100000}$		(80)	45												
2.4068 Nickel	$R_{p\,0,2}$	80	70		65		60		55		50		40			
	$R_{p\,1}$	105	95		90		85		80		75		65			
	R_m	340	290		275		260		240		210		150			
	$R_{p\,1/10000}$								75	55	35	19	10			
	$R_{p\,1/100000}$							85	60	40	23	11	6			
3.7025 Titan	$R_{p\,1}$	200	180	150	110	90										
	$R_{m\,10000}$	220	160	150	130	110										
	$R_{m\,100000}$	200	145	130	120	90										
Tantal	$R_{p\,0,2}$	140	100	90	80	70								Electron beam melted		
	R_m	225	200	185	175	160	150									
	$A_{30[\%]}$	35														
	$R_{p\,0,2}$	200	160	150	140	130								Sintered in vacuum		
	R_m	280	270	260	240	230										
	$A_{30[\%]}$	25														

1) Room temperature values valid up to 50 °C

Material no. to DIN EN	USA			JAPAN		
	Standard	UNS designation	Semi-finished product applications / title	Standard	Designation	Semi-finished product applications
1.0254	ASTM A 53-01	K02504 A 53	Welded and seamless black-oxidized and galvanized steel tubes	JIS G 3445 (1988)	STKM 12 A	Tubes
	ASTM A 106-99	K02501 A 106	Seamless tubes of high-temperature unalloyed steel	JIS G 3454 (1988)	STPG 370	Pipes under pressure
				JIS G 3457 (1988)	STPY 400	Welded tubes
1.0255	ASTM A 135-01	K03013 A 135	Electric resistance welded tubes	JIS G 3455 (1988)	STS 370	Pipes subjected to high pressures
1.0038	ASTM A 500-01	K03000 A 500	Welded and seamless fittings of cold-formed unalloyed steel			
1.0050				JIS G 3101 (1995)	SS 490	General structural steels
1.0570	ASTM A 694-00	K03014 A 694	Forgings of unalloyed and alloyed steel for pipe flanges, fittings, valves and other parts for high-pressure drive systems	JIS G 3106 (1999)	SM 490 A	Steels for welded constructions
				JIS G 3106 (1999)	SM 520 B	
1.0345	ASTM A 414-01	K02201 A 414	Sheet of unalloyed steel for pressure tanks	JIS G 3115 (2000)	SPV 450	Heavy plate for pressure vessels
1.0425	ASTM A 414-01	K02505 A 414		JIS G 3118 (2000)	SGV 480	
1.0481	ASTM A 414-01	K02704 A 414		JIS G 3118 (2000)	SGV 410	
1.5415	ASTM A 204-99	K12320 A 204	Sheet of molybdenum alloyed steel for pressure tanks	JIS G 3458 (1988)	STPA 12	Tubes
1.7335	ASTM A 387-99	K11789 A 387	Sheet of Cr-Mo alloyed steel for pressure tanks	JIS G 3462 (1988)	STBA 22	Boiler and heat exchanger pipes
1.7380	ASTM A 387-99	K21590 22 (22L)		JIS G 4109 (1987)	SCMV 4	Heavy plate for pressure vessels
1.0305	ASTM A 106-99	K02501 A 106	Seamless tubes of high-temperature unalloyed steel	JIS G 3461 (1988)	STB 340	Boiler and heat exchanger pipes

Material no. to DIN EN	KOREA			CHINA		
	Standard	Designation	Semi-finished product applications	Standard	Designation	Semi-finished product applications
1.0254	KS D 3583 (1992)	SPW 400	Welded tubes of carbon steel			
1.0255						
1.0038				GBT 700 (1988)	Q 235 B; U12355	(unalloyed structural steels)
1.0050	KS D 3503 (1993)	SS 490	General structural steels	GBT 700 (1988)	Q 275; U12752	
1.0570	KS D 3517 (1995)	STKM 16C	Unalloyed steel tubes for general mechanical engineering	GBT 713 (1997)	16Mng; L20162	Plate for steam boilers
				GBT 8164 (1993)	16Mn; L20166	Strip for welded tubes
1.0345	KS D 3521 (1991)	SPPV 450	Heavy plate for pressure vessels for medium application temp.			
1.0425	KS D 3521 (1991)	SPPV 315				
1.0481						
1.5415	KS D 3572 (1990)	STHA 12	Tubes for boilers and heat exchangers	GB 5310 (1995)	15MoG; A65158	Seamless tubes for pressure vessels
1.7335	KS D 3572 (1990)	STHA 22		YBT 5132 (1993)	12CrMo; A30122	Plate of alloyed structural steels
1.7380	KS D 3543 (1991)	SCMV 4	Cr-Mo steel for pressure vessels	GB 5310 (1995)	12Cr2MoG; A30138	Seamless tubes for pressure vessels
1.0305						

Material no. to DIN EN	USA			JAPAN		
	Standard	UNS designation (AISI)	Semi-finished product applications / title	Standard	Designation	Semi-finished product applications
1.0562	ASTM A 299-01	K02803 A 299	Plate of C-Mn-Si steel for pressure tanks	JIS G 3106 (1999)	SM 490 A;B;C;	Steels for welded constructions
	ASTM A 714-99	K12609 A 714 (II)	Welded and seamless tubes of high-strength low-alloy steel	JIS G 3444 (1994)	STK 490	Steels for welded constructions
1.0565	ASTM A 633-01	K12037 A633(D)	Normalized high-strength low-alloy structural steel			
	ASTM A 724-99	K12037 A724(C)	Plate of tempered unalloyed steel for welded pressure tanks of layered construction			
1.0566	ASTM A 573-00	K02701 A 573	Plate of unalloyed structural steel with improved toughness	JIS G 3126 (2000)	SLA 365	Heavy plate for pressure vessels (low temperature)
1.1106	ASTM A 707-02	K12510 A 707 (L3)	Forged flanges of alloyed and unalloyed steel for use in low temperatures	JIS G 3444 (1994)	STK 490	Tubes for general use

Material no. to DIN EN	KOREA			CHINA		
	Standard	Designation	Semi-finished product applications / title	Standard	Designation	Semi-finished product applications
1.0562						
1.0565						
1.0566	KS D 3541 (1991)	SLA1 360	Heavy plate for pressure vessels (low temperature)	GBT 714 (2000)	Q420q-D; L14204	Steels for bridge construction
1.1106				GB 6654 (1996)	16MnR; L20163	Heavy plate for pressure vessels

Material no. to DIN EN	USA			JAPAN		
	Standard	UNS designation (AISI)	Semi-finished product applications / title	Standard	Designation	Semi-finished product applications
1.4511				JIS G 4305 (1999)	SUS 430LX	Cold-rolled sheet, heavy plate and strip
1.4512	ASTM A 240-02	S40900; A 240 (409)	Sheet and strip of heatproof stainless Cr and Cr-Ni steel for pressure tanks			
1.4301	ASTM A 240-02	S30400; A 240 (304)		JIS G 4305 (1999)	SUS 304	Cold-rolled sheet, heavy plate and strip
1.4306	ASTM A 240-02	S30403; A 240 (340L)		JIS G 4305 (1999)	SUS 304L	
1.4541	ASTM A 240-02	S32100 A 240 (321)		JIS G 4305 (1999)	SUS 321	
1.4571	ASTM A 240-02	S31635 A240 (316Ti)		JIS G 4305 (1999)	SUS 316Ti	
1.4404	ASTM A 240-02	S31603 A240 (316L)		JIS G 4305 (1999)	SUS 316L	
1.4435	ASTM A 240-02	S31603 A240 (316L)		JIS G 4305 (1999)	SUS 316L	
1.4565	ASTM A 240-02	S34565 A240				
1.4539	ASTM A 240-02	N08904 A240 (904L)				
1.4529	ASTM B 625-99	N08925 B 625	Sheet and strip of low-carbon Ni-Fe-Cr-Mo-Cu alloys			

7.1 | Material data sheets
HYDRA
Material designations according to international specifications

Material no. to DIN EN	KOREA			CHINA		
	Standard	Designation	Semi-finished product applications	Standard	Designation	Semi-finished product applications
1.4511	KS D 3698 (1992)	STS 430LX	Cold-rolled sheet, heavy plate and strip			olled sheet, heavy plate and strip
1.4512				GBT 4238 (1992)	0Cr11Ti; S11168	Hot-rolled sheet of heatproof steel, ferritic
1.4301	KS D 3698 (1992)	STS 304	Cold-rolled sheet, heavy plate and strip	GBT 3280 (1992)	0Cr18Ni9; S30408	Cold-rolled sheet, heavy plate and strip
1.4306	KS D 3698 (1992)	STS 304L		GBT 3280 (1992)	00Cr19Ni10; S30403	
1.4541	KS D 3698 (1992)	STS 321		GBT 3280 (1992)	0Cr18Ni10Ti; S32168	
1.4571	KS D 3698 (1992)	STS 316Ti		GBT 3280 (1992)	0Cr18Ni12Mo2Cu2 S31688	
1.4404	KS D 3698 (1992)	STS 316L		GBT 4239 (1991)	00Cr17Ni14Mo2; S31603	
1.4435	KS D 3698 (1992)	STS 316L		GBT 3280 (1992)	00Cr17Ni14Mo2; S31603	
1.4565						
1.4539						
1.4529	KS D 3698 (1992)	STS 317J5L	Cold-rolled sheet, heavy plate and strip			

7.1 | Material data sheets

Material designations according to international specifications

Material no. to DIN EN	USA			JAPAN		
	Standard	UNS designation (AISI)	Semi-finished product applications / title	Standard	Designation	Semi-finished product applications
1.4948	ASTM A 240-02	S30409 A240 (304H)	Sheet and strip of heatproof stainless Cr and Cr-Ni steel for pressure tanks			
1.4919	ASTM A 240-02	S31609 A240 (316H)				
1.4958	ASTM A 240-02	N 08810 A 240				
1.4828	ASTM A 167-99	S30900 A 167 (309)	Sheet and strip of stainless heatproof Cr-Ni steel	JIS G 4312 (1991)	SUH 309	Heatproof sheet and heavy plate
1.4876	ASTM A 240-02	N 08800 A 240	Sheet and strip of stainless heatproof Cr and Cr-Ni steel for pressure tanks	JIS G 4902 (1991)	NCF 800	Special alloy in sheet form
2.4858	ASTM B 424-98	N 08825 B 424	Sheet and strip of low-carbon Ni-Fe-Cr-Mo-Cu alloys (UNS N08825 and N08221)	JIS G 4902 (1991)	NCF 825	
2.4816	ASTM B 168-98	N 06600 B 168	Sheet and strip of low-carbon Ni-Cr-Fe and Ni-Cr-Co-Mo alloys (UNS N06600 and N06690)			
2.4819	ASTM B 575-99	N 10276 B 575	Sheet and strip of low-carbon Ni-Mo-Cr alloys			
2.4856	ASTM B 443-99	N 06625 B 443	Sheet and strip of Ni-Cr-Mo-Nb alloy (UNS N06625)	JIS G 4902 (1991)	NCF 625	Special alloy in sheet form
2.4610	ASTM B 575-99	N 06455 B 575	Sheet and strip of low-carbon Ni-Mo-Cr alloys			
2.4360	ASTM B 127-98	N 04400 B 127	Sheet and strip of Ni-Cu alloy (UNS N04400)			

Material designations according to international specifications

Material no. to DIN EN	KOREA			CHINA		
	Standard	Designation	Semi-finished product applications	Standard	Designation	Semi-finished product applications
1.4948						
1.4919						
1.4958						
1.4828	KS D 3732 (1993)	STR 309	Heatproof sheet and heavy plate	GBT 1221 (1992)	1Cr20Ni14Si2; S38210	Heatproof steels, austenitic
1.4876	KS D 3532 (1992)	NCF 800	Special alloys in sheet and heavy plate form	GBT 15007 (1994)	NS 111; H01110	Stainless alloys
2.4858	KS D 3532 (1992)	NCF 825		GBT 15007 (1994)	NS 142; H01420	
2.4816				GBT 15007 (1994)	NS 312; H03120	
2.4819				GBT 15007 (1994)	NS 333; H03330	
2.4856	KS D 3532 (1992)	NCF 625	Special alloys in sheet and heavy plate form	GBT 15007 (1994)	NS 336; H03360	
2.4610				GBT 15007 (1994)	NS 335; H03350	
2.4360						

Permissible operating pressures and temperatures for threaded fittings in malleable cast iron

Threaded fasteners of malleable cast iron are applicable up to the operating pressures indicated in the table below, depending on type of fluid and operating temperature.

permissible operating pressure for the fluids					
DN	d inch	water and gas up to max. 120 °C	gases and steam up to max. 150 °C	gases and steam up to 300 °C	oils up to 200 °C
nipples, flat sealing threaded fasteners					
6-50	¼ - 2	65 bar	50 bar	40 bar	35 bar
conically sealing threaded fasteners					
6-32	¼ - 1 ¼	65 bar	50 bar	40 bar	35 bar
40	1 ½	65 bar	50 bar	40 bar	30 bar
50	2	55 bar	40 bar	32 bar	24 bar

Sealing is to be carried out with special care. The sealing materials are to be selected according to the operating conditions. Only approved sealing materials must be applied for sealing of threaded fasteners in drinking water and gas insulations.

Only high-quality threads are appropriate for high operating requirements.

General
Flexible metal elements are basically suitable for the transport of critical fluids if a sufficient resistance is ensured against all corrosive media that may occur during the entire lifetime.

The flexibility of the corrugated elements like bellows or corrugated hoses generally require their wall thickness to be considerably smaller than that of all other parts of the system in which they are installed.

As therefore increasing the wall thickness to prevent damages caused by corrosion is not reasonable, it becomes essential to select a suitable material for the flexible elements which is sufficiently resistant.

Special attention must be paid to all possible kinds of corrosion, especially pitting corrosion, intercrystalline corrosion, crevice corrosion, and stress corrosion cracking, (see Types of corrosion).

This leads to the fact that in many cases at least the ply of the flexible element that is exposed to the corrosive fluid has to be chosen of a material with even higher corrosion resistance than those of the system parts it is connected to (see Resistance table).

Types of corrosion
According to EN ISO 8044, corrosion is the "physicochemical interaction between a metal and its environment that results in changes in the properties of the metal, and which may lead to significant impairment of the function of the metal, the environment, or the technical system, of which these form a part. This interaction is often of an electrochemical nature".

Different types of corrosion may occur, depending on the material and on the corrosion conditions. The most important corrosion types of ferrous and non-ferrous metals are described below.

Uniform corrosion
A general corrosion proceeding at almost the same rate over the whole surface. The loss in weight which occurs is generally specified either in g/m^2h or as the reduction in the wall thickness in mm/year.

This type of corrosion includes the rust which commonly is found on unalloyed steel (e. g. caused by oxidation in the presence of water).

Stainless steels can only be affect by uniform corrosion under extremely unfavourable conditions, e.g. caused by liquids, such as acids, bases and salt solutions.

Pitting corrosion
A locally limited corrosion attack that may occur under certain conditions, called pitting corrosion on account of its appearance. It is caused by the effects of chlorine, bromine and iodine ions, especially when they are present in hydrous solutions.

This selective type of corrosion cannot be calculated, unlike surface corrosion, and can therefore only be kept under control by choosing an adequate resistant material.

The resistance of stainless steels to pitting corrosion increases in line with the molybdenum content in the chemical composition of the material.

The resistance of materials to pitting corrosion can approximately be compared by the so-called pitting resistance equivalent (PRE = Cr % + 3.3 · Mo % + 30 N %), whereas the higher values indicate a better resistance.

Intergranular corrosion
These deposit processes are dependent on temperature and time in CrNi alloys,

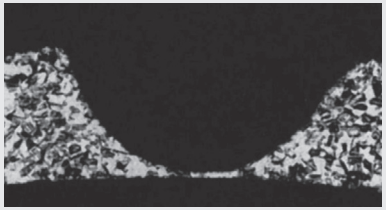


Fig. B.1: Pitting corrosion on a cold strip made of austenitic steel. Plan view (50-fold enlargement).

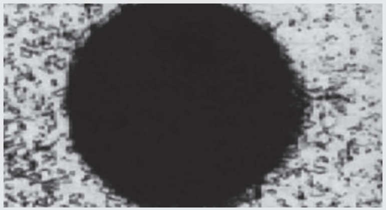


Fig. B.2: Sectional view (50-fold enlargement).

whereby the critical temperature range is between 550 and 650 °C and the period up to the onset of the deposit processes differs according to the type of steel. This must be taken into account, for example, when welding thick-walled parts with a high thermal capacity. These deposit-

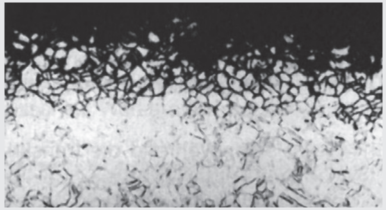


Fig. B.3: Intergranular corrosion (decay) in austenitic material 1.4828. Sectional view (100-fold enlargement).

related changes in the structure can be reversed by means of solution annealing (1000 – 1050 °C).

This type of corrosion can be avoided by using stainless steels with low carbon content (≤ 0,03 % C) or containing elements, such as titanium or niobium. For flexible elements, this may be stabilized material qualities like 1.4541, 1.4571 or low-carbon qualities like 1.4404, 1.4306.

The resistance of materials to intergranular corrosion can be verified by a standardized test (Monypenny - Strauss test according to ISO 3651-2). Certificates to be delivered by the material supplier, proving resistant to IGC according to this test are therefore asked for in order and acceptance test specifications.

Stress corrosion cracking
This type of corrosion is observed most frequently in austenitic materials, subjected to tensile stresses and exposed to a corrosive agent. The most important agents are alkaline solutions and those containing chloride.

The form of the cracks may be either transgranular or intergranular. Whereas the transgranular form only occurs at temperatures higher than 50 °C (especially in solutions containing chloride), the intergranular form can be observed already at room temperature in austenitic materials in a neutral solutions containing chloride.

At temperatures above 100 °C SCC can already be caused by very small concentrations of chloride or lye – the latter always leads to the transgranular form.

Stress corrosion cracking takes the same forms in non-ferrous metals as in austenitic materials.

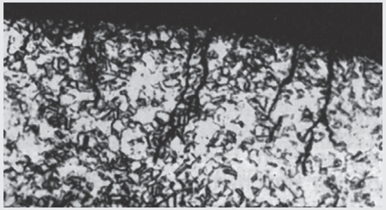


Fig. B.4: Transgranular stress corosion cracking on a cold strip made of austenitic steel. Sectional view (50-fold enlargement).

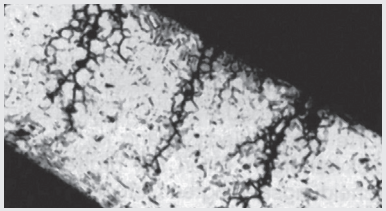


Fig. B.5: Intergranular stress corosion cracking on a cold strip made of austenitic steel. Sectional view (50-fold enlargement).

Damage caused by intergranular stress corrosion cracking can occur in nickel and nickel alloys in highly concentrated alkalis at temperatures above 400 °C, and in solutions or water vapour containing hydrogen sulphide at temperatures above 250 °C.

A careful choice of materials based on a detailed knowledge of the existing operating conditions is necessary to prevent from this type of corrosion damage.

Crevice corrosion

Crevice corrosion is a localized, seldom encountered form of corrosion found in crevices which are the result of the design or of deposits. This corrosion type is caused by the lack of oxygen in the crevices, oxygen being essential in passive materials to preserve the passive layer.

Because of the risk of crevice corrosion design and applications should be avoided which represent crevice or encourage deposits.

The resistance of high-alloy steels and Ni-based alloys to this type of corrosion increases in line with the molybdenum content of the materials. Again pitting resistance equivalent (PRE) (see Pitting corrosion) can be taken as criteria for a ssessing the resistance to crevice corrosion.

Fig. B.6: Crevice corrosion on a cold strip made from austenitic steel. Sectional view (50-fold enlargement).

Contact corrosion

A corrosion type which may result from a combination of different materials.

Galvanic potential series are used to assess the risk of contact corrosion, e.g. in seawater. Metals which are close together on this graph are mutually compatible; the anodic metal corrodes increasingly in line with the distance between two metals.

Materials which can be encountered in both the active and passive state must also be taken into account. A CrNi alloy, for example, can be activated by mechanical damage to the surface, by deposits (diffusion of oxygen made more difficult) or by corrosion products on the surface of the material. This may result in a potential difference between the active and passive surfaces of the metal, and in material erosion (corrosion) if an electrolyte is present.

Dezincing

A type of corrosion which occurs primarily in copper-zinc alloys with more than 20% zinc.

During the corrosion process the copper is separated from the brass, usually in the form of a spongy mass. The zinc either remains in solution or is separated in the form of basic salts above the point of corrosion. The dezincing can be either of the surface type or locally restricted, and can also be found deeper inside.

Conditions which encourage this type of corrosion include thick coatings from corrosion products, lime deposits from the water or other deposits of foreign bodies on the metal surface. Water with high chloride content at elevated temperature in conjunction with low flow velocities further the occurrence of dezincing.

7.2 | Corrosion resistance

Contact corrosion

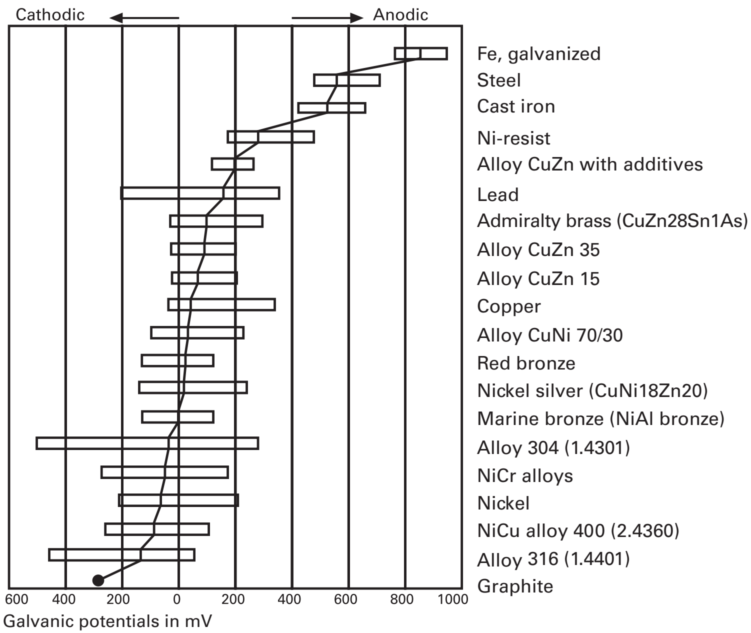


Fig. B.7:Galvanic potentials in seawater
Source: DECHEMA material tables

Resistance table
The table below provides a summery of the resistance to different media for metal materials most commonly used for flexible elements.

The table has been drawn up on the basis of relevant sources in accordance with the state of the art; it makes jet no claims to completeness.

The main function of the table is to provide the user with an indication of which materials are suitable or of restricted suitability for the projected application, and which can be rejected right from the start.

The data constitutes recommendations only, for which no liability can be accepted.

The exact composition of the working medium, varying operating states and other boundary operating conditions must be taken into consideration when choosing the material.

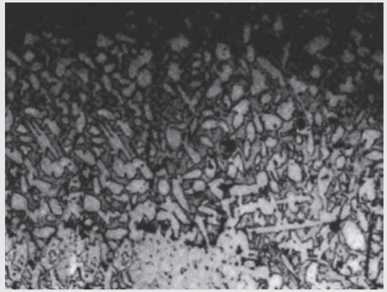


Fig. B.8: Dezincing on a Copper-Zinc alloy (Brass / CuZn37). Sectional view (100-fold enlargement).

Table keys

Assessment	Corrosion behaviour	Suitability
0	resistant	suitable
1	uniform corrosion with reduction in thickness of up to 1 mm/year	restricted suitability
P	risk of pitting corrosion	
S	risk of stress corrosion cracking	
2	hardly resistant, uniform corrosion with reduction in thickness of more than 1 mm/year up to 10 mm/year	not recommended
3	not resistant (different forms of corrosion)	unsuitable

Meanings of abbreviations:

dr: dry condition
mo: moist condition
hy: hydrous solution
me: melted
cs: cold-saturated (at room temperature)
sa: saturated (at boiling point)
bp: boiling point
adp: acid dew point

HYDRA

Resistance tables

Medium: Designation / Chemical formula	Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Acetanilide (Antifebrine) C_8H_9NO		<114	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
Acetic acid CH_3COOH or $C_2H_4O_2$	5 5 50 50 80 96 98	20 bp 20 bp 20 20 bp	3 3 3 3 3 3 3	0 3 3 3 3 3 3	0 0 0 3 P 3 3	0 0 0 0 P P 3	0 0 0 0 0 0 0	1 1 1 1 1 1 1	0 0 0 0 0 0 0	0 0 0 0 0 0 0	1 1 1 1 1 1 1				0 0 3	3 3 3 3 3	0 0 1 0 0 0 0	0 0 0 0 0 0 0	0 0 3 0	 0 1 0
Acetic acid vapour	33 100 100	20 >50 <bp		3 3 3	1 3 3	1 3 3	 0 0	 1 3		 0 0	 1 3	 3 3			 3 3	 3 3	 0 0		 1 3	
Acetic aldehyde CH_3–CHO	100	bp	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetic anhydride $(CH_3–CO)_2O$	all 100 100	20 60 bp	1 3 3	0	0 0 0	0 0 0	0	1 3	0	0 0 0	1	1	3	0 1	0 1	1 1 1	0 0 0	0 0 0	0 1 3	0 0 0
Acetic anilide (Antifebrine)		<114	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
Acetone CH_3COCH_3	100	bp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetyl chloride CH_3COCl		20	1	1	1	1	1	1	0	0	1	1		1	1	1		0	1	0
Acetylene dr H-C≡C-H dr		20 200	0 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	3 3	3 3	3 3	3 3	0 3	0 0	0 0	0 1	3 3
Acetylene dichloride hy $C_2H_2Cl_2$ dr	5 100	20 20	 0	 P	 P	 P	 0	 0	 0		 0					 0			1 0	
Acetylen tetrachloride $CHCl_2–CHCl_2$	100 100	20 bp bp	0 0 1	0 0	0 0	0 0				0 0					0 1 3	0 0 1	0 1		0 3 3	
Adipic acid $HOOC(CH_2)_4COOH$	all	200	0	0	0	0	0	0	0	0	0					0	0	0	0	0
Alcohol see ethyl or methyl alcohol																				

Medium				Materials																	
Designation Chemical formula		Concentration	Temperature	Non-/low- alloy steels	Stainless steels			Nickel alloys					Copper alloys			Pure metals					
		%	°C		Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Allyl alcohol		100	bp			0	0	0	0	0	1	0					0				
CH_2CHCH_2OH																					
Allyl chloride		100	25				0	0	0	0		0					0				
$CH_2{=}CHCH_2Cl$																					
Alum		100	20	1	1	0	0	0	1	0	0		1			1			0	1	
$KAl(SO_4)_2$	hy	10	20	1	0	0	0				1		1	1	1	1		0	0	1	
	hy	10	<80	1	1	0	0				1		1					0	0		
		sa			3	3	1				3		3								
Aluminium	me		750	3	3	3	3					3					3	3			
Al																					
Aluminium acetate	hy	3	20	3	0	0	0				0						0	0			
$(CH_3{-}COO)_2Al(OH)$ hy		sa		3	0	0	0				1							0	1		
Aluminium chloride	hy	5	20	3	3	3	P	1	1	0	0	1	3	3	1	3	1	0	0	3	1
$AlCl_3$																					
Aluminium fluoride	hy	10	25	3	3	3	3				1	1				1	1	0	3	1	1
AlF_3																					
Aluminium formate				1	0	0	0	0	0	0	0				0	1	0	0	0	0	
$Al(HCOO)_3$																					
Aluminium hydroxide	hy	10	20	1	3	0	0	0		0	0	1	0			0		0	0	1	
$Al(OH)_3$																					
Aluminium nitrate				0	0	0	0	0	0	0	0	0						0	0	1	
$Al(NO_3)_3$																					
Aluminium oxide			20	1	1	0	0	0		0	0	3	0	0	0	0			0	3	
Al_2O_3																					
Aluminium potassium sulphate see alum																					
Aluminium sulphate	hy	10	<bp	3	3	3	0	0	1	0	1	3	3	3	3	3	1	0	0	3	
$Al_2(SO_4)_3$	hy	15	50	3	3	3	1		1	1	1	1	1	1	1	1	1	0	0	3	
Ammonia	dr	10	20	0	0	0	0		0	0	0	1	0	S	S	0	3	0	0	0	0
NH_3	hy	2	20	0	0	0	0		0	0	0	0	3	S	S	3	3	0	0	1	0
	hy	20	40	0	0	0	0	0	1	1	1	3				3	3	0	0		
	hy	sa	bp	0	0	0	0	0	3	1	1	3						0	0		

Medium				Materials																	
Designation Chemical formula		Concentration	Temperature	Non-/low- alloy steels	Stainless steels			Nickel alloys					Copper alloys			Pure metals					
		%	°C		Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Ammonia bromide	hy	10	25	3	P	P	P	0		0	1								0	1	
NH_4Br																					
Ammonium acetate				1	0	0	0												0	0	
$CH_3{-}COONH_4$																					
Ammonium alum	hy	cs	20			0	0											3	0		
$NH_4Al(SO_4)_2$																					
Ammonium bicarbonate	hy			0	0	0	0	1	3			3	3			3			0	0	
$(NH_4)HCO_3$																					
Ammonium bifluoride	hy	10	25	3	3	3	3				0							3	0		
NH_4HF_2	hy	100	20	3	3	0	0				0							3	0		
Ammonium bromide see ammonia bromide																					
Ammonium carbonate	hy	1	20	0	0	0	0	0	0	0	1	0	1			1			0	0	0
$NH_4)_2CO_3$	hy	50	bp	0	0	0	0	0	0	0	1	0	1			1	1		0	0	0
Ammonium chloride	hy	1	20	1	P	P	P	0	0	0	0	0	1	S	S	1	1	0	0	1	1
NH_4Cl	hy	10	100	1	P	P	P	0	0	0	0	1	1	S	S	1	1	0	1	1	1
	hy	50	bp	1	P	P	P	0	1	0	1	1	1			1	1	0	1	1	1
Ammonium fluoride		10	25	1	1	0	0				0							1	0		
NH_4F	hy	hg	70	3																	
	hy	20	80	3		3	3				0			3	3	3			0		
Ammonium fluosilicate	hy	20	40	3		1	0	0	0	0	0	0					0				
$(NH_4)_2SiF_6$																					
Ammonium formate	hy	10	20	1	0	0	0	0	0	0	0	0						0	0	0	
$HCOONH_4$	hy	10	70																0	0	
Ammonium hydroxide		100	20		0	0	0	0	0	0	0	3	3			3	0	0	0	1	
NH_4OH																					
Ammonium nitrate	hy	5	20	3	0	0	0	0	1	0	0	3	3			3			0	0	
NH_4NO_3	hy	100	bp	3	0	0	0	0			0	3		3	3	3			0	0	
Ammonium oxalate	hy	10	20	1	1	0	0		1	0	0	1	1			1		0	0		
$(COONH_4)_2$	hy	10	bp	3	3	1	0		1	0		1	1			1		1	0		
Ammonium perchlorate	hy	10	20		P	P	P				1							0			
NH_4ClO_4																					

Designation / Chemical formula		Concentration %	Temperature °C	Non-/low-alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Ammonium persul-phate $(NH_4)_2S_2O_8$	hy	5	20		0	0	0	0	1	0	0	3	3			3	3	0	0	3	
	hy	10	25	3	1	1	1				0	3	3	3	3	3	3	0			3
Ammonium phos-phate $NH_4H_2PO_4$	hy	5	25	0	1	1	0	0	1	0	0	1	1			3	1	0	0	1	
Ammonium rhodanide NH_4CNS			70		0	0	0											0		0	
Ammonium sulphate $(NH_4)_2SO_4$	hy	1	20	0	0	0	0	0	1	0	0	1	3			3	1	0	0	P	
	hy	10	20	0	1	1	0	0	3		1	1	3	3	1	3	1	3	0	P	1
	hy	sa	bp	1		0					3	2	3					0	0		
Ammonium sulphite $(NH_4)_2SO_3$		cs	20		1	0	0	3	3			3	3			3	3	0	0		
		sa	bp		3	1	1	3	3			3	3			3	3	0	0		
Ammonium sulphocyanate see ammonium rhodanide																					
Amyl acetate $CH_3{-}COOC_5H_{11}$		all	20					1	1	1	1	1	1			1	1		1	1	
		100	bp	1		1	1		0	1	1	0	0				0			0	
Amyl alcohol $C_5H_{11}OH$		100	20	0	0	0	0		0	0	0	0	0	0	0	0	0		0		
		100	bp	1	0	0	0											0		1	
Amyl chloride $CH_3(CH_2)_3CH_2Cl$		100	bp	1		P	P	0	1	0	0	1	0			0	1	0	0	3	
Amyl thiol		100	160			0	0				0										
Aniline $C_6H_5NH_2$		100	20			0	0	0	1	0	0	3	3	3	3	3	3	0		0	0
		100	180			1	1					1								3	0
Aniline chloride $C_6H_5NH_2HCl$	hy	5	20		P	P	P				0		3			3	3	0	0	3	
	hy	5	100		P	P	P				0							0			
Aniline hydrochloride see anilin chloride																					
Aniline sulphate			20				0				0									1	
Aniline sulphite	hy	10	20				0		1		0										
	hy	cs	20				0				0										
Antifreeze Glysantine			20		0	0	0	0	0	0	0	0					0	0	0	0	

Designation / Chemical formula		Concentration %	Temperature °C	Non-/low-alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Antimony Sb	me	100	650	3						0	0							3		3	
Antimony trichloride $SbCl_3$	dr		20	0	3	3	3										0			3	
	hy		100	1	3	3	3										0			3	
Aqua regia $3HCl{+}HNO_3$			20	3	3	3	3		3		3		3	3	3	3		0	0		1
Arsenic As			65			0	0														
			110			1	1														
Arsenic acid H_3AsO_4	hy		20	3		0	0														
	hy	90	110		3	3	3		3				3			3				3	
Asphalt			20	0	0	0	0						0	0	0	0	0			0	
Azobenzene $C_6H_5{-}N{=}N{-}C_6H_5$			20		0	0	0	0	0	0	0	0						0	0	0	
Baking powder	mo			1	0	0	0	0	0	0	0	0				1				0	
Barium carbonate $BaCO_3$			20	3	0	0	0	0		0	0	0	0	0	0	0		0	0	1	
Barium chloride $BaCl_2$	hy	5	20		P	P	P	1	1	0	0	1	3			3	1	0	0	3	
	hy	25	bp		P	P	P	1	1	0	0	1					1	0	0	P	
Barium hydroxide $Ba(OH)_2$	solid	100	20	0	0	0	0	0	1		0	1	0	1	0	0	0	0		3	
	hy	all	20	0	0	0	0	0	1		0	1	0	1	0	0	1	0		3	
	hy	all	bp	0	0	0	0				1		0					0			
		100	815	0	0	0	0	0	1								1	0			
	hy	cs	20	0	0	0	0				1		0	1	0	0	0	0		0	
	hy	sa	bp	0	0	0	0				1						0	0		3	
		50	100	0	0	0	0	0	1			1					0	0			
Barium nitrate $Ba(NO_3)_2$	hy	all	bp		0	0	0	0	1	0			3			3		0	0	0	
Barium sulphate $BaSO_4$			25	0	0	0	0	0		0		0	0	0	0	0	1	0	0	0	
Barium sulphide BaS			25		0	0	0						3	1	3	3					

HYDRA

Medium				Materials																	
Designation Chemical formula		Concentration	Temperature		Stainless steels			Nickel alloys					Copper alloys			Pure metals					
		%	°C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Basic aluminium acetat see aluminium acetat																					
Beer		100 100	20 bp	3 3	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 1	0 0	1 1	0 0	0 0	0 0	0 0	
Benzaldehyde C_6H_5–CHO	dr		bp		0	0	0					1						1	0	0	0
Benzene		100 100	20 bp		0 0	0 0	0 0	0	0 1	0 1	1 1	0 1	0 1	0	0		0 1	0 1	0 0	0 1	1
Benzenesulfonic acid C_6H_5–SO_3H	hy hy	5 5	40 60	3 3	0 3	0 1	0 1														
Benzine		100	25		0	0	0	0	0	0	0	0	0	0	0	1		0		1	
Benzoic acid C_6H_5COOH	hy hy	all all	20 bp	1 3	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	 3	0 0	0 0	0 0	0 0	0 0	0 3	
Benzyl alcohol C_6H_5–CH_2OH		all	20	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
Biphenyl C_6H_5–C_6H_5		100 100	20 400	0 0	0 0	S S	S S	0 0	0 0	0 0	0 0	0 0	0	0	0	0 0	0 0	0 0	0 0	0 0	
Blood			20	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Boiled oil			20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
Borax $Na_2B_4O_7$	hy hy	cs sa		1 3	0 0	0 0	0 0						0	0	0	0		0 0	0 0	0 1	
Boric acid H_3BO_3	hy hy hy	50 50 70	100 150 150	3 3 3	0 1 1	0 0 1	0 0 1	0 0 0	1 1 1	0 0 0	0 0 0	1 1 1	 0	1 1 1	 1	1 1 1	1 1 1	0 0 0	0 0 0	1 1 1	1 0 0
Boron B			20 900	0 0	0	0	0														
Bromine Br	dr mo	100 100	20 20	P P	P P	P P	P P	1	0 3	0	0 3	0 0	 1	0 3	0 1	0 3	0 0	3 0		3 3	0 0
Bromine water		0.03 1	20 20		P P	P P	P P														

HYDRA

Medium				Materials																	
Designation Chemical formula		Concentration	Temperature		Stainless steels			Nickel alloys					Copper alloys			Pure metals					
		%	°C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Bromoform $CHBr_3$	dr mo		20	0 3	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0			0 0	0 0				3 3	
1,3-Butadiene CH_2=CHCH=CH_2								0	0	0		0				0	0			0	
Butane C_4H_{10}		100 100	20 120	0	0 1	0 0	0 0	0	0	0	0	0	0	0	0	1	0			1	
Butanol CH_3–CH_2–CH_2– CH_2OH		100 100	20 bp	0 0	0 0	0 0	0 0	0	0 0	0	0 0	0 0	0	0	0	0	0	0 0	0 0	0 0	0
Butter			20	3	0	0	0	0	0	0	0					3				0	
Buttermilk			20	3	0	0	0	0		0	0	3			3	3				0	
Butylacetate $CH_3COOC_4H_9$			20 bp	1 1	0 0	0 0	0 0	0 0		0 0	0 0	1 0	0 0	0	0	0 0		0 0	0 0	0 0	0
Butyric acid CH_3–CH_2–CH_2–COOH	hy hy	cs sa	20 bp	3 3	0 3	0 3	0 0	1 1	3 3	0 0	0 0	1 1					3 3			0 1	
Cadmium Cd	me					3	3														
Calcium Ca	me		850	3		3	3														
Calcium bisulphite $CaSO_3$		cs sa	20 bp	3 3	3 3	0 3	0 0						1	3	1	0		0 0			
Calcium carbonate $CaCO_3$			20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Calcium chlorate $Ca(ClO_3)_2$	hy hy	10 10	20 100		P 3	P 3	P P	1 1	1 1	1 1	1 1	1 1	3 3			1 1	1 1		0 0		
Calcium chloride $CaCl_2$	hy hy	5 10 cs sa	100 20	3 3 3 3	P P P 3	P P P P	P P P P	 0 0 0	 0 0 0	 0 0 0	0 0 0 0	 0 1 3	 0 0 0	 3 3 3	 1	 1 0	 0 1	0 0 0 P	0 0 0 0	3 3 3 3	
Calcium hydroxide $Ca(OH)_2$				0	0	0	0	1	1	0	0	1	0	0	0	1	1	0	0	3	

Medium			Materials																	
				Stainless steels			Nickel alloys					Copper alloys			Pure metals					
Designation Chemical formula	Concentration %	Temperature °C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Calcium hypochlorite hy $Ca(OCl)_2$ hy	2 cs	20	3 3	3 3	3 3	P P	0	3	0	0 1	3	3			3	3	0	0 0	3 3	
Calcium nitrate $Ca(NO_3)_2$	 all	20 100	3 3	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0						0 0		0 0	
Calcium oxalate mo $(COO)_2Ca$		20	1	0	0	0	0	0	0	0	0	0	0	0			0	0	3	
Calcium oxide CaO		20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		3	
Calcium sulphate mo $CaSO_4$ mo		20 bp	1 1	0 0	0 0	0 0	0 0		0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 1	
Calcium sulphite hy $CaSO_3$ hy	cs sa		0 0	0 0	0 0	0 0									1 1		0 0	0 0	1 1	
Carbolic acid $C_6H_5(OH)$ hy	 90	20 bp bp	0 3 3	0 3 3	0 3 3	0 0 0	0	1	0	0 1 1	1 0 0	0			0	1 0 0	0 0 0	0 0 0	0 3 3	
Carbon dioxide dr CO_2 dr mo mo	100 100 20 100	<540 1000 25 25	0 3 1 3	1 1 1	0 0 0	0 0 0	0 0 0	0 3 0 1	0 0 0	0 0 0	0 0 1	 0 0	 3	 1	3 1 0	0 1	 0	0 0 0 0	 3 3	
Carbon monoxide CO	100 100	20 <540	0 3	0 0	0 0	0 0		0 3	0	0 0	0 1				0 3	0 3	0 0	0 0	0 1	0 3
Carbon tetrachloride dr dr CCl_4 mo mo		20 bp 25 bp	0 1 1 3	0 0 1	0 0 1	0 0 1 1	0 0	0 0	0 0	0 0 0	0 0 0	0 0	0 0	0 0	0 0 1	0 0 0	0 0 0	0	0 3 3 3	
Carbonic acid see carbon dioxide																				
Caustic-soda solution see sodium hydroxide																				
Chilean nitrate see sodium nitrate																				
Chloral $CCl_3–CHO$		20								0								0	3	

Medium			Materials																	
				Stainless steels			Nickel alloys					Copper alloys			Pure metals					
Designation Chemical formula	Concentration %	Temperature °C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Chloramine			3	3	1	0	0		0	0	0									
Chloric acid hy $HClO_3$		20	3	3	3	3	0			0							0	0	3	3
Chlorinated lime see calcium hypochlorite																				
Chlorine dr Cl_2 dr dr mo mo	100 100 100	200 300 400 20 150	0 3 3 3 3	0 3 3 3 3	0 3 3 3 3	0 0 3 3 3	 0	0 0 0	0 0 0	0 0 0 0 0	0 0 0	0	0	0	0	0	1 0 0	0 0 0	0 3 3	0
Chlorine dioxide hy ClO_2	0.5	20	3	3	3	3				1				3			0	0		
Chloroacetic acid $CH_2Cl–COOH$ hy	all 30	20 80	3 3	3 3	3 3	L 3	3	 3	1	1 0	3	3	 3	 3	3 3	 1	0 0	0 0	3 3	
Chlorobenzene dr C_6H_5Cl mo	 100	 20	0 0	0 P	0 P	0 P	 0	 0	 0	0 0	 0	 0	 0	 0	 1	 1	 0	 0	 1	
Chloroethane C_2H_5Cl																				
Chloroform dr $CHCl_3$ mo			1 3	1 P	1 P	1 P	0 0	0 0	0 0	0	0 0	0	0	0	0	0	0 0		0 3	
Chloronaphthaline $C_{10}H_7Cl$			0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	
Chlorophenol $C_6H_4(OH)Cl$			1	0	0	0				0										
Chlorosulphon acid hy $HOSO_2Cl$ mo	100	20 20	0 3	0 3	0 3	0 1	0 1	0 1	0 1	0	0				0 3	0 3	0 3	0 0	0 3	3 3
Chrome alum hy $KCr(SO_4)_2$	1 cs sa	20	3 3 3	3 3 3	0 1 3	0 0 3		 0 0			1 0 1		 3 3			 1 3	0 0 0		1 3 3	
Chromic acid hy Cr_2O_3 hy (H_2CrO_4) hy hy hy hy hy	5 5 10 10 10 50 60	20 90 20 65 bp bp 20	3 3 3 3 3 3 3	3 3 0 3 3 3 3	0 3 0 3 3 3 3	0 3 0 3 3 3 3	1 1 1 3 1	3 3 3 3 3	0	0 1 0 0 0 3	3 3 3 3 3 3 3	3 3 3 3 3 3 3	3 3 3 3 3 3 3	3 3 3 3 3 3 3	3 3 3 3 3 3 3	3 3 3 3 3 3 3	0 0 0 0 0 0 0	0 0 0 0 0 0 0	1 1 3 3 3	0

Medium: Designation / Chemical formula	Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Chromic-acid anhydride see chromium oxide																				
Chromium oxide CrO_3			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Chromium sulphate $Cr_2(SO_4)_3$	cs sa		3 3	0 0	0 1	0 1		0 1	0 0	0 0	0 0					0 0				
Cider		20 bp	3 3	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0					0 0	0 0	0 0	1 1	0 0
Citric acid hy $C_6H_8O_7$ hy	all all	<80 bp	3 3	3 3	0 3	0 0		0 0		0 0										
Combustion gases free from S or H_2SO_4 and Cl		≤400	0	0	0	0				0										
with S or H_2SO_4 and Cl		>adp and ≤400	0	0	0	0				0										
Copper (II) acetate hy $CU_2(CH_3COO)_4$ hy		20 bp	3 3	0 0	0 0	0 0	0	1	0	0	1	3		3 3	3	1	0 0	0	3 3	1
Copper (II) chloride hy $CuCl_2$ hy	1 cs	20	3 3	3 3	P 3	P 3	0 3	3 3		1 0	3 3	3			3 3	3 3	0 0	0 0	3 3	
Copper (II) nitrate hy $Cu(NO_3)_2$ hy hy	1 50 cs	20 bp		0 0 0	0 0 0	0 0 0	0 0	3 3 3		0 1 1	3 3 3	3 3			3 3	3 0 3	0 0 0	0 3 0	3 3	
Copper (II) sulphate hy $CuSO_4$ hy	cs sa		3 3	0 1	0 0	0 0	0 0	3 3		0 0	3 3	3			3 3	3 3	0 0	0 0	3 3	 0
Cresol $C_6H_4(CH_3)OH$	all all	20 bp	3 3	1 1	0 1	0 0		0 0	0 0	 1	0 0					0 0	0 0		0 3	0 0
Crotonaldehyde CH_3–CH=CH–CHO		20 bp	3		0 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0		0				0 0	
Cyclohexane $(CH_2)_6$			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Diammonium phosphate see ammonium phosphate																				

Medium: Designation / Chemical formula	Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Dibromethane $CH_2Br–CH_2Br$			1		0	0										0			3	
Dichlorflourmethane dr CF_2Cl_2 dr mo		bp 20 20			0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0							0 0 0	0 0 0	
Dichloroethane dr $CH_2Cl–CH_2Cl$ mo	100 100	20 20	0	P P	P P	P P	1	0				0	1		1		0	0 0	0	1 1
Dichloroethylene see acethylene dichloride																				
Diethyl ether $(C_2H_5)_2O$			0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Ethane $CH_3–CH_3$		20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ether see diethyl ether																				
Ethereal oils		20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ethyl alcohol C_2H_5OH	all all	20 bp	0 1	0 0	0 0	0 0	0 0	0 0	0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Ethylbenzene $C_6H_5–C_2H_5$			1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ethyl chloride C_2H_5Cl			0	S	S	S	0	0	0	1	0	0	1	1	1	0		0	1	0
Ethylene $CH_2=CH_2$		20	0	0	0	0													0	
Ethylene dibromide see dibromethane																				
Ethylene dichloride see dichloroethane																				
Ethylene glycol $CH_2OH–CH_2OH$	100	20	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	
Exhaust gases see combustion gas																				

Medium			Materials																	
				Stainless steels		Nickel alloys					Copper alloys			Pure metals						
Designation Chemical formula	Concentration %	Temperature °C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	2.4858 / alloy 825	2.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Fats			0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
Fatty acid	100	20	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0
$C_{17}H_{33}COOH$	100	60	3	0	0	0	0	0	0	0	0		1	1	1	0	0	0	1	0
	100	150	3	3	0	0	0	0	0	0	1		1	1	3	0	0	0	3	0
	100	180	3	3	3	0	0	0	0	0	1		1	3	3	0	0	0	3	0
	100	300	3	3	3	0	0	0	0	0			3	3	3	0	0	0	3	0
Fixing salt																				
see sodium thiosulphate																				
Flue gases																				
see combustion gases																				
Fluorine mo		20	3	3	3	3				0	0	3	3	3	3	0	3		3	0
F dr	100	20	0	0	0	0				0	0	0	0	0	0	0	0		3	0
dr	100	200	0	0	P	P				0	0				3	0	0		3	
dr	100	500	3							0									3	
Fluorosilicic acid	100	20	3	3	P	P				1		1	3	1	1				3	
$H_2(SiF_6)$	25	20	3	3	3	3	1	1	1	1	3		3	1	1	1	3		3	
	70	20	3	3	3	3				1									3	
vapour			3	3	3	3				1							2		3	
Formaldehyde hy	10	20	3	0	0	0	0	0	0	0	0	0	3	0	0	0	0		1	0
CH_2O hy	40	20	3	0	0	0	0	0	0	0	0	0	3	0	0	0	0		1	0
hy	all	bp	3	0	0	0				0							0		3	
Formic acid	10	20	3	3	1	0	0	1	0	0	1		0		0	1	0	0	0	1
HCOOH	10	bp	3	3	3	1	0	1	0	0	1		0			3	0		3	3
	80	bp	3	3	3	3	0	1	0	0	3		0		0	1	3		3	3
	85	65	3	3	3	3	0	1	0	0	2		0		1	1	3		3	
Fuels																				
Benzine		20		0	0	0	0	0	0	0	0		0	0	0	0			0	
		bp		0	0	0	0	0	0	0	0		0	0	0	0			0	
Benzene		20		0	0	0	0	0	0	0	0		0	0	0	0			0	
		bp		0	0	0	0	0	0	0	0		0	0	0	0			0	
Benzine-alcohol-mixture		20		0	0	0	0	0	0	0	0		0	0	0	0			0	
Diesel oil		20		0	0	0	0	0	0	0	0		0	0	0	0			0	
Furfural	100	25	1	1	1	1				0		0	3	0	0			0	0	
	100	bp	3	1	1	1				0					3			0	0	
Gallic acid hy	1	20	1	0	0	0				0								0		
$C_6H_2(OH)_3COOH$	100	20	3	0	0	0												0		
	100	bp	3	0	0	0		3										0		

7.2 | Corrosion resistance
Resistance tables
HYDRA

Medium			Materials																	
				Stainless steels		Nickel alloys					Copper alloys			Pure metals						
Designation Chemical formula	Concentration %	Temperature °C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	2.4858 / alloy 825	2.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Gelatine		20	0	0	0	0		0		0								0		0
		80	1	0	0	0		0			0	0	1	0	0	0	0		0	0
Glacial acetic acid																				
CH_3CO_2H																				
see acetic acid																				
Glass me		1200	1		1	1														
Glauber salt																				
see sodium sulphate																				
Gluconic acid	100	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
$CH_2OH(CHOH)_4–COOH$																				
Glucose hy		20		0	0	0						0	1	0	0		0		0	
$C_6H_{12}O_6$																				
Glutamic acid		20	1	P	P	0	0	1	0	0	1					1				
$HOOC–CH_2–CH_2–$		80	3	P	P	0		1		1										
$CHNH_2–COOH$																				
Glycerine	100	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
$CH_2OH–CHOH–CH_2OH$	100	bp	1	1	0	0		0	0	0	0		1		0	0		0	0	
Glycol																				
see ethylenglycol																				
Glycolic acid		20	3	1	1	1				0							0		1	
$CH_2OH–COOH$		bp	3	3	3	3				0							0		1	
Glysantine																				
see antifreeze																				
Hexachloroethane		20			0	0	0	0	0	0	0						0		3	
$CCl_3–CCl_3$																				
Hexamethylene- hy	20	60	1		0	0				0										1
tetramine hy	80	60	3		0	0				0										
$(CH_2)_6N_4$																				
Household ammonia																				
see ammonium hydroxide																				
Hydrazene		20	0		0		3	3			3					3			1	
$H_2N–NH_2$																				

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Hydrazine sulphate $(NH_2)_2H_2SO_4$	hy	10	bp	3		3	3														
Hydrobromic acid aqueous solution of hydrogen bromide (HBr)			20	3	3	3	3	3	3	3	3	3	3	3	3	3	3		0	3	3
Hydrochloric acid		0.2	20	3	3	P	P				0						P	0	0		
HCl		0.5	20	3	3	3	P				0							0	0		
		0.5	bp	3	3	3	3				3							1	0		
		1	20	3	3	3	P	3	3		0	1	3	3	3	3	1	0	0	3	
		2	65	3	3	3	3				0							0	0	3	
		5	20	3	3	3	3	3	3		0	1	3		1	3	3		3		
		15	20	3	3	3	3	3	3		0	3	3			3	3	3	0	3	0
		32	20	3	3	3	3				0					3		3	0	3	1
		32	bp	3	3	3	3				3							3	0	3	
Hydrochloric-acid gas see hydrogen chloride																					
Hydrofluoric acid		10	20	3	3	3	3	1	1	0	0	1		3	3	3	1	3	3	3	
HF		80	20	1				1	1	1	1	1				1	1	3	3	3	
		80	bp								1	1						3	3	3	
		90	30					1	1			0					1	3	3	3	
Hydrogen			<300	0		0	0				0			0		0				0	
H			>300	3		0	0				0									0	
Hydrogen bromide	dr	100	20	0	0	0	0														
HBr	mo	30	20	3	3	3	3											0			
Hydrogen chloride	dr		20	0	3	1	1	0	0	0	0			3	3	3				1	0
HCl	dr		100	0	3	3	3	0	0	0	0			3		3				1	
	dr		250	1	3	3	3	0	0	0	0			3		3				3	3
	dr		500	3	3	3	3		1		0			3		3				3	3
Hydrogen cyanide	dr		20	3	0	0	0	0	1	0	0	1	3	3	3	1	0	0	0	0	
HCN	hy	20	20	3	1	0	0	0	1	0	0	1	3	3	3	1	0	0	0	0	
	hy	cs	20	3	1	0	0	0	0	0	0	3	3	3	3	1	0	0	0	0	
Hydrogen fluoride		5	20		3	3	3	3	0	0	0	0				3	0	3	3	3	
HF		100	500	3	3	3	3	3	3		0	3		3		3	0	3	3	3	
Hydrogen peroxide H_2O_2		all	20	3	3	0	0	0	1	0	0	1	3	3	3		3	1	3	0	0

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Hydrogen sulphide	dr	100	20	1	S	0	0	0	1		0	1	0	0	0	0	0	0	0	0	1
H_2S	dr	100	100	3	S	0	0									0				0	
	dr	100	200	3	3	0	0												0		
	mo		20	3	3	0	0		0	0	0	0	3	3	3	3	1	0		0	3
Hydroiodic acid	dr		20	0	0	0	0														
	mo		20	3	3	3	3														
Hypochlorous acid HOCl			20	3	3	3	3											0		3	
Indol			20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
Ink see gallic acid																					
Iodine	dr	100	20	0	P	P	P				0	0	3	3	3	3		3		0	
J_2	mo		20	3	3	3	3				1	3					3	0		3	3
	mo		bp	3	3	3	3				1	3					3			3	3
Iodoform	dr		60	0	0	0	0													0	
CHJ_3	mo		20	3	3	P	P														
Iron (II) chloride	hy	10	20	0		P	P				1		1	3	1	1		0	0	3	
$FeCl_2$	hy	cs						3	3		0	3	3			3	3	0	0	3	
Iron (II) sulphate $FeSO_4$	hy	all	bp	0	0	0	0				0	0					3	0		3	
Iron (III) chloride	dr	100	20	0	P	P	P	1	3		0	3	3	3	3	3	3	0	0	3	
$FeCl_3$	hy	5	25	3	3	3	3	3	3		0	3	3	3	3	3	3	0	0	3	
	hy	10	65	3	1	1	1				3						0	0			
	hy	50	20	3	3	3	3		3		1		3	3	3	3		0	0		
Iron (III) nitrate	hy	10	20	3	0	0	0				0							0			
$Fe(NO_3)_3$	hy	all	bp	3	0	0	0	3	3	3	3	3				3	0				
Iron (II) sulphate $FeSO_4$	hy	all	bp	0	0	0	0				0	0					3	0		3	
Iron (III) sulphate	hy	<30	20	3	0	0	0	0	3		0	1	3	3	3	3	3	0	0	3	
$Fe(SO_4)_3$	hy	all	bp	3	1	0	0				0							0	0	3	
Isatine $C_8H_5NO_2$			20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	

Medium				Materials																	
					Stainless steels			Nickel alloys					Copper alloys			Pure metals					
Designation Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Kalinite see alum																					
Ketene $R_2C=C=O$			20 bp		0 0	0 0	0 0	0 0	0 0	0 0	0 0						0 0	0 0	0 0	0 0	
Lactic acid $C_3H_6O_3$	hy hy hy hy	1 all 10 all	20 20 bp bp	3 3 3 3	3 3 3 3	0 1 3 3	0 0 3 1	0 0 	 3 	0 	0 0 0 0	 3 	0 1 	3 	1 	0 1 	 3 	0 0 0 0	0 0 0 0	0 3 3 3	
Lactose $C_{12}H_{22}O_{11}$	hy		20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
Lead Pb	me		388 900	3 3	1 3	1 3	1 3		0 		 0	3 				3 		0 	0 		
Lead acetate $(CH_3–COO)_2Pb$	me			3	0	0	0				0	0			3	3				3	
Lead acide $Pb(N_3)_2$		<20	<30					0	0	0		1					1				
Lead nitrate $Pb(NO_3)_2$	hy		100	1	0	0	0	0	0	0	0	0						0	0	0	
Lime see calcium oxide																					
Lithium Li	me		300	0	0	0	0	0	0	0	0	3	3	3	3	3		0		3	
Lithium chloride LiCl	hy	cs		3	3	3	P	0	0	0	0	1					0	0			
Lithium hydroxide LiOH	hy	all	20	1	0	0	0	0	0	0		0					0	0			
Magnesium Mg	me		650		1	3	3	3	3		3	3	3	3	3	3	3	0	0	3	
Magnesium carbonate $MgCO_3$	hy hy		20 bp	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0			0 0	0 0	0 0	0 0	1 1	

7.2 | Corrosion resistance
Resistance tables

HYDRA

Medium				Materials																	
					Stainless steels			Nickel alloys					Copper alloys			Pure metals					
Designation Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Magnesium chloride $MgCl_2$	hy hy hy	5 5 50	20 bp bp	3 3 3	3 3 3	P 3 3	P 3 3	0 0 	0 0 	0 0 	0 0 0	0 0 	3 3 			3 3 	0 0 	0 0 0	0 0 0	3 3 3	
Magnesium hydroxide $Mg(OH)_2$	hy hy	cs sa		0 0		0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	3 3	
Magnesium nitrate $Mg(NO_3)_2$		cs		0	0	0	0	3	3		3	0	3	0	0	3	3	0	0	1	
Magnesium oxide see magnesium hydroxide																					
Magnesium sulphate $MgSO_4$	hy hy hy	0.1 5 50	20 20 bp	0 3 3	1 1 1	0 0 0	0 0 0	 0 	 1 	 0 	0 0 1	 1 	 0 	 3 	 0 	 0 	 1 	0 0 0	0 0 0	3 0 0	
Maleic acid HOOC–HC=CH–COOH	hy hy	5 50	20 100	3 3	0 0	0 0	0 0	0 	1 1	0 	0 0	1 	0 				1 			0 0	
Maleic anhydride		100	285								0										
Mallic acid	hy hy	 50	20 100	3 3	3 3	0 0	0 0	0 0	1 1	0 0	0 0	1 1	3 3	 3	 3	3 3	3 3	0 0	0 0	0 0	
Malonic acid $CH_2(COOH)_2$			20 50 100			1 	1 	1 1 3	1 1 3	1 1 	1 1 3	1 1 3					1 1 3	1 1 3		1 	
Manganese(II) chloride $MnCl_2$	hy hy	5 50	100 20	3 1	P 3	P P	P P	1 1	1 1	1 1		1 1	3 3			3 3	1 1	0 0	0 0		
Manganese(II) sulphate $MnSO_4$		cs			0	0	0	0	0	0	0	0				0	0	0			
Maritime climate	mo			2P	1P	1P	0	0	0	0	0	0	0	1	0	0	0	0	0	2	1
Methanol see methyl alcohol																					
Menthol $C_{10}H_{19}OH$					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Mercury	dr	100	20	0	P	P	P		0	0	0	3	3	3	3	3	0	0		1	3
Hg		all	<500	1	1	1	0		0	0	0	3	3	3	3	3		0	0	3	
Methane			200	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	
CH_4			600							0						0					
Methyl acetate		60	20	0		0	0				0							0	0		
CH_3COOCH_3		60	bp	0		0	0				0							0	0		
Methyl alcohol		<100	20		0	0	0	0	0	0	0	0				0	0	0	1		
CH_3OH		100	bp	1	3	1	1		0	0	0	0		0	0	0	0	0	0	1	0
Methylamine $CH_3–NH_2$	hy	25	20	1	0	0	0	0		0	0	3	3	3	3	3		0		0	
Methyl chloride	dr	100	20	0	0	0	0		0	0	0	0		0	0	0	0	0		0	
CH_3Cl	mo		20	3	P	P	P		0	0								0		3	
	mo		100		P	P	P		0	0						1		0		3	
Methyldehyde see formaldehyde																					
Methylene dichloride	dr		20	0	P	P	P						0					0		0	
CH_2Cl_2	mo		20		P	P	P	0		1	1	1	0			0	1	0		3	
	mo		bp		P	P	P	1		1	1	1	1			0	1	0		3	
Milk of lime			20	0	1	0	0													0	
$Ca(OH)_2$			bp	0	1	0	0													0	
Milk sugar see lactose																					

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Mixed acids																					
HNO_3 % / H_2SO_4 % / H_2O %																					
90 / 10 / –			20	0		0	0					3		3	3	3	3	0		1	3
50 / 50 / –			20			0	0											0		3	
50 / 50 / –			90		3	1	1														
50 / 50 / –			120		3	3	3														
38 / 60 / 2			50		3	0	0														
25 / 75 / –			50		3	1	0														
25 / 75 / –			90		3	3	1														
25 / 75 / –			157		3	3	3														
15 / 20 / 65			20	3	3	0	0														
15 / 20 / 65			80		3	1	0														
10 / 70 / 20			50		3	0	0														
10 / 70 / 20			90		3	1	0														
5 / 30 / 65			20	3	3	0	0														
5 / 30 / 65			90	3	3	0	0														
5 / 30 / 65			bp	3	3	1	1														
5 / 15 / 80			134		3	1	1														
Molasses					0	0	0	0	0	0	0	0					0	0	0	0	
Monochloroacetic acid see chloroacetic acid																					
Naphthaline		100	20	0	0	0	0											0		1	
$C_{10}H_8$		100	390	0	0	0	0														
Naphthaline chloride		100	45								0										
		100	200								0										
Naphthaline sulphonic acid		100	20	0		0	0				0										
$C_{10}H_7SO_2H$		100	bp		3	3	3				0										
Naphthenic acid	hy	100	20		P	P	P	0	0	0		0					1			0	
Nickel (II) chloride	hy	10	20	3	P	P	P	0	1	0	0	1	1	3	1	3	1	0			0
$NiCl_2$	hy	10	bp	3	3	P	P				0							0			
		tot	70				0				1										
Nickel (II) nitrate	hy	10	25	3	0	0	0	0	0	0	0	3	3			3	3	0	0	3	
$Ni(NO_3)_2$	hy	<100	25	3	0	0	0	0	3		1	3				3	3	0	0	3	
Nickel (II) sulphate	hy		20	3	0	0	0	0	1	1	1	1					3	0			
$NiSO_4$	hy		bp	3	0	0	0		0		1	1					3	0			

Medium			Materials																	
				Stainless steels			Nickel alloys					Copper alloys			Pure metals					
Designation Chemical formula	Concentration %	Temperature °C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Nitric acid	1	20	3	0	0	0				0	0	1	3	3	3	0	0	0		
HNO_3	1	bp	3	0	0	0				1	3					3	0	0		
	5	20	3	0	0	0	0	3		0	3	3			3	3	0	0	3	
	5	bp	3	1	0	0				1							0	0		
	10	bp	3	1	0	0				1	3					3	0	0		
	15	bp	3	1	0	0				3							0	0		
	25	bp	3	3	0	0				3							1	0		
	50	bp	3	3	3	1	0	3		3	3	3			3	3	1	0	3	
	65	20	3	0	0	0		0		0							0	0	1	
	65	bp	3	3	3	3	0	3		3	3	3			3	3	0	0	3	
	99	bp	3	3	3	3	0	3		3	3	3			3	3	0	3		
	20	290	3	3	3	3				3							3	0		
	40	200	3	3	3	3				3							3	0		
Nitrobenzene hy $C_6H_x(NO_2)_y$			0	0	0	0	0	0	0	1	0	0	0	0	0	0	0		0	
Nitrobenzoic acid hy $C_6H_4(NO_2)COOH$		20	1	0	0	0	0	0	0	0	0	0	0	0		0			0	
Nitroglycerine hy $C_3H_5(ONO_2)_3$		20	0	0	0	0													0	
Nitrogen	100	20	0		0	0		0	0	0	0	0	0	0	0	0	0		0	0
N	100	900	1													3				
Nitrous acid HNO_2 similar to nitric acid																				
Oleic acid see fatty acid																				
Oleum see sulphur trioxide																				
Oxalic acid hy	all	20	3	3	0	0	1	1	0	0	1					3	0	0	0	
$C_2H_2O_4$ hy	10	bp	3	3	3	3	0	1	0	0	1	1			1	3	3	0	3	
hy	sa		3	3	3	3	1	1	1	1	1									
Oxygen O		500	1	0	0	0					0			3	3				0	3
Ozone				0	0	0	0	0	0	0	0				1		0		0	
Paraffin		20	0	0	0	0											0		0	
$CnH_{2n}+_2$ me		120	0	0	0	0						0	0	0	0		0		0	

Medium			Materials																	
				Stainless steels			Nickel alloys					Copper alloys			Pure metals					
Designation Chemical formula	Concentration %	Temperature °C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Perchlorethane see hexachlorethane																				
Perchloric acid (60%)	10	20	3	3	3	3											0		3	
$HClO_4$	100	20	3	3	3	3											0			
Perchlorethylene		20	0	0	0	0							0	0	0	0			0	
C_2Cl_4		bp	0	1	1	1							1	1	0	0			3	
mo			3	P	P	P														
Perhydrol see hydrogen superoxide																				
Petroleum		20	0	0	0	0		0	0	0	0	0	1	0	0	0	0		0	
		bp	0	0	0	0		0	0	0	0		1	0	0	3	0		0	
Petrol see benzine (benzene)																				
Phenol see carbolic acid																				
Phloroglucinol $C_6H_3(OH)_3$		20		0	0	0	0	0	0	0	0						0	0	0	
Phosgene dr $COCl_2$		20		0	0	0	0	0	0	0	0						0	0	0	
Phosphoric acid hy	1	20	3	0	0	0	0	0	0	0	1	3			3	0	0	0	3	
H_3PO_4 hy	10	20	3	3	0	0				0							0	0		
hy	30	bp	3	3	1	1				1	1	1	2	1	3	3	3	0	3	
hy	60	bp	3	3	3	3				1							3	0		
hy	80	20	3	3	1	0		0	0	0				0	1		3	0		0
hy	80	bp	3	3	3	3		0		3				1		3	3	0		1
Phosphorous dr P		20	0	0	0	0														
Phosphorous penta-chlorite PCl_5 dr	100	20	0	0	0					0					0	1				
Phtalic acid and phtalic anhydride		20	0		0	0				0	0		0	0	0	0			0	0
		200		0	3	0				0	0				0	0				0
$C_6H_4(COOH)_2$ dr		bp			0	0	0								0			0	0	

HYDRA

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Picric acid	hy	3	20	3	0	0	0											0		1	0
$C_6H_2(OH)(NO_2)_3$	hy	cs		3	0	0	0	3	3		0	3	3	3	3	3	3	0		0	
	me		150	3	0	0	0											0		3	
Plaster see calcium sulphate																					
Potash lye see potassium hydroxide																					
Potassium	me		604	0		0	0				1							0		0	
K			800			0	0				1							0	1	0	
Potassium acetate	me	100	292	1		0	0									1		0			
$CH_3–COOK$	hy		20	1	0	0	0		0	0	0	0			1	1	0	0			
Potassium bisulphate	hy	5	20	3	3	2	0											0			
$KHSO_4$	hy	5	90	3	3	3	3											3			
Potassium bitartrate	hy	cs		3	3	0	0										0	0		0	
$KC_4H_5O_6$	hy	sa		3	3	3	1										1	0		0	
Potassium bromide KBr	hy	5	30	3	P	P	P	0	1	0	0	1	0	0		0	0	0	0	3	
Potassium carbonate	hy	50	20	1	0	0	0	0	0	0	0	0	1	3	1	1	0	0	0	3	0
K_2CO_3	hy	50	bp	3	3	0	0	0	0	0	0	0		3			0	0	0	3	0
Potassium chlorate	hy	5	20	3	0	0	0	0	1	0		1	3	1	1	1	1	0		0	
$KClO_3$	hy	sa		3	0	0	0	0	3	0	0	3	3			1	3	0	0	1	
Potassium chloride	hy	10	20	3	3	P	P	0	0	0	0	0	0							1	
KCl	hy	10	<bp	3	3	P	P				1		3							1	
	hy	30	bp	3	3	P	P				1	0		3	1	3		0		0	0
	hy	cs		3	P	P	P				1										
	hy	sa		3	3	P	P				1										
Potassium chromate	hy	10	20	0		0	0	0	0	0	0	1	0	0	0	0	0	0		0	
K_2CrO_4	hy	10	bp	1		0	0											0		0	
Potassium cyanide	hy	10	20	3	0	0	0	0	3		0	1	3			3	3		0	3	
KCN	hy	10	bp	3	0	0	0						3	3	3	3				3	

7.2 | Corrosion resistance
Resistance tables

HYDRA

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Potassium dichromate	hy	10	40	3	0	0	0	1	1	1	1	1	0			3	1	0	0	0	
	hy	25	40	3	3	0	0	1	1	1	1	1	3	3	3	3	1	0	0	0	0
$K_2Cr_2O_7$	hy	25	bp	3	3	0	0				1		3	3	3	3		0	0	0	
Potassium ferricyanide	hy	1	20	0	0	0	1	1	0	0	0	0			0	1	0	0	0		
	hy	cs			0	0	0		0		0	0			0		0	0	0	0	3
$K_3(Fe(CN)_6)$	hy	sa		3	0	P	0		0		0						0	0	0	0	3
Potassium ferrocyanide	hy	1	20		0	0	0	1	1	0	0	0	0			0	1	0	0	0	
	hy	25	20		0	0	0	0	0	0	0	0	0		0		0	0	0	0	3
$K_4(Fe(CN)_6)$	hy	25	bp		1	1	0	0	0	0	0	0	0				0	0	0	0	3
Potassium fluoride	hy	cs		0	0	0	0				0									3	
KF	hy	sa		1	0	0	0				0										
Potassium hydroxide	hy	10	20		0	S	S	1	1	1	1	0	0			3	0	0	3	3	
KOH	hy	20	bp		0	S	S	1	1	1	1	0	3				0	0	3	3	
	hy	30	bp		3	S	S	1	3		1	0				3	0	3	3	3	
	hy	50	20	S	0	S	S	1	1	1	0	0	3				0	0	3	3	
	hy	50	bp	S	3	3	3	1	3		1	0	3			3	0	3	3	3	
	hy	sa		S	3	S	S				1		0						3	3	0
	me	100	360	3	3	3	3		3		3						0	3	3	3	
Potassium hypochloride KClO	hy	all	20		P	P	P	3	3		0	3	3				3	0		3	
	hy	all	bp		P	P	P	3	3		1	3	3				3	0		3	
Potassium iodide	hy		20	0	P	P	P	0	1	1	0	3	0			0	3	0	0	3	
KJ	hy		bp	0	3	P	P	0	1	1	0	3	0			0	3	0	0	3	
Potassium nitrate	hy	all	20		0	0	0	0	1	1	1	1					1	0		0	
KNO_3	hy	all	bp		0	0	0				1							0		1	
Potassium nitrite KNO_2		all	bp	1	0	0	0	1	0	0	0	0	1	1	1	1	1				
Potassium permang-anate $KMnO_4$	hy	10	20	0	0	0	0				0	1	0				0	0	0	0	3
	hy	all	bp	3	1	1	1	0	1	1	1	1	0			0	0	0	0	0	
Potassium persulphate $K_2S_2O_8$	hy	10	50	3	3	0	0		0		0	3		3	3	3	3	0		3	3
Potassium silicate K_2SiO_3			20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		3	
Potassium sulphate	hy	10	25	3	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	
K_2SO_4	hy	all	bp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Protein solutions			20	1	0	0	0	0	0	0	0	0	0					0	0	0	
Pyridine	dr	all	20		0	0	0											0		0	
C_5H_5N		all	bp		0	0	0		0	0	0	0					0	0		0	
Pyrogallol		all	20	3	0	0	0				0				0			0		0	
$C_6H_3(OH)_3$		all	bp	3	0	0	0				1				0			0		0	
Quinine bisulphate	dr		20	3	3	3	0	0		0	0	1	0			0		0	0		
Quinine sulphate	dr		20	3	0	0	0	0		0	0	1	0		0	0		0	0		
Quinol				3		0	0	0	0	0		1					1			0	
HO–C_6H_4–OH																					
Salicylic acid	dr	100	20	1	0	0	0	0	1	0	0	1	0			0	1	0	0	0	
HOC_6H_4COOH	mo	100	20	3		0	0				1	0						0			
	hy		cs	3		0	0	0	1	0	0	0	0				0	0		1	
Salmiac																					
see ammonium chloride																					
Salpetre																					
see potassium nitrate																					
Seawater																					
at flow velocity v (m/s)																					
$0 < v \leq 1.5$			20	1	P	P	P	P	P	0	0	P	1			1	P				
$1.5 < v < 4.5$			20	1	0	0	0	P	0	0	0	0	0	0		3	1				
Siliceous flux acid																					
see fluorsilicic acid																					
Silver nitrate	hy	10	20	3	0	0	0	0	1	1	1	3	3	3	3	3	3	0	0	3	
$AgNO_3$	hy	10	bp	3	0	0	0										3	0			
	hy	20	60	3	0	0	0											0			
	hy	40	20	3	0	0	0				1							0			
	me	100	250	3	3	0	0														
Soap	hy	1	20	0	0	0	0		0	0		0	0	1	0	0	0	0		0	
	hy	1	75	0	0	0	0					0	0	1	0	0	0			0	
	hy	10	20	0	0	0	0										0	0		0	
Sodium ($O_2 \leq 0.005$ %)			200	0	0	0	0											0		1	
Na	me		600	3	1	0	0											0			

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Sodium acetate	hy	10	25	0	0	0	0		0	0	0	0				0	0	0	0	0	0
CH_3–COONa	hy	sa		3	0	0	0				0							0	0		
Sodium aluminate		100	20	0	0	0	0											0			
Na_3AlO_3	hy	10	25	0	0	0	0				1							0		3	
Sodium arsenate	hy	cs		0	0	0	0											0		0	
Na_2HAsO_4																					
Sodium bicarbonate		100	20		0	0	0											0		0	
$NaHCO_3$	hy	10	20	0	0	0	0	0	1	1	1	1	0	3	1	1	1	0		0	
	hy	cs			0	0	0	0	1	0	0	1	0			0	1	0	0	1	
	hy	sa			0	0	0				1							0			
Sodium bisulphate	hy	all	20	3	3	3	0	0	1	1	1	1	3	3	1	1	1	0	0	0	
$NaHSO_4$	hy	all	bp	3	3	3	1	0	1	1	1	1	3	3	1	3	1	0	0	1	
Sodium bisulphite	hy	10	20	3	3	0	0				1			1	0	3	0	0		0	
$NaHSO_3$	hy	50	20	3	0	0	0				1	0		1	0	3	0	0			
	hy	50	bp	3	3	3	0					0						0			
Sodium borate	hy	cs			0	0	0	0		0	0	1	0			0		0	0	1	
$NaBo_3$ 4 H_2O	me			3	3	3	3				3										
(Borax)																					
Sodium bromide	hy	all	20	3	3	3	P				1							0		3	
NaBr	hy	all	bp	3	3	3	P				1							0		3	
Sodium carbonate	hy	1	20	3	0	0	0	0	1	0	0	0	0			0	0	0	0	2	
Na_2CO_3	hy	all	bp		0	0	0	0	0	0	0						0	0	0	3	
	hy		400	3	3	3	3														
	me		900	3	3	3	3					0					0				
Sodium chloride	hy	0.5	20		P	P	P	0	1	0	0	0	0				1	0	0		
NaCl	hy	2	20		P	P	P	0	1	0	0	0	0				1	0	0		
	hy	cs		3	P	P	P	0	1	0	0	0	0			0	1	0	0	2	0
	hy	sa		3	3	3	P	0	1	0	1	0	0			0	1	0	0	3	0
Sodium chlorite	dr	100	20	3	P	P	0		0									0			
$NaClO_2$	hy	5	20			3	P											0			
	hy	5	bp			3	3				1							0			
	hy	10	80	3		3	P		0		1							0			
Sodium chromate	hy	all	bp	0	0	0	0	0	0	0	0	0	0	0	0	0				0	
Na_2CrO_4																					

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Sodium cyanide	me		600	1								3	3	3	3	3				3	3
NaCN	hy	cs		1	0	0	0					3	1	3	3	3	0	0		3	3
Sodium fluoride	hy	10	20	0		0	0								3					0	
NaF	hy	10	bp	0		0	0														
	hy	cs				S	S													0	
Sodium hydrogensulphate see sodium bisulphate																					
Sodium hydrogensulphite see sodium bisulphite																					
Sodium hydroxide	solid	100	all	0	0	0	0		0	0	0	0					0				0
NaOH	hy	<10	<60	0	0	0	0		0	0	0						0				
	hy	<10	<bp	3	3	0	0		0	0	0						0				
	hy	<20	<60	0	0	0	0		0	0	0						0				
	hy	<20	<bp	3	3	0	0		0	0	0						0				
	hy	<40	<60	0	0	0	0		0	0	0						0				
	hy	<40	<100	3	3	0	0		0	0	0						0				
	hy	<40	<100	3	3	3	3		0	0	0						0				
	hy	<50	<60	0	0	0	0		0	0	0						0				
	hy	<50	<100	3	3	0	0		0	0	0						0				
	hy	<50	<100	3	3	3	3		0	0	0						0				
	hy	<60	<90	3	3	0	0		0	0	0						0				
	hy	<60	<140	3	3	3	3		0	0	0						0				
	hy	<60	<140	3	3	3	3		3	0	3						0				
	hy	<60	>140	3	3	3	3		3	0	3						0				
Sodium hypochlorite	hy	5	20	3	3	3	P	0	3		0	3	3			3	3	0		3	
NaOCl	hy	10	50	3		P	P		0		1							0		3	
Sodium hyposulphite		all	20		3	0	0	0	1	1	1	1	3			3	1		0		
$Na_2S_2O_4$		all	bp		3	0	0	0	1	1	1	1	3			3	1		0		
Sodium iodide					P	P	P	0	0	0	0						0			1	
NaJ																					
Sodium nitrate	hy	5	20	3	0	0	0	0	0	0	0	1	0			0	1	0	0	0	
$NaNO_3$	hy	10	20	1	0	0	0	0	0	0	1	1	0	3	1	1	1	0	0	0	
	hy	<10	bp	3	0	0	0				0						1	0	0	3	3
	hy	30	20	1	0	0	0	0	0	1	1	1	0				1	0	0	0	
	hy	30	bp	1	0	0	0	0	0		3	1					1	0	0	0	
	me		320	3	0	0	0				0						1	0	0	0	3
Sodium nitrite	hy		20			0	0	1	0	0	0	0	0			1	3	0	0	1	
$NaNO_2$																					

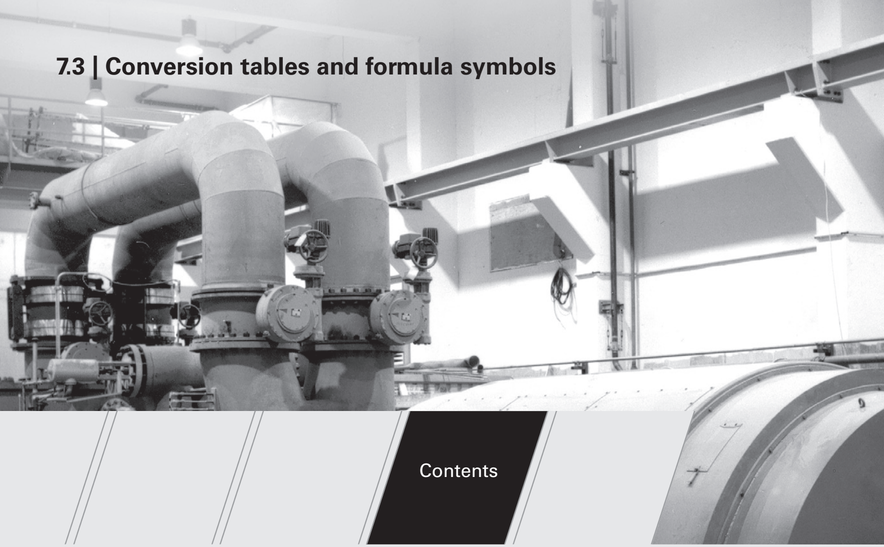
Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: steels 2.4858 / alloy	Nickel alloys: 8252.4816 / alloy 600	Nickel alloys: 2.4856 / alloy 625	Nickel alloys: 2.4610, 2.4819 /alloy C-4, C-246	Nickel alloys: 2.4360 / alloy 400	Copper alloys: 2.0882 / alloy CuNi 70/30	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Sodium perborate	hy	10	20	3	0	0	0				1							1			
$NaBO_2$	hy	10	bp	3	0	0	0				1							1			
Sodium perchlorate	hy	10	20	3	3	0	0	1			1							0			
$NaClO_4$	hy	10	bp	3		0	0	1			1							0			
Sodium peroxide	hy	10	20	3	1	0	0	1	1	1	1	0	3			3	0	3	3	3	3
Na_2O_2	hy	10	bp	3	3	0	0	1	1	1	1	0	3			3	1	3	3	3	3
	me		460					3	1		3	3					0				
Sodium phosphate	hy	10	20		0	0	0	0	0	0	0	0	0	3	1	1	0	0	0	0	
Na_2HPO_4	hy	10	bp		0	0	0	0	0	0	0	0				3		0	0	1	
	hy	cs			0	0	0	0	0	0	0	0					0	0	0	0	
Sodium salicylate	hy	all	20		0	0	0	0			0					0	0	0		0	
$C_6H_4(OH)COONa$																					
Sodium silicofluoride	hy	cs		3	3	3	3	0	0	1	1	0				0				1	
$Na_2(SiF_6)$																					
Sodium sulphate	hy	10	20	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Na_2SO_4	hy	cs		3	1	0	0	0	1	0	0	1	0			0	1	0	0	0	
	hy	sa		3	3	0	0	0	0	0	0	0						0	0	1	
Sodium sulphide	hy	1	20	3	0	0	0	0	0			1					1	0			
Na_2S	hy	cs	20	3	3	3	0	0	1	0	0		3			3	1	0	0	1	
	hy	sa		3	3	3	1											0		3	
Sodium sulphite	hy	10	20	3	1	0	0					0	1	3	1	1		0		0	
Na_2SO_3	hy	50	bp	3	3	0	0											0		3	
Sodium superoxide see sodium peroxide																					
Sodium tetraborate see borax																					
Sodium thiosulphate	hy	1	20	1	0	0	0					0					0	0		0	
$Na_2S_2O_3$	hy	10	20	3	0	0	0											0		0	
	hy	25	bp	3	P	P	P										0	0		1	
		cs		3	3	0	0		1			1	3			3	1	0	0	0	
Spirit of terpentine		100	20	3	0	0	0						0	1	0	0		0		0	
		100	bp	3	0	0	0						0	1	0	0		0		0	

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Materials	Stainless steels			Nickel alloys					Copper alloys			Pure metals					
				Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Spirits			20	1	0	0	0	0	0	0	0	0									
			bp	3	0	0	0	0	0	0	0	0									
Steam																					
$O_2 < 1$ ppm; Cl < 10 ppm			< 560	1	1	1	0				0							0			
$O_2 > 1$ ppm; Cl < 10 ppm			< 315	S	S	S	S				0						0	0			
$O_2 > 15$ ppm; Cl < 3 ppm			> 450	S	S	S	S				0							0			
Stearic acid		100	20	1	0	0	0		0	0	0	0	1	3	1	1	0	0		0	0
$CH_3(CH_2)_{16}COOH$		100	95	3	0	0	0	0	1		0	1	1			0	1	0	0	3	
		100	180								1							0		3	
Succinic acid			bp	1	0	0	0	0	0	0	0	0	0	0	0						
HOOC–CH_2–CH_2–COOH																					
Sulphur	dr	100	60	0	0	0	0				0						0				
S	me		130	1	0	0	0		0		0	3	3	3	3	3	3	0			3
	me		240	3	0	0	0				0					3		0			
	mo		20	3	2	1	0				0	3	3	3	3	3	3	0			
Sulphur dioxide	dr	100	20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
SO_2	dr	100	60	3	3	1	1				0							0		0	
	dr	100	400	3	3	3	0				1			3				0		0	3
	dr	100	800	3	3	3	3				3						3	0		0	
	mo	100	20	3	3	3	0	0	0	0	0	0	3	3	1	3	0	0	0	3	
	mo	100	60	3	3	3	0				0							0		3	
	mo	100	70	3	3	3	3				0							0		3	
Sulphuric acid		0.05	20	3	1	0	0											0	0	1	
H_2SO_4		0.05	bp	3	1	1	0											1	0	3	
		0.1	20	3	3	0	0											0	0	1	
		0.2	bp	3	3	3	0											1	0	3	
		0.8	bp	3	3	3	3											1	0	3	
		1	20	3	3	1	0		1	0	0	1	3			1	0	0	0	1	
		3	bp	3	3	3	3				1		3					1	0	3	
		5	bp	3	3	3	3	1	3		3	1	3			3	3	3	0	3	
		7.5	20	3	3	1	0											1	0	1	
		10	bp	3	3	3	3	1	3		3	3	3			3	3	3	0	3	
		25	20	3	3	3	3				0		3					3	0	1	
		25	bp	3	3	3	3				3		3					3	0	3	
		40	20	3	3	3	3				0	1	3	3	3	3		1	0	1	
		40	bp	3	3	3	3				3		3					3	0	3	1
		50	20	3	3	3	3	1	3		0	3	3			3	3	3	0	3	
		50	bp	3	3	3	3	3	3		3	3	3			3	3	3		3	

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Materials	Stainless steels			Nickel alloys					Copper alloys			Pure metals					
				Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Sulphuric acid		60	20	3	3	3	3				0	1		3	3	3	0	3	0	3	
H_2SO_4		80	20	3	3	1	1				0	1	3	3	1	1		3	0	3	
		90	20	3	3	1	0				0							3	0	3	
		96	20	1	1	1	0				0	3	3			1	1	3	0	3	
Sulphurous acid	hy	1	20	3	3	0	0		1		0	3					3		0	1	
H_2SO_3	hy	cs		3	3	0	0				0	3						1	0	3	
	hy	sa		3	3	1	0				1								0	3	
Sulphur trioxide	hy	100	20																	3	
SO_3	dr	100	20	0				2	3		0	3	2	0	0	0	3		3	0	
Tannic acid	hy	5	20	3	0	0	0		0			0	0	1	0	0	0	0		0	
$C_{76}H_{52}O_{46}$	hy	25	100	3	3	0	0											0			
	hy	50	bp	3	3	0	0						0					0			
Tar			20	0	0	0	0						0	1	0	0		0		1	
Tartaric acid	hy	10	20	1	0	0	0	0	1	0	0	1	0	3	0		1	0	0	3	
	hy	10	bp	3	1	0	0	0	3		1	3	0	3			3	1	0	3	
	hy	25	20	3	1	0	0		0		0	0	0			0		0	0	3	
	hy	25	bp	3	3	1	0		0		1	1	0			1		1	0	3	
	hy	50	20	3	3	0	0				0		0					0	0	3	
	hy	50	bp	3	3	3	3				1		0					3	0	3	
Tetrachloroethane see acetylen tetrachloride																					
Tetrachloroethylene	pure	100	20	0	0	0	0				0		0	0	0	0	0	0		0	
	pure	100	bp			0	0				0		0	0	0	0	0	0		0	
	mo		20	3	3	P	P				0		1	3	1	1	0	0		3	
	mo		bp	3	3	P	P				0		1	3	1	1	0	0		3	
Tin chloride		5	20	3	3	3	3	3	3		0	1	3				1	0	0	3	
$SnCl_2$; $SnCl_4$		sa		3	3	3	3														
Toluene		100	20	0	0	0	0					0	0	0	0	0		0		0	
C_6H_5-CH_3		100	bp	0	0	0	0					0	0	0	0	0		0		0	
Town gas				0	0	0	0	0	0	0	0	1	1	0	0	1	1				
Trichloroacetaldehyde see chloral																					
Trichloroethylene	pure	100	20	0	0	0	0				0		0	0	0	0	0	0		0	
$CHCl{=}CCl_2$	pure	100	bp			0	0				0		0	0	0	0	0	0		0	
	mo		20	3	3	P	P				0		1	3	1	1	0	0		3	
	mo		bp	3	3	P	P				0		1	3	1	1	0	0		3	

Medium			Materials																			
	Concentration	Temperature		Stainless steels			Nickel alloys					Copper alloys			Pure metals					
Designation Chemical formula		%	°C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	steels 2.4858 / alloy	8252.4816 / alloy 600	2.4856 / alloy 625	2.4610, 2.4819 /alloy C-4, C-246	2.4360 / alloy 400	2.0882 / alloy CuNi 70/30	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Trichloromethane see chloroform																					
Tricresylphosphate				0	0	0	0	0	0	0	0					0					0
Trinitrophenol see picric acid																					
Trichloroacetic acid see chloroacetic acid																					
Urea $CO(NH_2)_2$		100 100	20 150	0 3	0	0 1	0 0		 3		0 1	0 1					0 1	0 0	0 0	0 3	 1
Uric acid $C_5H_4O_4N_3$	hy hy		20 100	3 3	0 0	0 0	0 0	0 0	1 1	0 0	0 0	0 0	0 0			1 1		0 0		3 3	
Vinyl chloride CH_2=CHCl	dr		20 <400	0 0	0 0	0 0	0 0				0 0				0		 0	 0		0	
Water vapour see steam																					
Wine			20 bp	3 3	0 0	0 0	0 0		0 0					3 3	3 3		3 3		0 0	3 3	
Yeast			20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow potassium prussiate see potassium ferricyanide																					
Zinc chloride $ZnCl_2$	hy hy hy hy hy	5 5 10 20 75	20 bp 20 20 20	3 3 3 3 3	P 3 P P 3	P 3 P P P	P 3 P P P	0 0	1 3	0	0 1	1 3 3	3 3 3	 3	 3		1 1 0	0 0 0 0 0	0 0 0 0 0	3 3 0	
Zinc sulphate $ZnSO_4$	hy hy hy hy hy	2 20 30 cs sa	20 bp bp	3 3 3 3 3	0 0 3 0 3	0 0 0 0 0	0 0 0 0 0	 0	 1	 0	0 1 1 1 1	 1	0 0				 1	0 0 0 0 0	0 0 0 0 0	0 3 3 1 3	

7.3 | Conversion tables and formula symbols

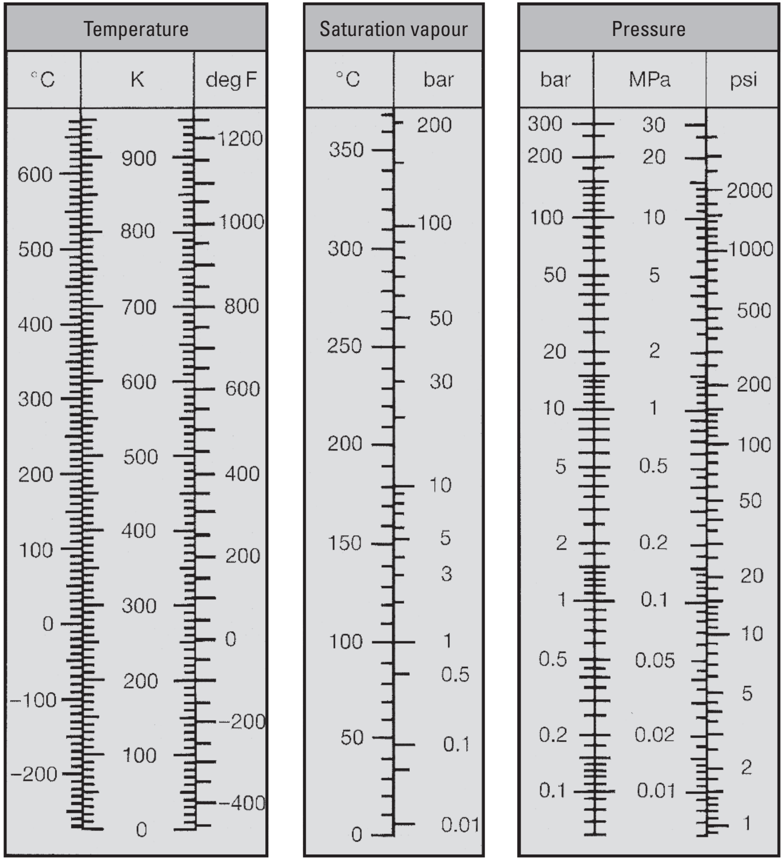


Contents

Conversion tables and formula symbols

Pressure (absolute)	Saturation temperature	Kinematic viscosity of vapour	Density of vapour
bar	°C	10^{-6} m²/s	kg/m³
p	t	ν"	ρ"
0.020	17,513	650,240	0.01492
0.040	28,983	345,295	0.02873
0.060	36,183	240,676	0.04212
0.080	41,534	186,720	0.05523
0.10	45,833	153,456	0.06814
0.14	52,574	114,244	0.09351
0.20	60,086	83,612	0.1307
0.25	64,992	68,802	0.1612
0.30	69,124	58,690	0.1912
0.40	75,886	45,699	0.2504
0.45	78,743	41,262	0.2796
0.50	81,345	37,665	0.3086
0.60	85,954	32,177	0.3661
0.70	89,959	28,178	0.4229
0.80	93,512	25,126	0.4792
0.90	96,713	22,716	0.5350
1.0	99,632	20,760	0.5904
1.5	111.37	14,683	0.8628
2.0	120.23	11,483	1,129
2.5	127.43	9,494	1,392
3.0	133.54	8,130	1,651
3.5	138.87	7,132	1,908
4.0	143.62	6,367	2,163
4.5	147.92	5,760	2,417

Pressure (absolute)	Saturation temperature	Kinematic viscosity of vapour	Density of vapour
bar	°C	10^{-6} m²/s	kg/m³
p	t	ν"	ρ"
5.0	151.84	5,268	2,669
6.0	158.84	4,511	3,170
7.0	164.96	3,956	3,667
8.0	170.41	3,531	4,162
9.0	175.36	3,193	4,655
10.0	179.88	2,918	5,147
11.0	184.07	2,689	5,637
12.0	187.96	2,496	6,127
13.0	191.61	2,330	6,617
14.0	195.04	2,187	7,106
15.0	198.29	2,061	7,596
20.0	212.37	1,609	10.03
25.0	223.94	1,323	12.51
30.0	233.84	1,126	15.01
34.0	240.88	1,008	17.03
38.0	247.31	913	19.07
40.0	250.33	872	20.10
45.0	257.41	784	22.68
50.0	263.91	712	25.33
55.0	269.93	652	28.03
60.0	275.55	601	30.79
65.0	280.82	558	33.62
70.0	285.79	519	36.51
75.0	290.50	486	39.48



α	Alpha	Α	Alpha
β	Beta	Β	Beta
γ	Gamma	Γ	Gamma
δ	Delta	Δ	Delta
ε	Epsilon	Ε	Epsilon
ζ	Zeta	Ζ	Zeta
η	Eta	Η	Eta
ϑ θ	Theta	Θ	Theta
ι	Jota	Ι	Jota
ϰ	Kappa	Κ	Kappa
λ	Lambda	Λ	Lambda
μ	My	Μ	My
ν	Ny	Ν	Ny
ξ	Xi	Ξ	Xi
ο	Omikron	Ο	Omikron
π	Pi	Π	Pi
ϱ	Rho	Ρ	Rho
σ ς	Sigma	Σ	Sigma
τ	Tau	Τ	Tau
υ	Ypsilon	Υ	Ypsilon
φ	Phi	Φ	Phi
χ	Chi	Χ	Chi
ψ	Psi	Ψ	Psi
ω	Omega	Ω	Omega

Formula symbol	Significance
A	Constant to describe fatigue behaviour
C_m	Hardening factor to determine pressure resistance of bellows
C_d, C_f, C_p	Anderson factors - geometry-dependent correction factors to calculate stress on bellows
D_A	Bellows outside diameter
D_{AT}	Pressurised diameter of connecting piece
D_m	Average bellows diameter
E(T)	Temperature-dependent value of E-module
F	Force, reaction force
$K_{P\delta}$	Reduction factor for pressure at high temperatures
$K_{\Delta N}$	Correction factor for the effect of load cycles on impulse
$K_{\Delta P}$	Correction factor for the effect of pressure on impulse
M_B	Bending moment
M_T	Torque
$M_{T,c}$	Critical torque
N	Load cycles
$N_{xx\%}$	Number of load cycles for a failure probability of xx %
P	Damage parameter
PS	Operating pressure at temperature TS
$R_{P1,0}(T)$	Temperature-dependent value of 1% elastic limit
$R_m(T)$	Temperature-dependent value of tensile strength
S	Safety factor
S_F	Safety factor for plastic flow
S_K	Safety factor for buckling
T	Temperature
TS	Operating temperature
c_{ang}	Angular spring rate of entire bellows
c_{ax}	Axial spring rate of entire bellows
c_{lat}	Lateral spring rate of entire bellows
c_α	Angular spring rate of one bellows corrugation
c_δ	Axial spring rate of one bellows corrugation
c_λ	Lateral spring rate of one bellows corrugation

Formula symbol	Significance
d_i	Bellows inside diameter
d_{hyd}	Bellows hydraulic diameter
h	Corrugation height
k	Woehler curve exponent
l_f	Flexible (corrugated) length of bellows
l_W	Corrugation length
n_L	Number of layers
n_W	number of corrugations
p	Pressure
Δp	Pressure pulsation
p_K	Buckle pressure
P_N	Nominal pressure
p_{RT}	Design pressure (operating pressure converted to room temperature)
p_T	Design test pressure
s	Wall thickness of individual layer
α	Angular bellows deflection (incline of bellows ends towards each other)
α_n	Angular deflection per corrugation
$\alpha_{n,0}$	Angular nominal deflection per corrugation (10,000 load cycles)
δ	Axial bellows deflection
δ_n	Axial deflection per corrugation
$\delta_{n,0}$	Axial nominal deflection per corrugation (10,000 load cycles)
δ_{equ}	Equivalent axial bellows deflection
λ	Lateral bellows deflection (perpendicular to bellows axis)
λ_n	Lateral deflection per corrugation
$\lambda_{n,0}$	Lateral nominal deflection per corrugation (10,000 load cycles)
λ_E	Dimension-less buckling length
η_P	Pressure capacity
$\sigma_{B,\ meridional}$	Bending stress parallel to bellows surface
σ_{um}	Average circumferential stress
$\sigma_{max,\ meridional}$	Maximum permissible meridional stress under pressure
τ	Shear stress

Physical units (D, GB, US)
DIN1301-1, Version 10.2002

SI base units

Size	SI base unit	
	Name	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Strength of electrical current	Ampere	A
Thermodynamic temperature	Kelvin	K
Quantity of material	Mol	mol
Light intensity	Candela	cd

Prefix symbol

Prefix	Prefix symbol	Factor by which unit is multiplied
Piko	p	10^{-12}
Nano	n	10^{-9}
Mikro	µ	10^{-6}
Milli	m	10^{-3}
Centi	c	10^{-2}
Deci	d	10^{-1}
Deca	de	10^{1}
Hecto	h	10^{2}
Kilo	k	10^{3}
Maga	M	10^{6}
Giga	G	10^{9}

Length - SL unit meter, m

Symbol	Name	in m
mm	Millimetre	0.0010
km	Kilometre	1000.00
in	Inch	0.0254
ft	Foot (=12 in)	0.3048
yd	Yard (=3ft / = 36 in)	0.9144

Mass - SL unit kilogram, kg

Symbol	Name	in kg
g	Gram	0.00100
t	Tonne	1000.00
oz	Ounce	0.02835
lb	Pound	0.4536
sh tn	Short ton (US)	907.20
tn	Ton (UK)	1016.00

Time - SI unit seconds, s

Symbol	Name	in s
min	Minute	60
h	Hour	3600
d	Day	86400
a	Year	$3.154 \cdot 10^{7}$ (≙ 8760 h)

Temperature - SI unit Kelvin, K (also see above alignment table)

Symbol	Name	in K	in °C
°C	Degrees Celsius	ϑ/°C + 273.16	1
deg F	Degrees Fahrenheit	ϑ/deg F · 5/9 + 255.38	(ϑ/deg F - 32) · 5/9

Angle - SI unit radiant, rad = m/m

Symbol	Name		in rad
	Full angle		2π
gon	Gon	Degree (grd)	$\pi/200$
°		Minute	$\pi/180$
'			$\pi/1.08 \cdot 10^{-4}$
"	Second		$\pi/6.48 \cdot 10^{-5}$

Pressure - SI unit Pascal, Pa = N/m² = kg/ms²

Symbol	Name	in Pa	in bar
Pa = N/m²	Pascal	1	0.00001
hPa = mbar	Hectopascal = Millibar	100	0.001
kPA	Kilopascal	1000	0.01
bar	Bar	100000	1
MPa = N/mm²	Megapascal	1000000	10
mm WS	Millimetre water column	9.807	0.0001
lbf/in² = psi	pound-force per square inch	6895	0.0689
lbf/ft²	pound-force per square foot	47.88	0.00048

Energy (also work, heat quantity) SI unit Joule, J = Nm = Ws

Symbol	Name	in J
kWs	Kilowatt second	1000
kWh	Kilowatt hour	$3.6 \cdot 10^6$
kcal	Kilocalorie	4186
lbf x ft	Pound-force foot	1.356
Btu	British thermal unit	1055

Capacity - SI unit Watt, W = m² kg/s³ = J/s

Symbol	Name	in W
kW	Kilowatt	1000
PS	Horsepower	735.5
hp		745.7

Volume - SI unit, m³

Symbol	Name	in m³
l	Liter	0.001
in³	Cubic inch	$1.6387 \cdot 10^{-5}$
ft³	Cubic foot	0.02832
gal	Gallon (UK)	0.004546
gal	Gallon (US)	0.003785

INQUIRY SPECIFICATIONS FOR HYDRA METAL BELLOWS

Company:	Date:
	Inquiry No./Project:
Person in charge:	Deadline for proposal:
Tel./Fax:	**Recipient re: Inquiry specification – WI Group:**
e-mail:	

Dimensions		
Bellows type		
Inside diameter	mm	exact value ☐ or minimum permissible value ☐
Outside diameter	mm	exact value ☐ or maximum permissible value ☐
Production length	mm	exact value ☐ or maximum permissible value ☐
Bellows material		☐1.4571 ☐ 1.4541 ☐ other material:
Connecting pieces		☐ manufactured by Witzenmann ☐ supplied
Connecting piece material		☐1.4571 ☐ 1.4541 ☐ other material:

Operating conditions		
Operating pressure PS	bar	inside pressure ☐ or outside pressure ☐ static pressure ☐ or pressure pulsations ☐
Operating temperature TS	°C	
Design pressure p_T	bar	
Test temperature	°C	
Medium		
Torsion loads	Nm	
Absorption of movement	± mm	axial
	± mm	lateral
	± mm	angular
Load cycles		☐ > 1000 ☐ > 2000 ☐ > 5000 ☐ > 10000
		☐ other load cycle number
Spring rate (axial)	N/mm	

Specifications
Acceptance tests
Inspection documents

Notes
Drawings

Metal hose manual

Manual of the expansion joint technology

For more product information,
see www.witzenmann.de/service