HYDRA®

Quality by Witzenmann

WITZENMANN

managing flexibility

METAL BELLOWS MANUAL

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Fully revised version of metal bellows manual.

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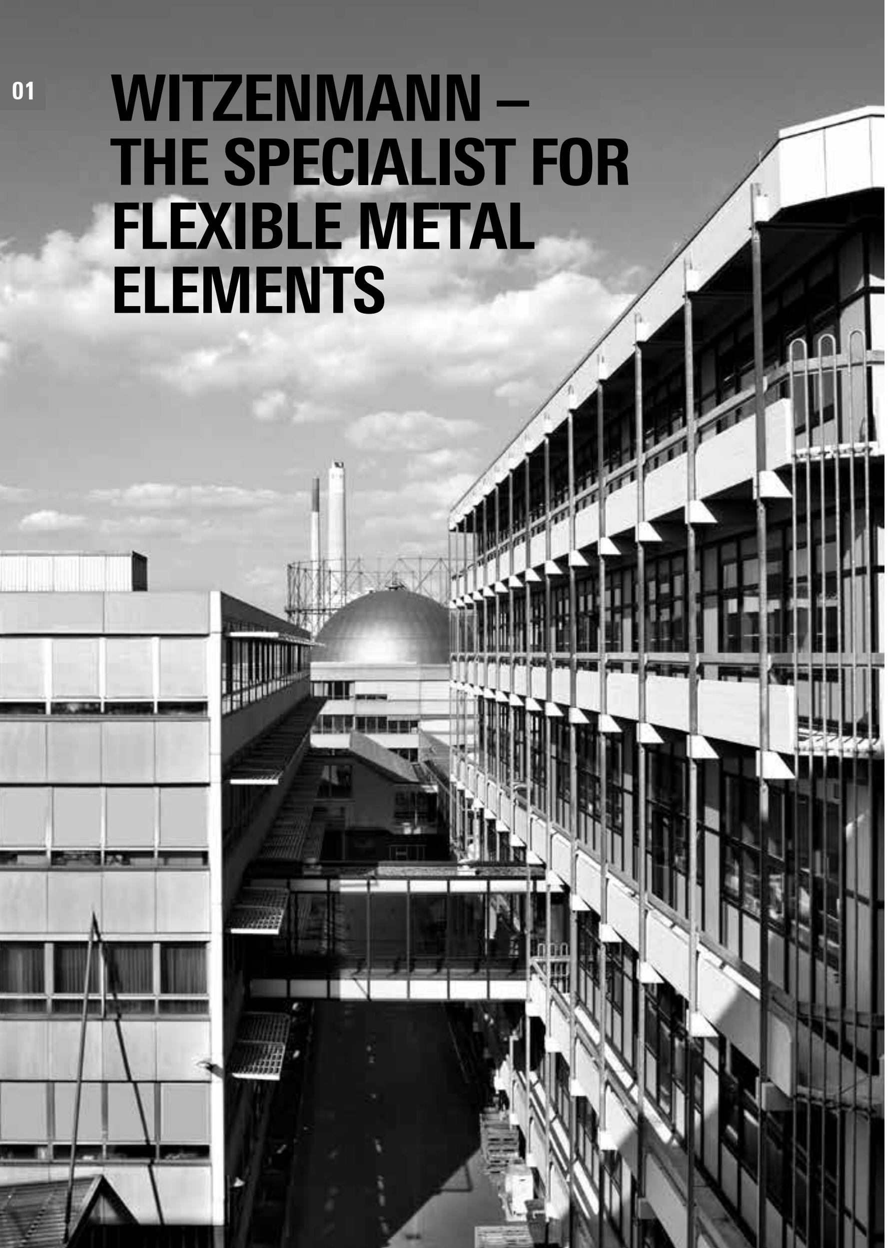
Subject to technical alterations.

You can also find technical information as a PDF download at www.flexperte.com

CONTENTS

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 tube 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.

Worldwide presence

As an international group of companies with more than 4,600 employees and 24 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.

PRODUCTS AND PRODUCTION METHODS

METAL 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 characteristics is required; for example

- as pressure and temperature-resistant seals for valve shafts in fittings
- as vacuum switching bellows in medium-voltage switchgear
- 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 shaft couplings
- as tight spring element in floating ring seals or
- as tight and mechanically tension-free duct through container walls.

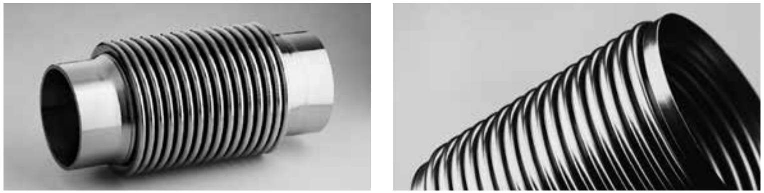


Figure 2.1.1.: HYDRA metal bellows with connectors (left) and without connectors (right)

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

HYDRA metal bellows are manufactured from thin-walled tubes by hydraulic reshaping. Depending on the profile of requirements, they can be designed with one or multiple plies. Single-ply bellows feature low spring rates and are used particularly for vacuum applications. Single-ply bellows have small spring rates and are employed particularly in vacuum technology. Multi-ply bellows are very pressure resistant and at the same time very flexible. They are used, for example, as valve shaft seals for operating pressures up to 1000 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 (Fig 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 multiple ply bellows, several finely graduated tube cylinders are telescoped before pressing the bellows (Figure 2.1.2). During the pressing of the bellows, a cylinder portion is separated using outside and inside tools, subsequently hydraulic fluid with high pressure is applied inside. The fluid pressure shapes the sealed tube section into the pre-convolution. During the next working step the tool is closing axially and the actual bellows corrugation is formed as the pre-convolution 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.), which offers a more economic method for larger numbers of units.

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-base 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). In the simultaneous procedure, the diameter ratios that can be produced are slightly smaller.

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, bellows get 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 overall length, a bellows with omega profile has more corrugations than with a sinus-shaped profile and can therefore compensate larger movements.

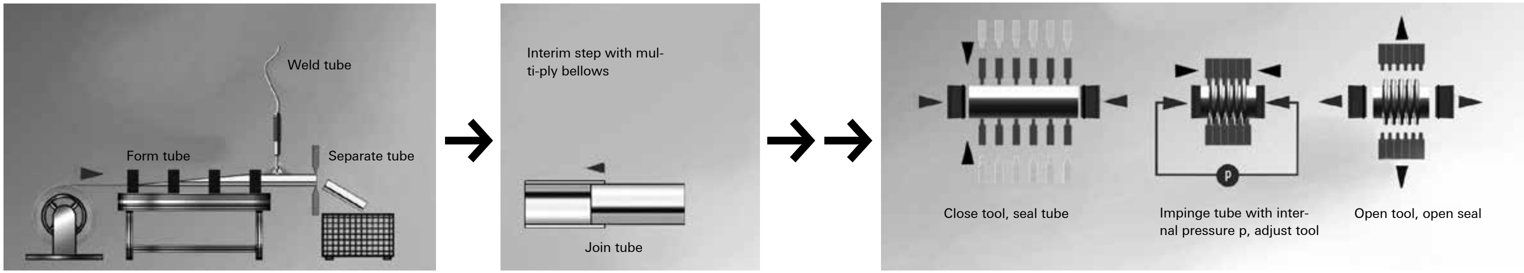


Figure 2.1.2.: Production of metal bellows in simultaneous procedure

Bellows with blind end

Bellows with blind ends can be manufactured directly from deep-drawn or extruded sleeves. Bronze is a particularly well suited material 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, this method is only recommended for larger quantities due to economic reasons.

In the case of smaller quantities or multi-ply bellows, it is more cost-efficient to solder swivel or press workpieces into bronze 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.

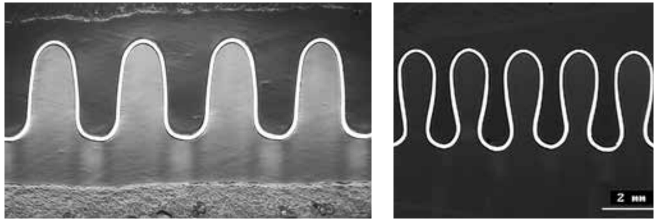
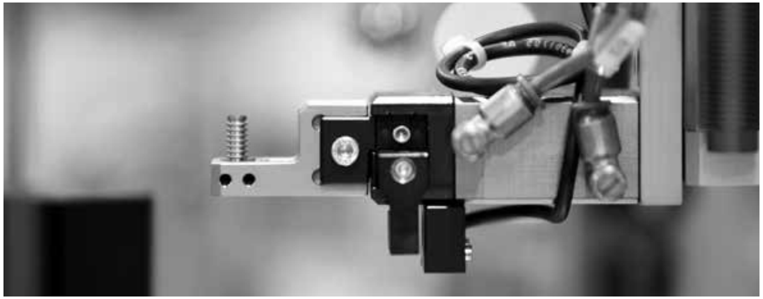


Figure 2.1.3.: Sinus profile (left) and omega profile (right)

HYDRA® PRECISION BELLOWS



HYDRA precision bellows meet the highest demands for dimensional stability, cleanliness, functionality and service life. Specifically adapted to customer specifications and economical mass production, these bellows are manufactured under clean room conditions. The smallest HYDRA precision bellows are just a few millimetres in size.

Figure 2.2.1.: HYDRA Precision bellows

HYDRA precision bellows are used in the automotive industry as high-pressure resistant and flexible seals. 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.

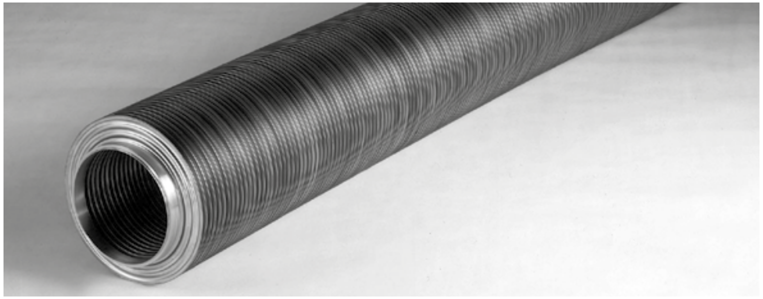
02

Precision bellows can also be used as highly flexible seals. These precision bellows are usually used in modern petrol 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.

Figure 2.2.2.: HYDRA precision bellows under clean room conditions

HYDRA® DIAPHRAGM BELLOWS



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

HYDRA diaphragm bellows are used in measurement and control instruments, vacuum technology, aerospace and aviation industry, medical technology, specialised controls and instrument engineering, sliding ring seals as well as in volume compensation units.

Diaphragm bellows are offered in two series: diaphrgm bellows with standard profile and diaphragm bellows with narrow profile. The latter are particularly suitable for floating ring seals thanks to their compact installation dimensions and their relatively high spring rate.

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 movement into 80 %
compression (bellows contraction) and 20 % stretching (bellows extension). The bellows should be installed prestressed for load distributions that deviate from this.

Figure 2.3.1.: HYDRA diaphragm bellows

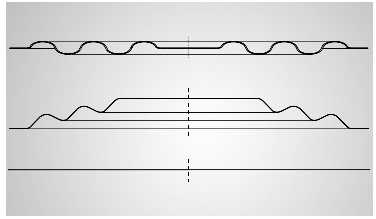


Figure 2.3.3.: HYDRA diaphragm rings: grooved diaphragm discs (above), grooved diaphragm discs with flat bottom (centre) as well as flat diaphragm discs (below)

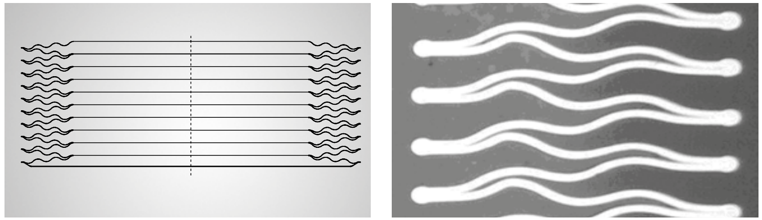


Figure 2.3.2.: Diaphragm bellows profile as a diagram (left) and as a metallographical cut (right)

Additional items available upon request in addition to HYDRA diaphragm bellows include:

- Grooved diaphragm discs (Figure 2.3.3 above),
- Grooved diaphragm discs with flat bottom (Figure 2.3.3. centre) as well as
- Flat diaphragm rings (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 are offered. These diaphragm rings as elastic elements lend themselves to conditions where working strokes or volumes displaced are small, and a high degree of system rigidity is required.

HYDRA® LOAD CELLS

HYDRA expansion 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 have less pressure resistance. However, pressure resistance can be significantly increased through the use of profiled cores.

The pressure-volume characteristic curves for HYDRA load cells are non-linear (Figure 2.4.2.); the related increase in volume $\delta\varsigma/\delta\pi$ decreases as pressure increases.

HYDRA load cells are made 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 upon 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. Another application area uses HYDRA load cells as highly-dynamic dampening elements to reduce pressure impulses.

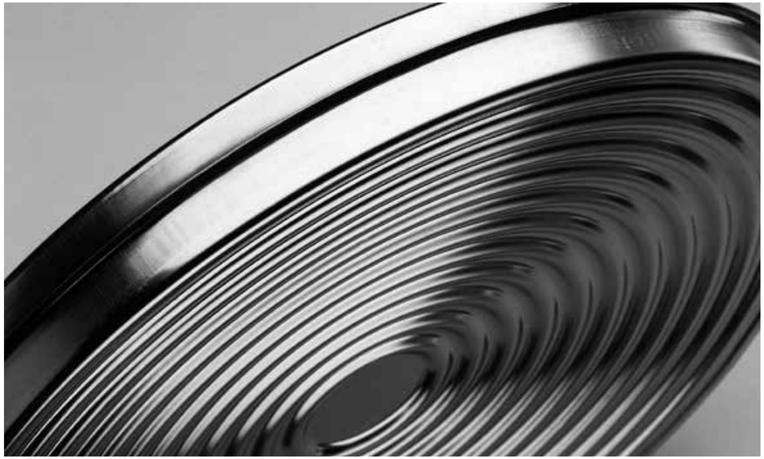
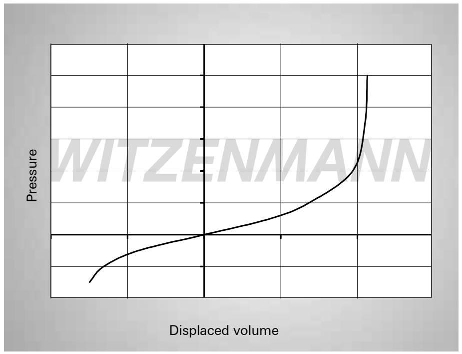
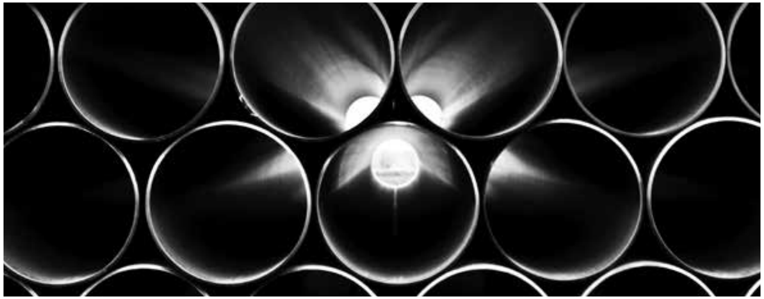


Figure 2.4.1.: HYDRA load cell



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

HYDRA® PRECISION TUBES



Thin-walled stainless steel tubes with a longitudinally welded butt weld are manufactured as semi-finished products for the manufacture of metal bellows. Standard material is 1.4571, the majority of sizes is also available in stainless steel qualities 1.4541, 1.4404 as well as in various nickel-base alloys. 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 pieces are available in any length.

Figure 2.5.1.: HYDRA precision tubes

BELLOWS MATERIALS

Bellows materials must feature a high degree of formability. For this reason, metals with a cubic face-centered lattice grid structure are preferred. The most important materials used in bellows production are austenitic stainless steels, nickel and nickel-base alloys as well as copper and bronze. The materials are selected on the basis of requirements as regards media and corrosion resistance, temperature resistance as well as static stability 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 titanium-stabilised austenitic stainless 1.4571. It features 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, Ti(CN) discharges, which are typical for titanium-stabilised materials, are configured parallel to the bellows surface owing to the method used, so that they do not impair the performance of the bellows either.

Stainless steels 1.4404 or 1.4441, which are often not titanium-stabilized, are used in food, medical and vacuum technology applications. These materials have a higher degree of cleanliness, slightly reduced yield strength, minimally reduced fatigue strength as well as a higher tendency for heat fractures during welding as compared to 1.4571.

Heat-resistant steels have proven themselves for temperatures exceeding 550 °C. An example is the material 1.4876 for metal bellows near the engine in the exhaust equipment.

Material number	Material type/ Trade name	Suitability for		Remark
-	-	Corrugated bellows	Diaphragm bellows	-
1.4541	Titanium-stabilised	++	++	
1.4571	Austenitic stainless steel	++	++	Standard material
1.4404	Titanium-free	++	++	Food and vacuum technology
1.4441	Austenitic stainless steel	++	++	Upon request
1.4828	scaling resistant stainless steel	+	+	
1.4876	Alloy 800 H	++	++	Suitable for temperatures over 550 °C
1.4564	17-7 PH	++	+	
1.4568		++	+	Hardenable stainless steel
–	AM 350	+	+	
2.4816	Alloy 600	+	+	Upon request
2.4856	Alloy 625	++	++	Standard materials for high pressures,
2.4819	Alloy C-276	++	++	Temperature and/or increased corrosion requirements
2.4610	Alloy C-4	+	–	high degree of acid resistance
3.7025	Pure titanium, Grade 1	+	+	Upon request
2.4360	Monel	+	–	Upon request
2.1020	Bronze CuSn6	++	–	Upon request
2.1030	Bronze CuSn8	++	–	Upon request

Table 2.6.1: Available bellow materials, standard materials

It exhibits excellent long-time rupture strength parameters and is approved for components under compressive stresses at temperatures above 550 °C.

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

The service life of bellows made of nickel-base alloys at room temperature is shown in Figure 2.6.2 as compared to the service life of austenitic stainless steel bellows. The use of nickel-base 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-base alloys is generally higher than that of stainless steels.

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

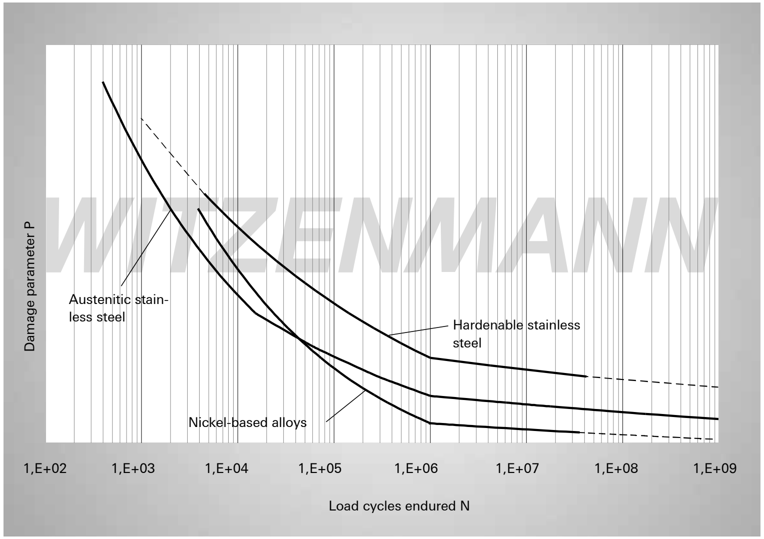
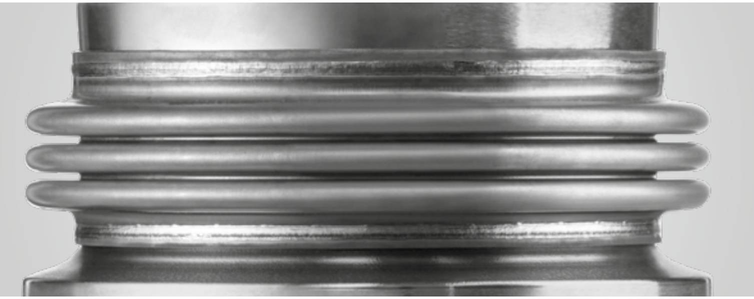


Image 2.6.2.: 50 % Woehler curve at room temperature for metal bellows made of austenitic stainless steel, nickel-base alloys and hardenable stainless steel in comparison.

CUFFS AND CONNECTORS



The bellows cuffs are used to connect the bellows with their connectors. 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 cuff
Bellows with these ends can be supplied in all types on short notice.

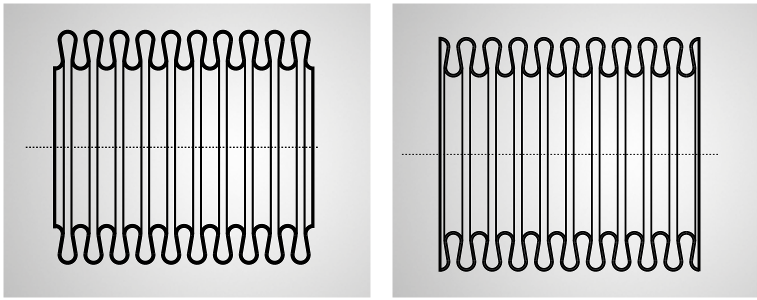


Figure 2.7.1.: Bellows cut off at inside lip (left) and cut off at outside lip (right)

B-cuff
This cuff is simple and cost-effective to produce from a bellows corrugation, either by punching or turning. The connector geometries are simple. The B-cuff is suitable for laser, microplasma or arc welding. Bellows with up to 0.8 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 overall length and the gap-free connection between bellows and connector which is located on the outside of the bellows. The latter is particularly important for bellows applications in the food industry and vacuum technology.

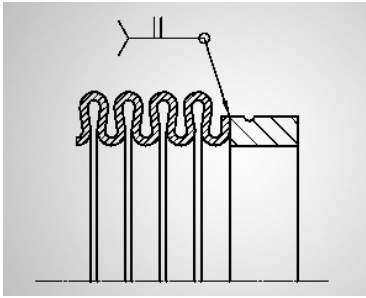


Figure 2.7.2.: Metal bellows with B-cuff and connector

S-cuff
The S-cuff is a cylindrical cuff. In the case of smaller quantities, it can be formed mechanically from a bellows corrugation. This is only possible for thinner total wall thicknesses. For larger numbers of units and greater wall thicknesses it is manufactured hydraulically. 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 of cuff is suitable for welding, soldering and glue joints.

The design of the connectors is more elaborate than for B-cuffs, since the bellows must be placed on the connector in a manner that is nearly gap-free, to ensure a high-quality weld. For glue-based or solder connections, the connector should be fitted with a slot that corresponds with the cuff.

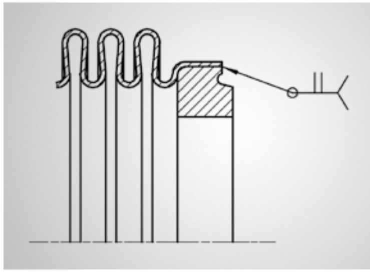


Figure 2.7.3.: Metal bellows with S-cuff and connector

I-cuff
The I-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. The I-cuff connection can be done gap-free, and is frequently used for vacuum valves. The gap-free joining of the I-cuff to the connector is more elaborate than pressing the S-cuff, hence it has only limited suitability for large series.

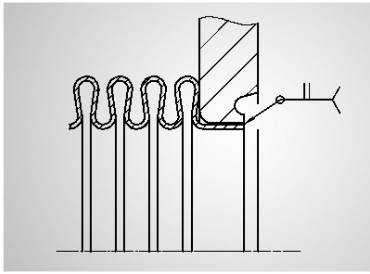


Figure 2.7.4.: Metal bellows with I-cuff and connector

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.

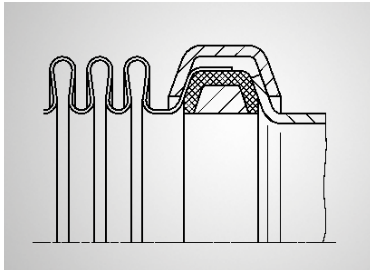


Figure 2.7.5. Metal bellows with V-cuff, V-cuff clamp and connector

Geometry of the connection parts

The geometry in the joining area of the connection part must be adapted to the selected cuff 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 connector, using weld lips, among others. They are targeted cross-section reductions at the connection part, which reduce heat outflow from the weld zone. These are defined wall thickness reductions at the connection part, which reduce heat outflow from the weld zone.

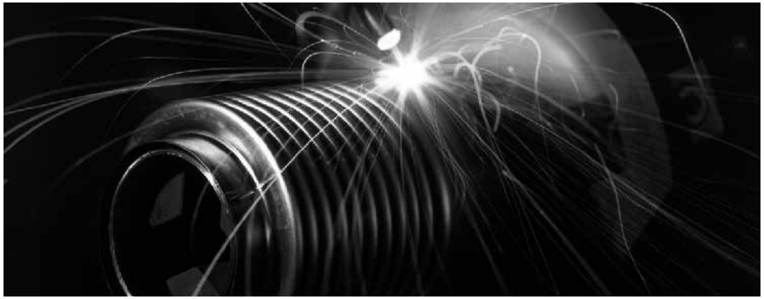
Advantages and disadvantages of the individual cuffs are illustrated in Table 2.7.1. The preferred connection part geometries and dimensions for standard ends of HYDRA metal and diaphragm bellows are listed in Section 6.

Advantages and disadvantages of individual cuffs

	B-cuff	S-cuff	I-cuff	V-cuff
Fatigue resistance	+	++	++	+
Pressure resistance under				
Internal pressure	+	++	++	–
External pressure	++	++	+	–
Tightness	++	++	++	–
Release-ability	–	–	–	++
Suitability for				
Welding	++	++	+	–
Soldering	–	++	++	–
Gluing	–	++	++	–
Terminals	–	–	–	++

Table 2.7.1.

JOINING TECHNIQUES



Bellows and connectors 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. TÜV welding method tests based on the AD Data Sheet H 1 are available for commonly-used material combinations.

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 connection parts.

In welding, the material combination bellows/connection part has a great influence on the quality of the weld seam. Optimum welding results are obtained with the use of titanium-stabilised stainless steels 1.4541 or 1.4571 as connection part 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 (alloy C-276) or 2.4856 (alloy 625).

Bellows made of 1.4541 or 1.4571 with connection parts made of stainless steel 1.4306, 1.4307 or unalloyed quality steels such as 1.0305 are also very suitable for welding. The material combination 1.4404/1.4404 is more difficult to weld due to heat fracture tendencies in case of non-ferric primary solidification.

Soldering is the most commonly used joining method for non-ferrous metals or connection parts. Application examples include switch bellows for high-voltage facilities or actuator bellows for thermostat valves in heaters.

Solder vapour (flux melting agent residues), which particularly accumulate in the bellows interior, must be removed after soldering to prevent soldering corrosion. 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.

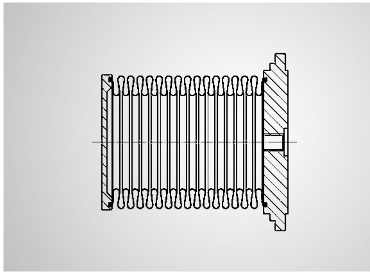


Figure 2.8.1.: Example of a solder or glued connection

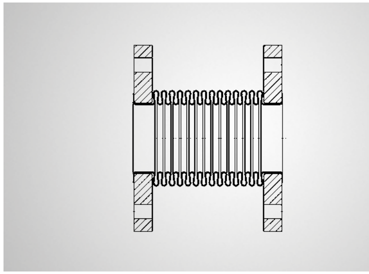
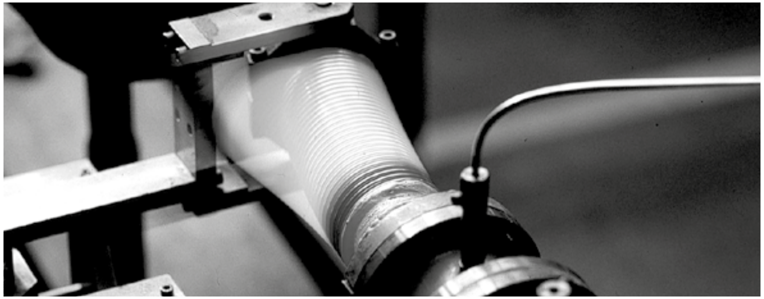


Figure 2.8.2.: Metal bellows with rotating flanges and flange cuff

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 is authorized to issue directives to all employees engaged in activities that influence quality.

Meticulous Control of Suppliers

We work exclusively with suppliers we have concluded quality assurance agreements with and which are certified at least according to ISO 9001.

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. We ensure that the supplied products meet our order and acceptance specifications by means of receiving inspections in our incoming goods department and material laboratory. 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.

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 Processes

Welding processes are regulated based on written instructions. Welders are certified as per EN 287-1 (EN ISO 9601-1) / EN ISO 9606-4. The most important and frequently applied welding techniques are certified by means of process audits. The welding supervision meets the respective requirements according to AD Sheet HP3.

Supervision of Measuring and Testing Equipment

All measuring and test facilities are regularly checked for accuracy and reliability. The date of calibration is recorded by control marks.

Approval tests

Prior to delivery, all products are subject to measurement and visual testing, i.e. a visual inspection of bellows, weld seams and connection 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

- Leak tests,
- Spring rate measurements,
- Pressure resistance testing at room temperature,
- Pressure resistance testing at application temperature
- Load cycle testing in a non-pressurised environment at room temperature,
- Load cycle testing in a non-pressurised environment in near-practice 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. Serial components are tested for re-qualification as per IATF 16949.

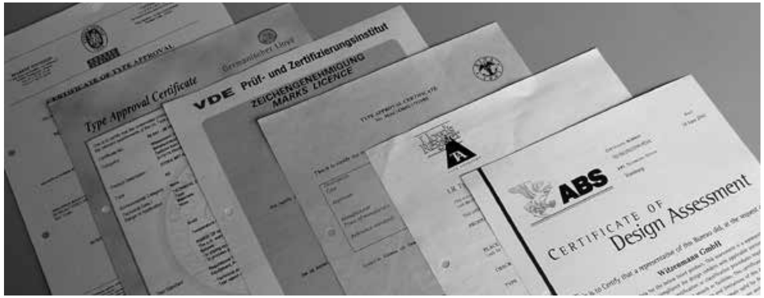
Test certificates

Test certificates for the materials can be requested; strip material, which is normally available in stock, can be confirmed with test certificate 3.1 or also 3.2 according to DIN EN 10204.
Possible certificates related to the testing undertaken are listed in DIN EN 10204 (see Table 2.9.1.)

Test certificate as per DIN EN 10204

Name	Test certificate	Type	Contents of certificate	Conditions	Confirmation of certificate
2.1	Certificate of conformity	non-specific	Confirmation of conformity with the order.	According to the delivery conditions of the order or, if requested, according to the official regulations and associated technical regulations.	By the manufacturer.
2.2	Factory certification		Confirmation of agreement with the order stating results of nonspecific test.		
3.1	Inspection certificate 3.1	specific	Confirmation of agreement with the order stating results of specific test.		By the manufacturer's acceptance officer who is independent of the production department.
3.2	Inspection certificate 3.2			According to official regulations and associated technical rules.	By the manufacturer's acceptance officer who is independent of the production department as well as by the acceptance officer authorised by the orderer or the acceptance officer stated in the official regulations.

CERTIFICATION AND CUSTOMISED APPROVALS



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:

- IATF 16949
- ISO 9001
- ISO 14001
- EN 9100
- Pressure devices guideline
- AD 2000 – Data sheet W 0
- AD 2000 – Data sheet HP 0 / DIN EN ISO 3834-2 / HP 100 R
- KTA 1401 and AVS D100/50
- ASME BPVC Sec. VIII Division 1 – U-Stamp
- NADCAP Welding and Nondestructive Testing

SPECIFIC APPROVALS (SELECTION)

02

Gas/Water

DVGW - German Technical and Scientific Association for Gas and Water

FM Global, USA

LPCB – Loss Prevention Certification Board, UK

ÖVGW – Austrian Association for Gas and Water

SVGW – Swiss Association for Gas and Water

VdS – Association of Insurers

Shipping

ABS – American Bureau of Shipping, USA

BV – Bureau Veritas, France

CCS – China Classification Society, China

DNV GL, Norway/Germany

KR – Korean Register, Korea

LRS – Lloyd's Register of Shipping, United Kingdom

RINA – Registro Italiano Navale, Italien

RS – Russian Maritime Register of Shipping, Russia

Other

BAM – Federal Agency for Material Research and Testing

CNAS – China National Accreditation Service for Conformity Assessment, China

EAC – Eurasian Conformity, Russia

EJMA – Expansion Joint Manufacturers Association

GOST – Gossudarstwenny Standard, Russia

Türk Loydu – The Royal Institution of Naval Architects, Turkey

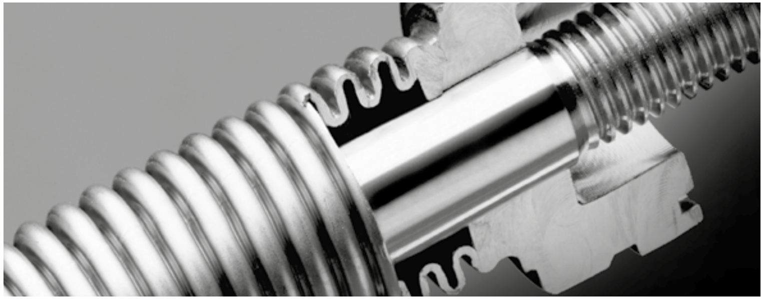
TÜV – German technical standards organisation

VDE – Association of Electrical Engineering, Electronics

TYPICAL BELLOWS APPLICATIONS

The application fields of metal bellows are diverse. Wherever pressure and temperature resistance, tightness as well as flexibility are required, they are used. Aging resistance, corrosion resistance and torsional rigidity are also among their characteristics. The wide application of components ranges from valve and power plant construction, solar technology up to engine technology.

VALVE SHAFT BELLOWS



Metal bellows are used for the glandless sealing of high-grade valves. This type of valve design features absolute tightness, high pressure, temperature and media-resistance, and is also subject to no wear and tear. In this case the metal bellows are 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.).

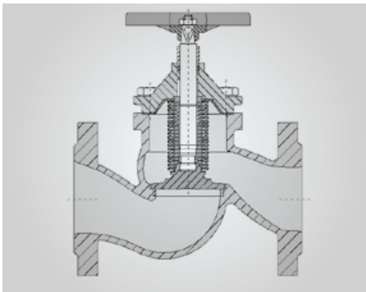


Figure 3.1.1. / Figure 3.1.2.: Valve with metal bellows for stem seal

Valve shaft bellows are usually multi-ply in order to achieve short overall lengths. Hence, the pressure load is 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 movement increases with the same overall length and pressure resistance increases as the number of layers increase and the thickness of individual layers decreases. The bellows material is determined by the ambient medium and working temperature. The preferred material for temperatures up to 550 °C is austenitic stainless steel 1.4571. For higher temperatures or with very aggressive media, nickel-base alloys, such as 2.4819 (Hastelloy C 276) or 2.4856 (Inconel 625) are also available. In addition to increased corrosion resistance, nickel-base alloys also feature higher strength and heat resistance parameters 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, external pressure should always be applied to valve shaft bellows.

The number of corrugations and thus the overall length of the bellows are determined by the stroke and required service life. A typical number of load cycles endured for stop valves is 10,000 operations. Greater load cycles endured with reduced stroke are required for bellows for control valves, among others.

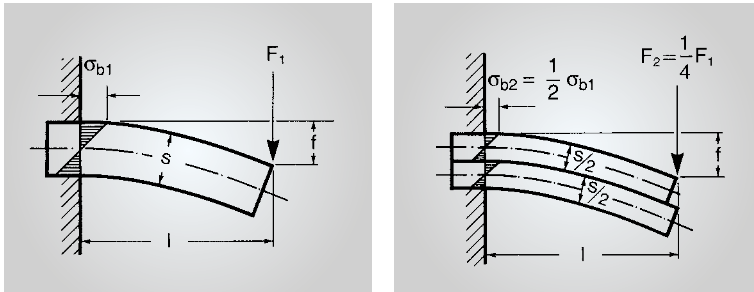


Figure 3.1.3.: Stress distribution in one- or two-layer beams

VALVE SHAFT BELLOWS FOR NUCLEAR POWER PLANTS

Valve shaft bellows for nuclear power plants are sized according to the same technical configuration criteria as conventional valve shaft bellows. However, higher safety factors relating to pressure resistance and service life are mostly considered. Documentation and tests are increasingly necessary here to a larger extent. These are determined by the rules of the Nuclear Committee (KTA) and 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 are:

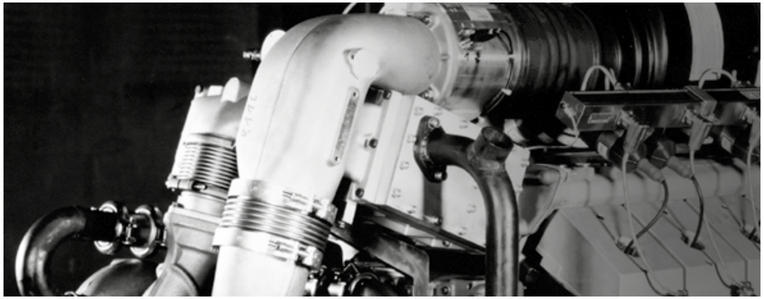
- Testing and confirmation of calculation for pressure resistance and service life of the bellows by an independent individual in charge of approvals,
- Certification of materials and production methods according to KTA, EN 9001 and AD 2000; which also includes special approvals for welding methods and welding personnel,
- Tensile tests, high-temperature tensile tests,
  grain size determination and testing corrosion resistance of the metal strip,
- X-ray and dye penetration testing on weldseams, as well as
- leak testing, pressure and load cycle testing on bellows.

VACUUM APPLICATIONS

Metal bellows are also used in vacuum technology as flexible sealing elements. The main areas of application include stem seals in vacuum valves as well as the sealing of vacuum switches (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 environment, and are configured for a high switching frequency with a high degree of freedom of maintenance. Due to the small differential pressures, vacuum bellows feature a single wall and usually have a bellows profile with a high degree of movement. This means narrow and high corrugations. Design criteria include the required stroke and associated service life, which usually ranges over 30,000 load cycles. Often a low spring rate for the bellows is also required in order to achieve high switching speeds. Bellows for vacuum valves are welded with their connection parts. A gap-free design of the weld seams are preferred to allow for a safe evacuation process, leading to a preferred use of I- or B-cuffs. Bellows for vacuum switches are soldered into the connectors. 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.

Figure 3.3.1.: Bellows for vacuum switch

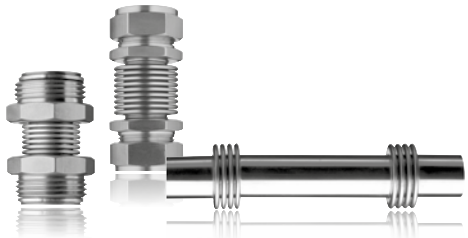
EXPANSION JOINTS



Expansion joints are used for compensating thermal expansion and misalignments in piping systems, as well as for the absorption of 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 expansion joints in plant engineering and construction 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 cycles endured are demanded of 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 construction - one bellows with two rotating flanges attached by angular rings. Bellows with weld ends are also often used as expansion joints. In the case of larger nominal diameters or higher operating pressures, expansion joints designs capable of absorbing reaction forces are preferred. These include expansion joints relieved from pressure or articulation. Comprehensive information on this topic, as well as our expansion joint product range can be found in the Witzenmann manual of expansion joints.

SOLAR APPLICATIONS

Solar thermal is becoming an increasingly significant factor in energy generation; both on an industrial-scale in solar power plants as well as in building technology. The combination of materials with different thermal expansion coefficients results in thermal expansions that must be compensated by metal bellows at all solar thermal plants.



Examples include collector tubes for solar power plants or for building technology. Collector tubes are the heart of parabolic trough power plants. They are configured along the focal line of parabolic mirrors and thermo oil or liquid salt heated by thermal radiation passes through them. The heated heat transfer medium is then used to generate steam for a conventional power plant.

The collector itself consists of an outer cladding tube made of coated and highly-transparent borosilicate glass and an interior absorber tube made of specially coated steel. The space in between is evacuated to avoid 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.

In solar collector panels in building technology, thermal expansions also have to be compensated at the connection points of the individual collectors. Flexible collector joints are used for this. Figure 3.5.1. shows a metal bellows design that can be attached to the copper piping of the collectors. Hydraulically formed O-ring grooves and flanges are integrated for attachment purposes at the cuffs of the bellows.

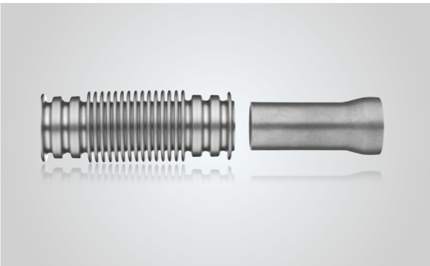


Figure 3.5.1.: Collector connection to attach on copper tubes in building technology

FLOATING RING SEALS

Floating ring seals are dynamic seals for rotating shafts. The main components are the spring-supported slip ring and a counter ring, whose gliding surfaces are pressed against each other by spring tension. One of the rings rotates with the corrugation, while the other one is rigidly 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 slip rings and to achieve secondary sealing between the slip ring and corrugation or slip ring and housing, metal bellows or diaphragm bellows are used in high-grade floating ring seals. The latter is preferred because of its shorter overall length. Figure 3.6.1. shows an example of a sliding ring holder with a HYDRA diaphragm bellows.
Bellows for floating ring seals must be pressure and temperature resistant and also resistant to the transported medium. In addition, the pre-load force of the floating ring seal must not relax during the operation. This is why hardenable bellows materials are often used for this purpose. Typical hardenable materials for HYDRA diaphragm bellows include AM 350 or Inconel 718 (for higher demands on corrosion-resistance) (2.4668).

Figure 3.6.1.: Sliding ring holder with HYDRA diaphragm bellows

SENSORS AND ACTUATORS

Similar to a piston, metal bellows 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 hardenable bellows materials can be used to their advantage.

Examples include the pressure-force converter used to make fine adjustments to optical systems, or sensors for gas-insulated electric control cabinets, which are shown in Figure 3.7.1. These electric control cabinets are filled with SF_6 under excess pressure. In the case of a leak, the pressure inside the electric control cabinet decreases. A gas-filled and hermetically sealed metal bellows is used as a sensor for the pressure in the electric control cabinet.

Figure 3.7.1.: Metal bellows actuators

Its length always adjusts as to create a force equilibrium of the spring tension of the bellows and the compressive forces resulting from the bellows internal pressure, and the pressure in the electric control cabinet. A decrease in electric control 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 end, bronze bellows filled with alcohol are used. The alcohol enclosed in the bellows expands as temperatures rise, and as a result, the bellows elongates in an axial direction. The elongation of the bellows is used to throttle the valve, and the power of the heater decreases. If room temperature decreases, the bellows becomes shorter again. This further opens the control valve and heating power increases again.

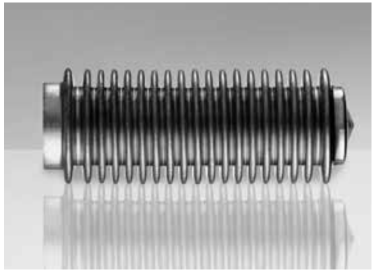
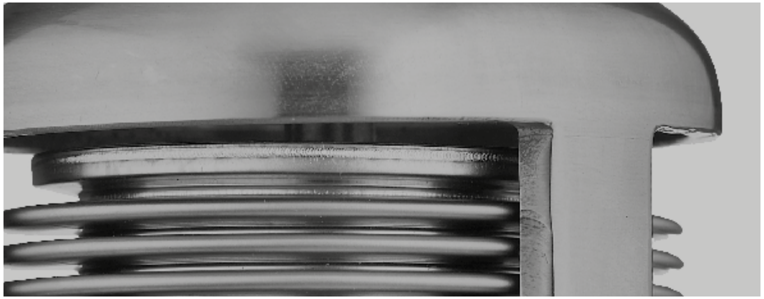


Figure 3.7.2.: Bronze Bellows for Heater Thermostats

METAL BELLOWS ACCUMULATOR



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 that 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-ply diaphragms or plastic bubbles are often used as media separators. They are not completely resistant to diffusion, however, and are subject to ageing. For example, if the diffusion of storage gases in brake systems is not permissible, 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 difference between the gas and liquid is caused by the spring rate of the bellows. To protect the metal bellows from damage, care must be taken to ensure that there are enough valves to prevent a complete emptying of the metal bellows accumulator, and thereby to always maintain the pressure balance between the gas and liquid side.

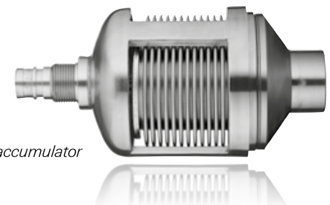


Figure 3.8.1.: Sectional model of a metal bellows accumulator

BELLOWS COUPLINGS

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

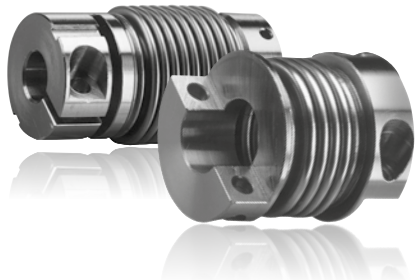


Figure 3.9.1.: Metal bellows coupling

METAL BELLOWS FOR MODERN CAR ENGINES

Reductions in fuel consumption through efficiency increases as well as observance of 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 petrol engines. HYDRA precision bellows have established themselves as reliable, highly flexible, pressure- and temperature-resistant seals in piezo injectors, fuel pumps or pressure sensor glow plugs for such modern engines.
Due to 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.

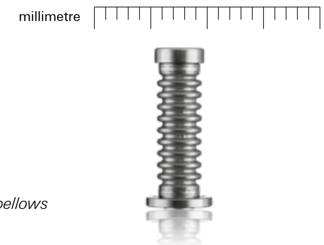


Figure 3.10.1.: Injector bellows (Witzenmann)

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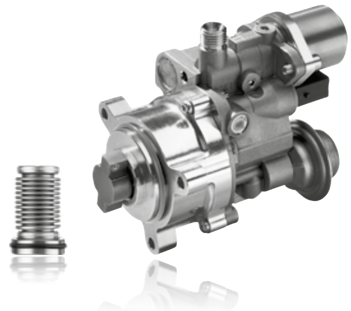
Piezo injector

Spray-guided direct injection reduces the fuel consumption of petrol engines with equal or enhanced engine performance. The requirement for a spray-form combustion consists of highly exact dosages and fine atomization of the injected fuel. There requirements can be met with rapidly switching piezo injectors and injection pressures that exceed 200 bar. The key component of the injector is a piezo actuator, which extends with voltage and thus 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.

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.

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



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-resistant 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.

Fig, 3.10.3.: Metal bellows (Witzenmann) and Pressure sensor glow plugs (PSG, BorgWarner)

BELLOWS CALCULATION AND CHARACTERISTICS

STRESS ANALYSIS FOR METAL BELLOWS

The main requirements for metal bellows are
- Media and corrosion resistance
- Temperature resistance
- Tightness
- Pressure resistance
- 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 mathematically verified.

The principal procedure for preparing a stress analysis for metal bellows is shown in image 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 (if applicable). 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 access to a database, which is constantly maintained and updated, consisting of more than 1,500 pressure resistance tests and more than 1,800 load cycle tests, of which approximately 300 are conducted under operating pressure and at high temperatures.

04

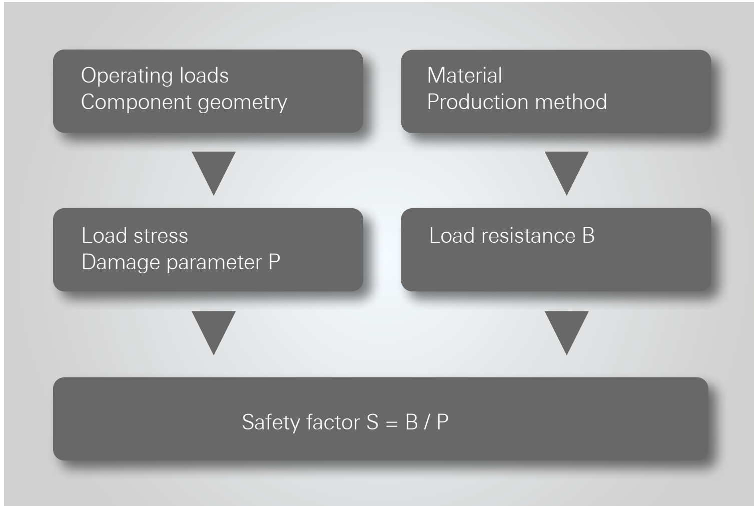
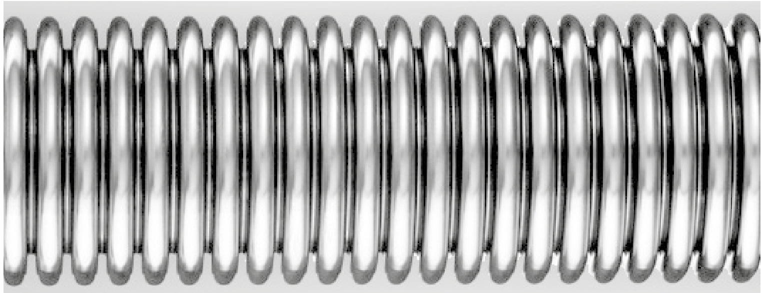


Image 4.1.1.: Principal procedure for preparing a mathematical stress analysis for metal bellows

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.

LOAD STRESS



Load 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 to the typical fracture positions of fatigue fractures. Since similar stress conditions always exist, stress from pressure and movement may be superimposed in addition for evaluating the combined loads.

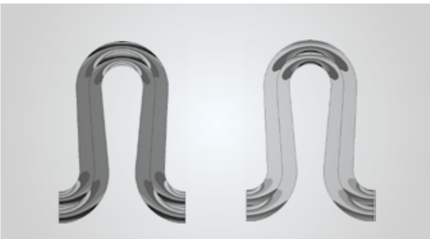


Figure 4.2.1.: Meridional stress on a double-wall metal bellows at axial tensile (left) and at external compressive load (right)

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

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

(4.2.1.)

E is the elasticity module of the bellows material, s is the wall thickness of the individual layer, nw 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 bellow's flexibility since the load on the single corrugation are reduced. For this reason, narrow corrugation profiles are often used for highly flexible bellows, since they allow for the maximization of the number of corrugations in a given installation space.
Not considering the diaphragm stress portions, the following also applies to meridional stresses resulting from pressure (p)

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

(4.2.2.)

whereby n_L is the number of bellows layers, C_P on the other hand is a dimension-less and geometry dependent correction factor (Anderson factor).
In accordance with equation 4.2.2., pressure-resistant profiles feature a large wall thickness (s) and/or large number of layers (n_L), as well as low corrugation heights (h).

PRESSURE RESISTANCE AND BUCKLING RESISTANCE

When subjected to outside excessive pressure, metal bellows usually fail by way of corrugation buckling which is preceded by a plastic deformation at the inner crests (image 4.3.1.). For bellows with very low corrugation height, in relation to the diameter, ovalization 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 (image 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 flow limit 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 flow limit.

Plastic flow and corrugation buckling

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

This verification may be done on a mathematical or 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 correspondingly analysed.

The nominal pressure (PN) 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).

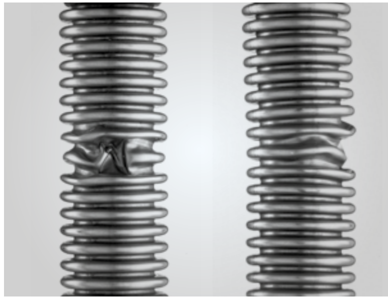


Image 4.3.1.: Corrugation buckling of a metal bellows under outside pressure

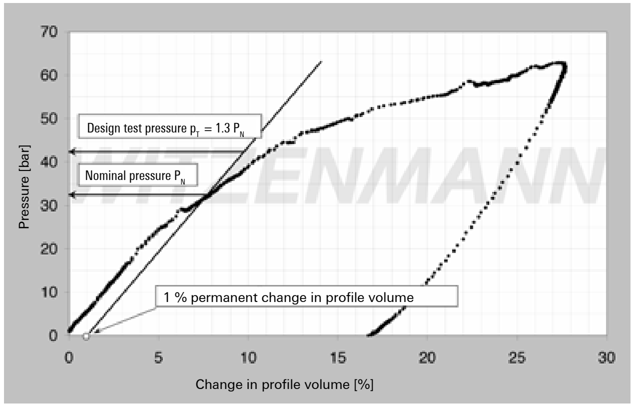


Image 4.3.2.: Pressure-volume characteristic of a metal bellows and nominal pressure determination as per the Witzenmann method

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 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 design pressure (p_T) of 130 % of nominal pressure. Higher design test pressures may damage the bellows profile and are therefore not permitted.

For systems in which the design test 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 design test pressure. In this case, the design test 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 mathematical configuration criteria to determine the nominal pressure of metal bellows 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. have to be met. In this vein, C_m describes the increase in material strength as compared to the value determined for the band material by way of bracing, support effects and stress transfers.

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

(4.3.4.)

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

(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 BPVC, Section III, NB 3228.2). The recommended method (ASME BPVC, 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 incipient column buckling (image 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:

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

(4.3.6.)

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

$$l_f = n_w \cdot l_w$$

(4.3.7.)

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

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 proportionate to the reduction in the E-module of the bellows material.

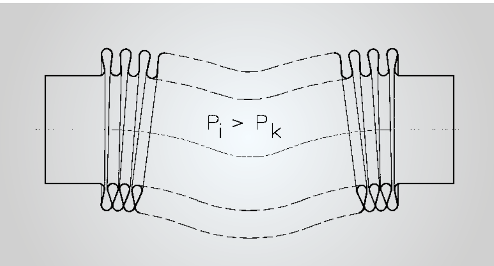


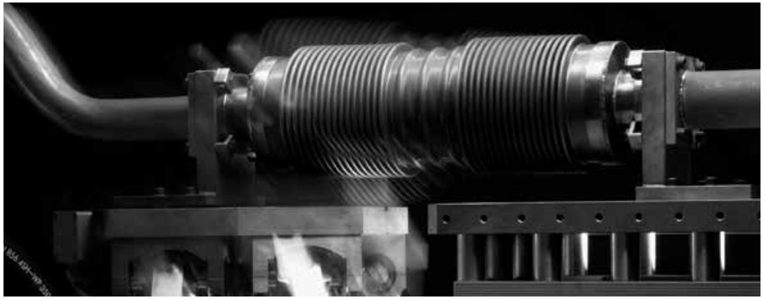
Image 4.3.3.: Column buckling of a metal bellows under inside pressure (schematic)

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 formula 4.3.2. For applications which explicitly require a minimum bursting pressure for the bellows, verification using a burst test under near-operating installation conditions is recommended. Experimental protection against bursting pressure is also useful for high-strength materials with an elastic limit $R_{P1.0}/R_m$ near 1.

04

FATIGUE LIFE



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 cyclical creep 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 of the bellows corrugation. 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. shows fatigue fractures on the inner flute of a bellows on the left side.
In the metallographical 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.

The dependence of the fatigue life on the load is described by using S-N-curves. Image 4.4.2. shows the Witzenmann S-N-curve for metal bellows made of austenitic steel. The S-N-curve diagram also contains the test results for metal bellows. They are distributed in the form of a statistical spread around the 50 % S-N-curve.

Besides the actual cylindrical load (recurring deformation and/or pulsating pressure), the fatigue life is also affected by primary 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 lifetime calculation for a general load cycle can be done by Witzenmann at request.

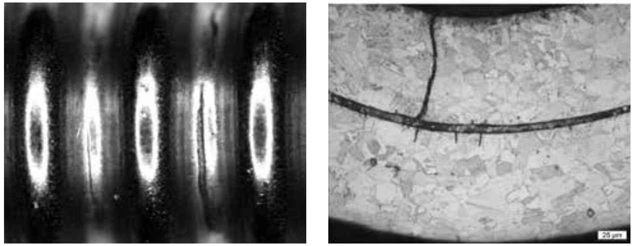


Figure 4.4.1: Fatigue fracture at inner crest of a metal bellows in top view (left) and as a metallographical cut (right)

04

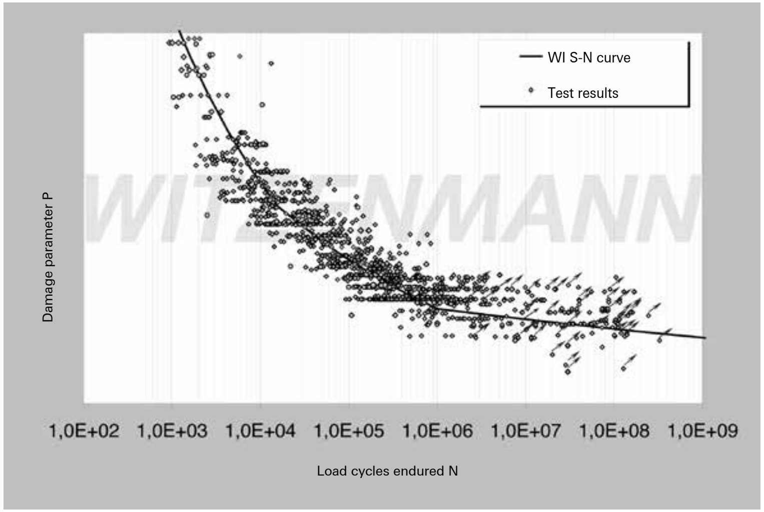


Figure 4.3.2. shows the Witzenmann S-N-curve for metal bellows made of austenitic stainless steel. Tests marked with an arrow were suspended without failure of the bellows.

In the special case of a static pressure loaded bellows, load cycles (N) may be estimated as a function of stroke (δ) 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 one-level test 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 %:

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

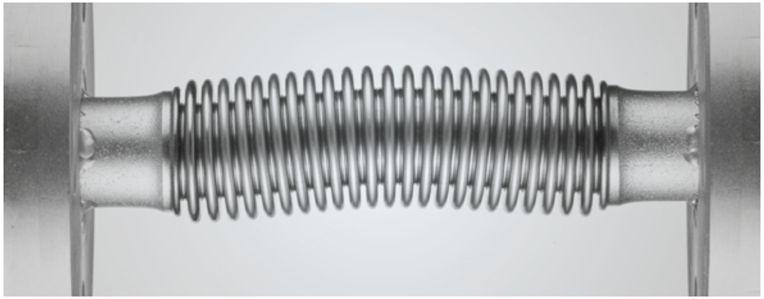
(4.4.3.)

Damage accumulation with load cycles numbers in the fatigue limit $N_{50\,\%}$ > 1 million), which are derived from the S-N-curve for a one-level test, 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.

04

ANGULAR AND LATERAL DEFORMATION



Metal bellows may also deform perpendicularly to the bellows axis. The basic movement forms - displacement of bellows ends perpendicular to bellows axis (lateral deformation) without an incline, or an incline and displacement of bellows ends 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.)

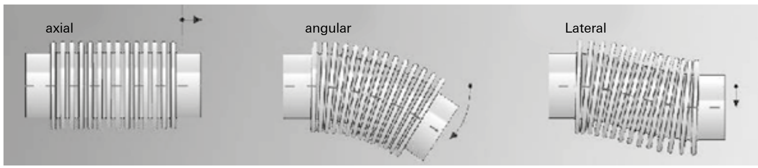


Image 4.5.1.: Axial, angular and lateral bellows deformation

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 deflections, as well as taking into account that the angular deflection as 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 ends to each other:

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

(4.5.4.)

These calculations accurately apply to long bellows not subject to pressure loads. For laterally loaded short bellows (lf $\leq D_m$), 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 (PS > 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 manual, however, more information may be obtained from Witzenmann.

TORSION AND TORSIONAL BUCKLING

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 structural torsion resistance and protection against torsional buckling must be verified in addition to service life under lateral and/or angular loads. A structural 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.)

whereby the bellows inside diameter is d_i. With the aid of 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.)

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.

BELLOWS SPRING RATES

An important characteristic of a bellows is its spring rate under axial, angular or lateral deformation.

The axial spring rate of a metal bellows 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.)

can be calculated. C_d, in turn, is a dimension-less correction factor (Anderson factor) which depends on the geometry of the bellows corrugation.
The spring rate is more dependent on wall thickness(es) and corrugation height (h) than vibrations (cp. 4.2.1. and 4.2.2.) and also 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:

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

(4.7.2.)

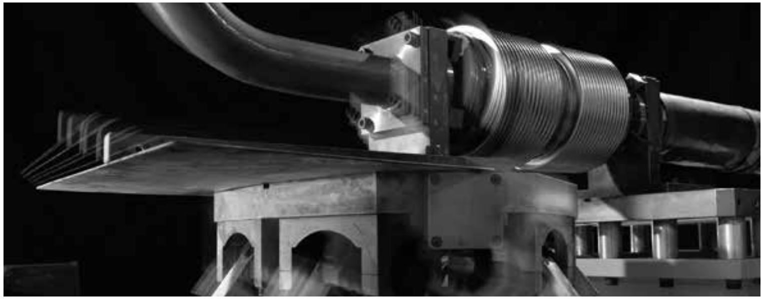
and

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

(4.7.3.)

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

VIBRATIONS



If deflections no longer occur very slowly but with higher load cycle frequencies, dynamic effects can result in a higher load of the bellows. Dynamic effects do not have to be considered in the service life design if the load cycle frequency does not exceed 20 % of the lowest bellows frequency in the initiation direction.

The lowest axial natural frequency of the metal bellows according to:

$$f_{ax,\,1} = 0.5 \cdot \sqrt{\frac{c_{ax}}{m_B}}$$

can be calculated.

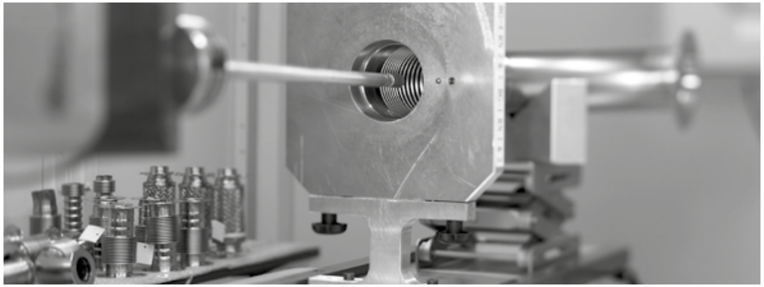
The lowest lateral natural frequency is decisive for deflections in lateral and angular directions:

$$f_{lat,\,1} = 1.03 \cdot \sqrt{\frac{c_{lat} \cdot \left(1 - \frac{PS}{p_K}\right)}{m_B \cdot \left(1 + 1.54\,\frac{D_m^2}{l_f^2}\right)}}$$

whereby p_K is the buckle pressure for column buckling according to Section 3. The equations specify the lowest natural frequency for gaseous media on the inside and outside of the bellows. If the bellows is filled or surrounded by liquid, the natural frequencies are reduced by the inertial effect of the liquid that must also be moved.

When considering dynamic effects, metal bellows are also suitable for high frequencies, e.g. for decoupling vibrations on rotating machines such as pumps, compressors and reciprocating engines. Designing dynamically stressed bellows requires sound knowledge of dynamic operating loads and can be carried out by Witzenmann on request.

PRESSURE REACTION FORCE AND HYDRAULIC DIAMETER



In contrast to a rigid tube, the flexibility of the bellows results in reaction forces which act on subsequent tubelines or components. It is possible to accurately determine the hydraulic diameter (d_{hyd}) of the bellows on a numerical or experimental basis. A very good approximate value of 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 connectors, the amount and direction of the reaction force depend on the ratio of the pressure-applied diameter at the connector (DAT) 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.)

Image 4.8.1. illustrates these linkages. If the pressure-loaded diameter of the connector corresponds to the hydraulic diameter of the bellows, there are no pressure reaction forces in the connection.

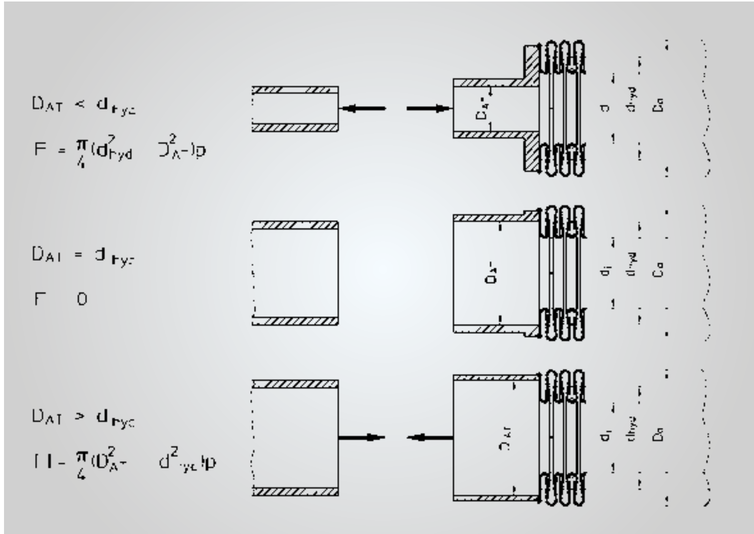
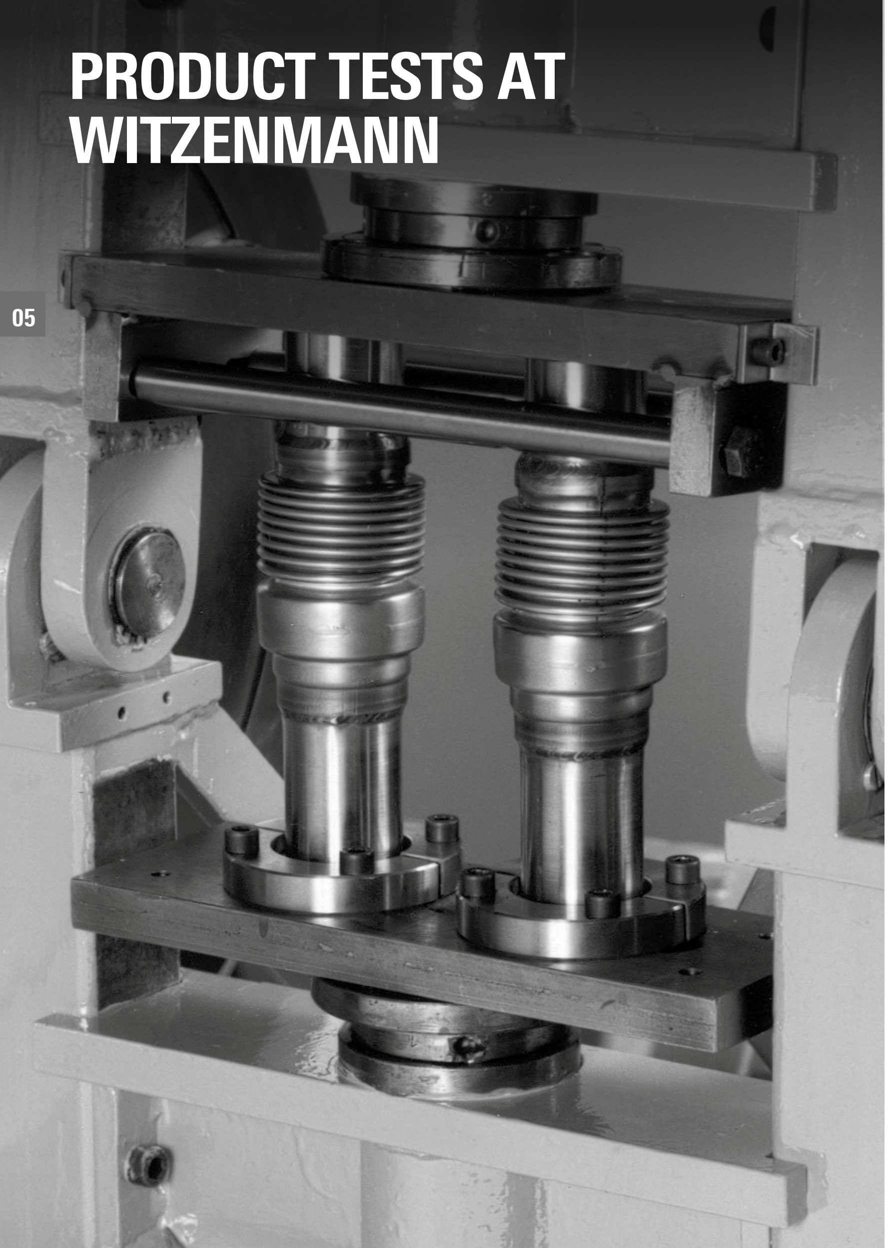


Image 4.8.1.: Reaction forces on a bellows connection under inside pressure.

PRODUCT TESTS AT WITZENMANN



A successful product test and product analysis provide the proof that a component will safely meet the required service life and stability even under extreme operating conditions. Furthermore, trials, tests and analyses already provide product insights during the early development stage with a high degree of validity.

Properties such as tightness, static and dynamic rigidity, motion limits and flow characteristics are mainly responsible for ensuring that a Witzenmann product serves its function as a component of a larger system according to the specific application. These functional properties are determined experimentally using measuring facilities that are specially adapted to the specific requirements in the characterisation of flexible metallic tubeline elements.

TESTING AND ANALYSIS OPTIONS

Witzenmann has a comprehensive range of test and analysis options for determining and checking product characteristics on an experimental basis. The test field includes, among other things:

- 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 vibrators
- one pressure impulse stand
- test stands for structural pressure testing as well as
- leakage test stands

Witzenmann also has a materials' laboratory for mechanical, technological and metallographical tests, as well as for welding process and approval tests. The laboratory equipment includes the following:

- Tension and impact-bend testing machines,
- Comprehensive preparation technology for metallographical grinding
- Raster electronic microscope with integrated X-ray spectrum analysis
- Clean cabinet
- Corrosion test stands
- 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 connector materials at room temperature or at high temperatures
- Macro grindings to evaluate geometry of bellows and weld seams
- Micro grindings to analyse structure, determine grain size and δ ferrite
- Measurements of small loads and micro hardening
- Analyses of material composition and the local element distribution
- Fracture surface and inclusion analyses
- Residual contamination analysis

Other tasks of the metallographical 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 has the authorisation to issue approval certificates.

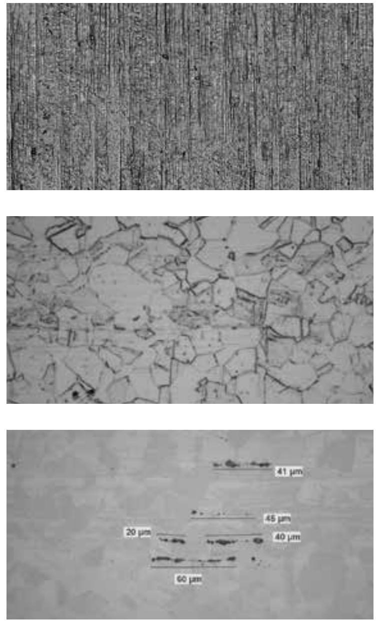
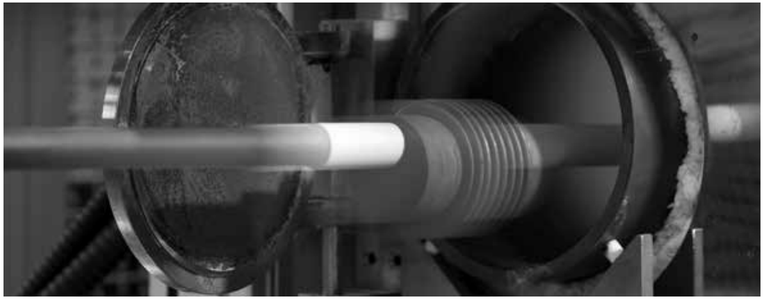


Figure 5.1.1.: Surfaces (top), structure (middle) and purity analysis (bottom) on precision strip made of material 1.4571.

TYPICAL TESTING OF METAL BELLOWS



Leak test

All bellows equipped with connection 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 bubbles may occur. This test detects leakage rates of greater than approximately 10^{-4} mbar l/sec.

The helium leakage test is used as standard for higher leak tightness requirements as well as for the testing of diaphragm bellows. The vacuum method of the helium leakage test is a high-resolution leak test. The component to be tested is evacuated and the surface away from the vacuum is exposed to a helium atmosphere. Helium atoms entering the vacuum can be detected using a mass spectrometer. 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 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 weldseams

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 surface crack detection test with the dye penetration process. The inspection occurs visibly; with the red-white method during daylight and, with the fluorescent method, under UV lighting.

05

Leak rates and associated volume flows for helium leak test

Leakage rate [mbar l/sec]	Leak diameter [µm]	Volume flow [l/sec]	Volume flow [l/ year]	Remark
		(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* an air bubble (Ø 1 mm) per sec
10^{0}	100	10^{-3}	31500	Leaky water tap

**non-standard representation, no exact definition for a leakage rate*

Table 5.2.1

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

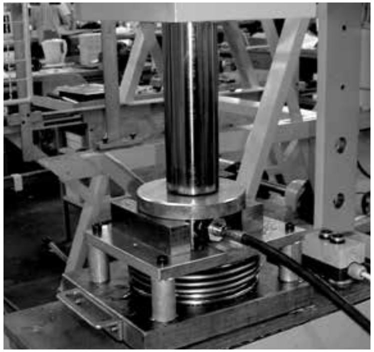


Figure 5.2.1.: Pressure resistance testing on a metal bellows

Figure 5.2.2.: Axial load cycle test.

Pressure resistance testing

Image 5.2.1. shows a pressure resistance 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, pressure resistance testing may be continued until the bellows bursts.

Load cycle testing

Proof of service life for metal bellows can be carried out mathematically 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 such cases, it is often easier to produce the proof of service life only mathematically 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 can be carried out as acceptance tests for design approval, e.g. for metal bellows used in nuclear engineering applications, for approval of material batches as well as for regular requalification tests for components subject to the 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, complex deformations during load cycle testing may also be shown along with load cycle testing 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:

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

TECHNICAL TABLES

06

06

BELLOWS SELECTION FROM THE MANUAL

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 test pressure (p_T):

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

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

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

considers 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 expansion joint manual.

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, apart from the condition

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

the ***buckle resistance*** must additionally be checked ***under internal pressure***. Condition

(6.1.3.) $$p_{RT} \leq 2 \frac{c_\delta}{n_w^2 \cdot l_w}$$

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, and back to the extreme value of the other side over the starting position, and again in the starting position.

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

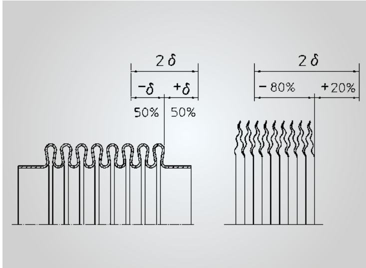

Figure 6.1.1

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

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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. They are based on a service life of at least 10,000 load cycles at room temperature and nominal pressure. Depending on the required load cycles endured and pressure capacity, the permissible deflection per corrugation ($2\delta_n$, $2\lambda_n$, $2\alpha_n$) from the nominal deflection per corrugation ($2\delta_{n,0}$, $2\lambda_{n,0}$, $2\alpha_{n,0}$) and correcting factor $K_{\Delta N}$ for the load cycles endured result in the following:

Axial load:

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

Lateral load:

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

Angular load:

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

Influence of load cycles on impulse

Load cycles endured	Correction factor $K_{\Delta N}$	Load cycles endured	Correction factor $K_{\Delta N}$	Load cycles endured	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

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If less than 10,000 load cycles endured 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 the nominal deflection. The corresponding influencing factor $K_{\Delta N}$ is shown in Table 6.1.2.

Pressure pulsations

The pressure surges or growing pulsating loads added to the static pressure can considerably reduce the service life of the bellows. Their influence can be determined arithmetically. It depends on the size of the pulsating loads and their frequency. For pulsating loads $\Delta p > 0.25$ PN we recommend a mathematical 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 load (6.1.5.a)

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

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)

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

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)

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

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

Temperatures °C	Material 1.4571
20	1.00
100	0.97
200	0.93
300	0.90
400	0.86
500	0.83

At higher temperatures the bellows spring rate decreases in proportion to the elasticity module of the bellows material. Die appropriate reduction factors are contained in table 6.1.4.

(6.2.7.)

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

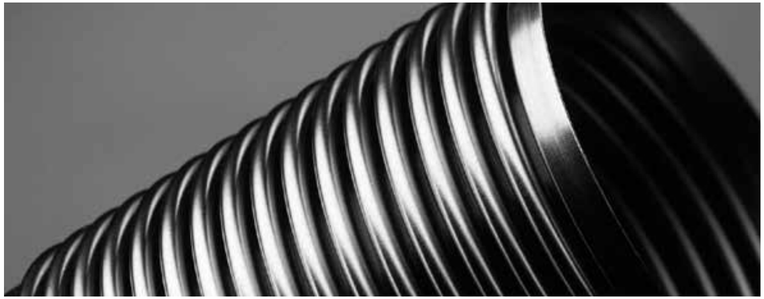
BELLOWS SELECTION WITH FLEXPERTE

Flexperte is a design tool for flexible metal elements. It is a specially developed software and selects the appropriate products from the standard range to suit the particular application. In addition to metal bellows, the program can also be used to configure expansion joints, metal hoses and tube supports.

When the operating conditions have been entered, the program offers 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.

A fully functional version of the program for direct use is also available online at www.flexperte.de.

HYDRA® STAINLESS STEEL METAL BELLOWS



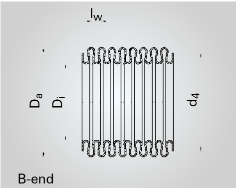
HYDRA metal bellows from our preferred series feature a high degree of flexibility and pressure resistance with minimal installation length.
The standard material for metal bellows made of longitudinally welded tube is 1.4571. Other materials are available on request. Bellows with a small diameter are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

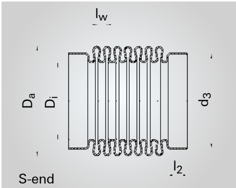
Bellows description
The bellows description describes the bellows profile, i.e. diameter, number of layers and thickness of individual layers, corrugations and material used. The first letters indicate whether the bellows described concerns a bellows without connection parts (BAO) or a bellows with connection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

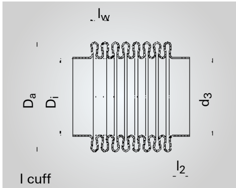
Bellows description:
(example)

BAT	60.0	x	82.0	x	6	x	0.3	x	15W	x	1.4571
Bellows with connectors	Inside diameter d_i = 60 mm		Outside diameter D_A = 82.0 mm		Individual number of layers n_L = 6		Individual layer thickness s = 0.3 mm		15 corrugations		Material 1.4571

HYDRA® STAINLESS STEEL METAL BELLOWS PREFERRED SERIES







Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff Ø
	PN*	D_i	D_a	n_L	s		l_W		D_i	D_a	d_4
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm
3	400	3.35	4.7	2	0.06	1.4541**	1.00	10	-0.1/+0.1	±0.1	-
4	90	4.06	6.1	1	0.07	1.4541**	0.80	37	-0.4/+0.1	±0.3	5.5
5	65	5.3	8.0	1	0.08	1.4541**	0.95	63	-0.4/+0.1	±0.3	7.0
	100	5.3	8.0	1	0.10	1.4541**	0.85	70	-0.4/+0.1	±0.3	7.0
	150	5.3	8.5	1	0.15	1.4541**	1.10	45	-0.4/+0.1	±0.3	7.0
	200	5.3	8.5	1	0.20	1.4541**	1.20	41	-0.4/+0.1	±0.3	7.0
	500	5.3	8.5	2	0.20	1.4541**	1.20	42	-0.4/+0.1	±0.5	7.0
6	55	6.2	9.7	1	0.20	1.4541**	1.20	63	-0.4/+0.1	±0.3	8.5
8	26	8.0	13.0	1	0.10	1.4571	1.40	235	-0.4/+0.1	±0.3	11.0
	68	8.0	13.0	2	0.10	1.4571	1.60	277	-0.4/+0.1	±0.3	11.0
	115	8.0	13.0	3	0.10	1.4571	1.80	242	-0.4/+0.1	±0.5	11.0
	150	8.0	13.5	4	0.10	1.4571	2.00	150	-0.6/+0.2	±0.5	11.0
9	22	9.0	14.5	1	0.10	1.4571	1.35	234	-0.4/+0.1	±0.3	13.4
	55	9.0	14.5	2	0.10	1.4571	1.75	233	-0.4/+0.1	±0.3	13.0
	90	9.0	14.5	3	0.10	1.4571	1.85	198	-0.4/+0.1	±0.5	13.0
	250	9.0	13.0	4	0.10	1.4571	1.50	258	-0.6/+0.2	±0.5	13.0
10	16	10.0	16.5	1	0.10	1.4571	1.65	189	-0.4/+0.1	±0.3	14.5
	38	10.0	16.5	2	0.10	1.4571	1.90	216	-0.4/+0.1	±0.3	14.5
	60	10.0	17.0	3	0.10	1.4571	2.00	208	-0.4/+0.1	±0.5	14.5
	90	10.0	17.0	4	0.10	1.4571	2.40	125	-0.6/+0.2	±0.5	14.5
	130	10.0	17.0	5	0.10	1.4571	2.70	111	-0.6/+0.2	±0.5	14.5
12	13	12.0	19.0	1	0.10	1.4571	1.90	168	-0.4/+0.1	±0.3	18.0
	26	12.0	20.0	2	0.10	1.4571	2.10	178	-0.1/+0.1	±0.3	18.0
	40	12.0	20.0	3	0.10	1.4571	2.45	163	-0.4/+0.1	±0.5	18.0
	60	12.0	20.0	2	0.15	1.4571	2.40	166	-0.4/+0.1	±0.5	18.0
	90	12.0	20.0	3	0.15	1.4571	2.40	166	-0.6/+0.2	±0.5	18.0
	260	12.4	18.5	4	0.15	1.4571	2.50	144	-0.6/+0.2	±0.5	16.3

* Outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)
** Bellows made of seamless tube

S-end		I cuff		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per corrugation
Ø	Length	Ø	Length								
d_3	l_2	d_3	l_2	axial	angular	lateral	axial	angular	lateral		
inside		inside		$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	mm	mm	mm	mm	degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
4.2	2	-	-	±0.025	±0.50	-	1475	0.052	-	0.12	0.02
-	-	4.06	5	±0.040	±0.70	±0.002	260	0.016	15500	0.21	0.02
-	-	5.34	5	±0.065	±1.10	±0.003	180	0.020	13500	0.36	0.04
-	-	5.30	5	±0.045	±0.75	-	420	0.050	-	0.36	0.05
-	-	5.30	5	±0.035	±0.55	-	830	0.080	-	0.37	0.08
-	-	5.30	5	±0.025	±0.40	-	1850	0.190	-	0.38	0.11
-	-	5.30	5	±0.017	±0.20	-	6300	0.650	-	0.37	0.19
8.5	1.8	6.30	5	±0.090	±1.00	±0.004	160	0.022	11100	0.51	0.07
11.6	1.8	8.00	6	±0.17	±1.30	±0.006	120	0.028	10500	0.87	0.13
11.6	1.8	8.00	6	±0.15	±1.20	±0.006	245	0.058	15800	0.87	0.26
11.6	1.8	8.00	6	±0.13	±1.10	±0.005	385	0.092	19700	0.87	0.39
-	-	8.00	6	±0.13	±1.00	±0.004	460	0.116	19900	0.91	0.44
13.1	2.0	9.00	6	±0.21	±1.60	±0.008	75	0.022	8500	1.08	0.17
13.1	2.0	9.00	6	±0.19	±1.40	±0.008	160	0.048	10600	1.08	0.34
13.1	2.0	9.00	6	±0.17	±1.30	±0.008	260	0.080	15000	1.08	0.52
-	-	9.00	6	±0.07	±0.50	±0.003	1230	0.320	98000	0.94	0.43
14.3	2.5	10.0	6	±0.25	±1.70	±0.010	60	0.023	5800	1.38	0.22
14.3	2.5	10.0	6	±0.23	±1.60	±0.010	120	0.045	8700	1.38	0.44
15.1	2.5	10.0	6	±0.22	±1.50	±0.010	170	0.070	11600	1.43	0.66
-	-	10.0	6	±0.21	±1.30	±0.008	250	0.100	11900	1.43	0.88
-	-	10.0	6	±0.19	±1.10	±0.007	310	0.120	11600	1.43	1.10
16.8	2.5	12.0	6	±0.30	±1.70	±0.010	65	0.038	6300	1.89	0.30
17.6	2.5	12.0	6	±0.33	±1.70	±0.011	95	0.053	7500	2.01	0.60
17.6	2.5	12.0	6	±0.30	±1.50	±0.011	135	0.075	8600	2.01	0.90
17.6	2.5	12.0	6	±0.24	±1.40	±0.011	300	0.170	20000	2.01	0.92
-	-	12.0	6	±0.20	±1.30	±0.010	560	0.320	37000	2.01	1.39
-	-	12.4	6	±0.12	±1.20	±0.008	1745	0.900	100000	1.86	1.39

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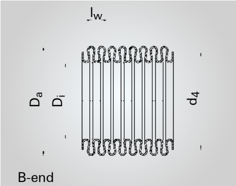
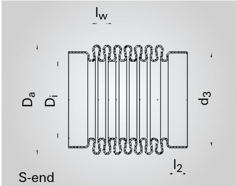
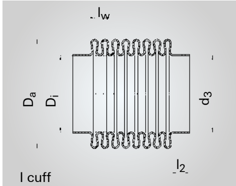


B-end



S-end



I cuff

Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff Ø
	PN*	D_i	D_a	n_L	s		l_W		D_i	D_a	d_4
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm
12	360	12.8	18.5	5	0.15	1.4571	2.50	155	-0.6/+0.2	±0.5	16.3
	385	12.4	19.0	6	0.15	1.4571	3.00	137	-0.6/+0.2	±0.8	16.3
13	20	13.0	19.0	1	0.10	1.4571	1.80	153	-0.4/+0.1	±0.5	16.3
	45	13.0	19.0	2	0.10	1.4571	1.85	204	-0.4/+0.1	±0.5	16.3
	110	13.0	19.0	2	0.15	1.4571	2.15	186	-0.4/+0.1	±0.5	16.3
	165	13.0	19.0	3	0.15	1.4571	2.20	155	-0.6/+0.2	±0.5	16.3
14	17	14.6	21.0	1	0.10	1.4571	1.90	145	-0.4/+0.1	±0.5	19.0
	30	14.6	22.0	2	0.15	1.4571	2.15	196	-0.4/+0.1	±0.5	20.0
	55	14.2	22.0	2	0.15	1.4571	2.30	170	-0.4/+0.1	±0.5	20.0
	110	14.6	22.0	3	0.15	1.4571	2.75	151	-0.6/+0.2	±0.5	20.0
	150	14.2	22.0	4	0.15	1.4571	2.80	142	-0.6/+0.2	±0.5	20.0
	220	14.2	21.2	5	0.15	1.4571	2.80	149	-0.6/+0.2	±0.5	18.5
	280	14.2	22.0	6	0.15	1.4571	3.40	88	-0.6/+0.2	±0.8	20.0
16	14	16.6	24.0	1	0.10	1.4571	2.00	138	-0.4/+0.1	±0.5	21.5
	28	16.6	24.0	2	0.10	1.4571	2.00	179	-0.4/+0.1	±0.5	21.5
	70	16.8	24.0	2	0.15	1.4571	2.30	155	-0.4/+0.1	±0.5	21.5
	110	16.4	24.0	3	0.15	1.4571	2.50	160	-0.6/+0.2	±0.5	21.5
	185	16.8	24.0	4	0.15	1.4571	3.00	140	-0.6/+0.2	±0.5	21.5
	250	16.8	24.0	5	0.15	1.4571	3.50	85	-0.6/+0.2	±0.5	21.5
	300	16.0	24.5	4	0.20	1.4571	3.80	105	-0.6/+0.2	±0.8	21.5
	370	16.0	24.5	5	0.20	1.4571	4.10	73	-0.6/+0.2	±0.8	21.5
18	16	18.0	28.0	1	0.15	1.4571	2.40	130	-0.4/+0.1	±0.5	25.0
	38	18.0	28.0	2	0.15	1.4571	2.70	143	-0.6/+0.2	±0.5	25.0
	70	18.0	28.0	3	0.15	1.4571	3.20	137	-0.6/+0.2	±0.5	25.0
	75	18.0	28.0	2	0.20	1.4571	3.10	137	-0.6/+0.2	±0.5	25.0
	105	18.0	28.0	4	0.15	1.4571	3.50	118	-0.6/+0.2	±0.5	25.0
	125	18.0	28.0	3	0.20	1.4571	3.50	120	-0.6/+0.2	±0.5	25.0

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

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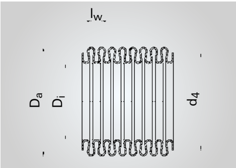
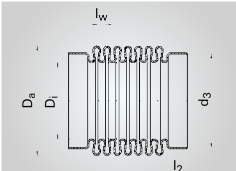
S-end		I cuff		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per corrugation
Ø	Length	Ø	Length								
d_3	l_2	d_3	l_2	axial	angular	lateral	axial	angular	lateral		
inside		inside		$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	mm	mm	mm	mm	degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
-	-	12.8	6	±0.09	±0.65	±0.006	3400	1.800	199900	1.92	1.73
-	-	12.4	6	±0.08	±0.55	±0.005	4000	2.150	164000	1.94	2.20
16.8	2.5	13.0	6	±0.26	±1.60	±0.008	74	0.040	8800	2.01	0.24
16.8	2.5	13.0	6	±0.24	±1.50	±0.008	160	0.090	18000	2.01	0.48
16.8	2.5	13.2	6	±0.17	±1.20	±0.007	600	0.340	50500	2.04	0.72
16.8	2.5	13.2	6	±0.13	±1.00	±0.006	900	0.510	72000	2.04	1.10
18.3	4.0	14.6	6	±0.28	±1.40	±0.011	85	0.065	11200	2.51	0.30
18.3	4.0	14.6	6	±0.30	±1.40	±0.010	130	0.093	14100	2.63	0.66
18.8	4.0	14.2	6	±0.22	±1.20	±0.009	330	0.240	30600	2.57	1.01
-	-	14.6	6	±0.17	±1.00	±0.008	720	0.550	48000	2.63	1.35
-	-	14.2	6	±0.14	±0.70	±0.007	800	0.570	50000	2.57	1.70
-	-	14.2	6	±0.12	±0.60	±0.006	1300	0.880	77900	2.46	2.00
-	-	14.2	6	±0.14	±0.50	±0.005	1500	1.070	63800	2.57	2.50
21.1	4.0	16.6	6	±0.33	±1.60	±0.011	60	0.05	9000	3.25	0.37
21.1	4.0	16.6	6	±0.32	±1.50	±0.011	126	0.11	19200	3.25	0.73
21.1	4.0	16.8	6	±0.20	±1.00	±0.009	420	0.38	49600	3.25	1.10
21.1	3.5	16.4	6	±0.20	±1.00	±0.009	680	0.60	66600	3.20	1.70
-	-	16.4	6	±0.18	±0.80	±0.009	1000	0.89	68000	3.20	2.36
-	-	16.4	6	±0.16	±0.70	±0.008	1420	1.26	71000	3.20	2.80
-	-	16.0	6	±0.13	±0.50	±0.007	2150	1.92	91600	3.22	3.30
-	-	16.0	6	±0.12	±0.40	±0.006	2800	2.50	102500	3.22	3.80
25.2	3.0	18.0	6	±0.36	±1.50	±0.014	90	0.11	12400	4.10	0.83
25.2	3.0	18.0	6	±0.34	±1.30	±0.013	185	0.21	20100	4.05	1.73
25.2	3.0	18.0	6	±0.32	±1.10	±0.013	310	0.36	24000	4.15	2.63
25.2	3.0	18.0	6	±0.28	±1.00	±0.012	600	0.69	49500	4.15	2.40
-	-	18.0	6	±0.27	±0.90	±0.013	485	0.56	31400	4.15	3.52
-	-	18.0	6	±0.24	±0.80	±0.012	1000	1.15	64800	4.15	3.50

HYDRA® STAINLESS STEEL METAL BELLOWS PREFERRED SERIES



B-end



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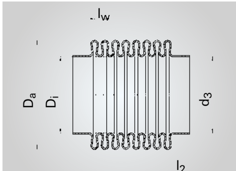
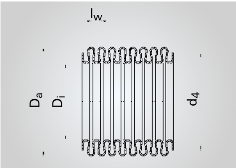


I cuff

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

Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff Ø	S-end		I cuff		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per corrugation
												Ø	Length	Ø	Length	axial	angular	lateral	axial	angular	lateral		
	PN*	D_i	D_a	n_L	s		l_W		D_i	D_a	d_4	d_3 inside	l_2	d_3 inside	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
18	200	18.0	28.0	3	0.25	1.4571	3.80	115	-0.6/+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	-0.6/+0.2	±0.8	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	-0.6/+0.2	±0.8	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	-0.6/+0.2	±0.8	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	-0.6/+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	-0.6/+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	-0.6/+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	-0.6/+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	-0.6/+0.2	±0.8	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	-0.6/+0.2	±0.8	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	-0.4/+0.1	±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
	32	21.0	31.5	2	0.15	1.4571	2.70	138	-0.6/+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	-0.6/+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	-0.6/+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	-0.6/+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	-0.6/+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	-0.6/+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	-0.6/+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	±0.5	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	-0.6/+0.2	±0.5	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	-0.6/+0.2	±0.5	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	-0.6/+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	0.20	1.4571	4.00	98	-0.6/+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	0.30	1.4571	4.60	86	-0.6/+0.2	±0.8	34.0	-	-	24.0	8	±0.25	±0.90	±0.010	1200	2.40	77800	7.15	9.0

HYDRA® STAINLESS STEEL METAL BELLOWS PREFERRED SERIES



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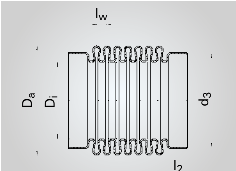

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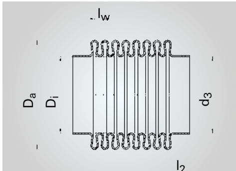


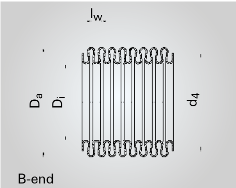
I cuff

Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff Ø
	PN*	D_i	D_a	n_L	s		l_W		D_i	D_a	d_4
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm
24	220	24.0	36.5	5	0.30	1.4571	4.90	61	-0.6/+0.2	±0.8	33.0
	320	24.0	36.5	6	0.30	1.4571	5.30	80	-0.6/+0.2	±0.8	33.0
27	7	27.0	41.0	1	0.15	1.4571	3.10	99	-0.4/+0.1	±0.5	37.5
	20	27.0	41.0	2	0.15	1.4571	3.40	100	-0.6/+0.2	±0.5	37.5
	32	27.0	41.0	2	0.20	1.4571	3.70	100	-0.6/+0.2	±0.5	37.5
	50	27.0	41.0	2	0.25	1.4571	4.10	99	-0.6/+0.2	±0.5	37.5
	60	27.0	41.0	3	0.20	1.4571	4.30	100	-0.6/+0.2	±0.5	37.5
	70	27.0	41.0	2	0.30	1.4571	3.55	99	-0.6/+0.2	±0.5	37.5
	90	27.0	40.0	4	0.20	1.4571	4.30	93	-0.6/+0.2	±0.8	36.5
	110	27.0	41.0	3	0.30	1.4571	4.40	90	-0.6/+0.2	±0.8	37.5
	160	27.0	41.0	4	0.30	1.4571	5.20	76	-0.6/+0.2	±0.8	37.5
29	10	29.5	42.0	1	0.15	1.4571	3.10	97	-0.4/+0.1	±0.5	39.0
	18	29.0	43.0	1	0.25	1.4571	3.70	73	-0.6/+0.2	±0.5	39.0
	36	29.0	43.0	2	0.20	1.4571	3.80	101	-0.6/+0.2	±0.5	39.0
	50	29.0	43.0	2	0.25	1.4571	4.20	101	-0.6/+0.2	±0.5	39.0
	90	29.0	43.0	3	0.25	1.4571	4.70	94	-0.6/+0.2	±0.5	39.0
	140	29.0	43.0	4	0.25	1.4571	5.00	88	-0.4/+0.1	±0.8	39.0
	180	29.0	44.0	4	0.30	1.4571	5.50	73	-0.6/+0.2	±0.8	38.0
	240	29.0	44.0	6	0.25	1.4571	6.20	70	-0.6/+0.2	±0.8	38.0
	280	29.0	44.5	7	0.25	1.4571	6.80	61	-0.8/+0.3	±0.8	38.0
	350	29.0	44.5	7	0.30	1.4571	6.00	50	-0.8/+0.3	±0.8	38.0
30	10	30.2	43.5	1	0.15	1.4571	3.60	111	-0.4/+0.1	±0.5	39.0
	20	30.2	43.5	2	0.15	1.4571	3.70	101	-0.6/+0.2	±0.5	39.0
34	6	34.0	50.0	1	0.15	1.4571	3.40	74	-0.4/+0.1	±0.5	47.0
	11	34.0	50.0	1	0.20	1.4571	3.50	74	-0.6/+0.2	±0.5	47.0
	25	34.0	50.0	2	0.20	1.4571	4.20	73	-0.6/+0.2	±0.5	47.0
	40	34.0	50.0	2	0.25	1.4571	4.40	73	-0.6/+0.2	±0.5	47.0

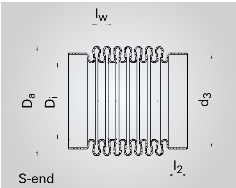
* Outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

S-end		I-cuff		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per corrugation
Ø	Length	Ø	Length								
d_3	l_2	d_3	l_2	axial	angular	lateral	axial	angular	lateral		
inside		inside		$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	mm	mm	mm	mm	degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
-	-	24.0	8	±0.20	±0.75	±0.008	2200	4.40	126000	7.15	11.4
-	-	24.0	8	±0.19	±0.60	±0.006	3700	7.39	180800	7.15	13.6
37.2	4.0	27.0	8	±0.65	±1.60	±0.019	52	0.13	9400	9.10	1.7
37.2	4.0	27.0	8	±0.60	±1.50	±0.019	110	0.27	16500	9.10	3.5
37.2	4.0	27.0	8	±0.46	±1.30	±0.016	260	0.65	32900	9.10	5.2
36.0	4.0	27.0	8	±0.36	±1.00	±0.014	520	1.31	53600	9.10	7.0
37.2	4.0	27.0	8	±0.40	±1.00	±0.013	430	1.10	40300	9.10	7.0
36.0	4.0	27.0	8	±0.30	±0.90	±0.011	900	2.26	123800	9.10	8.0
-	-	27.0	8	±0.32	±0.80	±0.012	700	1.71	63700	8.80	8.7
36.0	4.0	27.0	8	±0.26	±0.80	±0.011	1500	3.80	134000	9.10	12.0
-	-	27.0	8	±0.23	±0.70	±0.011	2200	5.54	141100	9.10	16.0
38.5	4.0	29.5	8	±0.55	±1.50	±0.018	70	0.19	14000	10.0	2.0
39.0	4.0	29.0	8	±0.48	±1.40	±0.018	210	0.61	29800	10.2	3.2
39.0	4.0	29.0	8	±0.50	±1.30	±0.017	260	0.74	35000	10.2	4.9
39.0	4.0	29.0	8	±0.44	±1.20	±0.017	510	1.44	56200	10.2	6.3
-	-	29.0	8	±0.40	±1.10	±0.017	920	2.60	81000	10.2	9.5
-	-	29.0	8	±0.35	±1.00	±0.016	1360	3.85	106000	10.2	12.6
-	-	29.0	8	±0.35	±0.90	±0.015	2100	6.10	138000	10.5	17.0
-	-	29.0	8	±0.26	±0.75	±0.014	2320	6.80	122000	10.6	19.6
-	-	29.0	8	±0.24	±0.60	±0.031	2900	8.50	127000	10.6	23.5
-	-	29.0	8	±0.17	±0.50	±0.011	5200	15.30	293000	10.6	29.0
39.0	4.0	30.2	8	±0.65	±1.60	±0.020	55	0.16	8600	10.7	2.2
39.0	4.0	30.2	8	±0.55	±1.50	±0.018	135	0.40	20000	10.7	4.4
45.3	5.0	34.0	10	±0.80	±1.70	±0.022	46	0.18	10500	13.9	2.5
45.3	5.0	34.0	10	±0.65	±1.50	±0.018	95	0.36	20500	13.9	3.4
45.3	5.0	34.0	10	±0.63	±1.45	±0.018	200	0.77	30000	13.9	6.9
45.3	5.0	34.0	10	±0.53	±1.25	±0.018	390	1.50	53300	13.9	8.6

HYDRA® STAINLESS STEEL METAL BELLOWS PREFERRED SERIES



B-end



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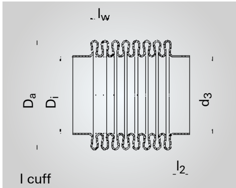
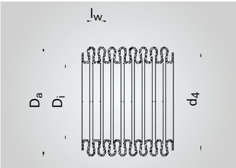


I cuff

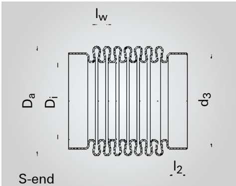
* Outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff Ø	S-end		I-cuff		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per corrugation
												Ø	Length	Ø	Length								
												d_3	l_2	d_3	l_2	axial	angular	lateral	axial	angular	lateral		
	PN*	D_i	D_a	n_L	s		l_W		D_i	D_a	d_4	inside		inside		$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	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	55	34.0	50.0	2	0.30	1.4571	4.60	73	-0.6/+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	50.0	3	0.30	1.4571	5.10	72	-0.6/+0.2	±0.8	46.0	-	-	34.0	10	±0.40	±1.00	±0.016	1200	4.57	122000	13.9	16.0
	130	34.0	51.0	4	0.30	1.4571	5.50	72	-0.6/+0.2	±0.8	46.0	-	-	34.0	10	±0.38	±0.95	±0.016	1500	5.90	134400	14.2	21.8
	240	34.0	48.0	5	0.30	1.4571	5.60	72	-0.6/+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	-0.8/+0.3	±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	-0.8/+0.3	±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	-0.8/+0.3	±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	-0.6/+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	-0.6/+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	-0.6/+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	-0.6/+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	-0.6/+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	-0.8/+0.3	±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	-0.8/+0.3	±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	-0.8/+0.3	±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	-0.6/+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	-0.6/+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	-0.6/+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	-0.6/+0.2	±0.8	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	-0.6/+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	-0.6/+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	-0.6/+0.2	±0.8	55.0	-	-	42.0	10	±0.42	±0.90	±0.018	2000	11.60	162400	20.8	34.0
	165	42.0	62.0	6	0.30	1.4571	7.60	39	-0.8/+0.3	±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	-0.8/+0.3	±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	-0.8/+0.3	±0.8	55.0	-	-	42.0	10	±0.30	±0.65	±0.014	4000	23.20	225500	20.8	58.0

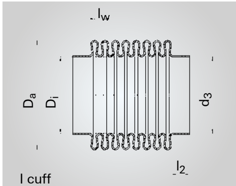
HYDRA® STAINLESS STEEL METAL BELLOWS PREFERRED SERIES



B-end



S-end



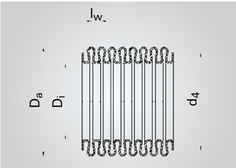
I cuff

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

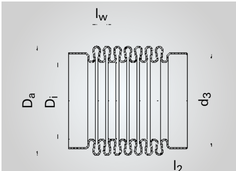
Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff Ø
	PN*	D_i	D_a	n_L	s		l_W		D_i	D_a	d_4
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm
47	8	47.6	66.0	1	0.20	1.4571	4.30	62	-0.6/+0.2	±0.8	62.5
	17	47.6	66.0	2	0.20	1.4571	4.70	62	-0.6/+0.2	±0.8	62.5
	28	47.8	66.0	2	0.25	1.4571	5.10	63	-0.6/+0.2	±0.8	62.5
	40	47.4	66.0	2	0.30	1.4571	5.20	63	-0.6/+0.2	±0.8	62.5
	65	47.4	66.0	3	0.30	1.4571	5.70	52	-0.6/+0.2	±0.8	62.5
	95	47.4	66.0	4	0.30	1.4571	6.60	45	-0.6/+0.2	±0.8	62.5
	130	47.4	66.0	5	0.30	1.4571	6.70	44	-0.8/+0.3	±1.0	57.0
	200	47.4	64.0	6	0.30	1.4571	7.10	42	-0.8/+0.3	±1.0	57.0
	270	47.4	64.0	8	0.30	1.4571	7.70	38	-0.8/+0.3	±1.0	57.0
51	10	51.4	71.0	1	0.25	1.4571	4.20	59	-0.6/+0.2	±0.8	61.0
	22	51.4	71.0	2	0.25	1.4571	4.90	58	-0.6/+0.2	±0.8	67.5
	32	51.4	71.0	2	0.30	1.4571	5.20	60	-0.6/+0.2	±0.8	67.5
	50	51.4	71.0	3	0.30	1.4571	5.80	58	-0.6/+0.2	±0.8	65.0
	75	51.4	71.0	4	0.30	1.4571	6.50	61	-0.6/+0.2	±0.8	65.0
	110	51.4	71.0	5	0.30	1.4571	7.30	41	-0.8/+0.3	±1.0	65.0
	145	51.4	71.0	6	0.30	1.4571	7.70	38	-0.8/+0.3	±1.0	65.0
56	9	56.1	77.0	1	0.25	1.4571	4.90	55	-0.6/+0.2	±0.8	68/73
	22	56.1	77.0	2	0.25	1.4571	5.70	53	-0.6/+0.2	±0.8	68/73
	30	56.1	77.0	2	0.30	1.4571	5.80	55	-0.6/+0.2	±0.8	68/73
	50	56.1	77.0	3	0.30	1.4571	6.20	56	-0.8/+0.3	±0.8	68/73
	65	56.1	77.0	4	0.30	1.4571	6.70	58	-0.8/+0.3	±0.8	73.0
	83	56.1	77.0	5	0.30	1.4571	7.20	41	-0.8/+0.3	±1.0	73.0
60	8	60.0	82.0	1	0.25	1.4571	5.20	52	-0.6/+0.2	±0.8	78.0
	18	60.0	82.0	2	0.25	1.4571	5.90	52	-0.6/+0.2	±0.8	78.0
	22	60.0	82.0	2	0.30	1.4571	6.00	52	-0.6/+0.2	±0.8	78.0
	42	60.0	82.0	3	0.30	1.4571	6.00	54	-0.8/+0.3	±0.8	78.0
	65	60.0	82.0	4	0.30	1.4571	6.70	59	-0.8/+0.3	±0.8	78.0

Reference diameter	PN*	S-cuff		I cuff		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per corrugation
		Ø	Length	Ø	Length	axial	angular	lateral	axial	angular	lateral		
		d_3 inside	l_2	d_3 inside	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	degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
47	8	61.3	5.0	47.6	10	±0.80	±1.50	±0.021	86	0.65	22500	25.3	4.9
	17	61.0	5.0	47.6	10	±0.77	±1.40	±0.021	178	1.40	39000	25.3	9.9
	28	61.0	5.0	47.8	10	±0.70	±1.20	±0.020	320	2.30	59800	25.4	12.5
	40	61.0	5.0	47.4	10	±0.56	±1.00	±0.017	610	4.40	108800	25.2	14.9
	65	-	-	47.4	10	±0.51	±0.90	±0.017	1240	8.60	184000	25.2	22.4
	95	-	-	47.4	10	±0.48	±0.80	±0.015	1850	12.90	204000	25.2	30.8
	130	-	-	47.4	10	±0.44	±0.70	±0.015	2550	17.80	274000	25.2	38.0
	200	-	-	47.4	10	±0.32	±0.60	±0.013	4400	29.80	406200	24.3	42.0
	270	-	-	47.4	10	±0.22	±0.40	±0.010	7000	47.00	549400	24.3	57.0
51	10	65.0	5.0	51.4	10	±0.80	±1.40	±0.018	160	1.30	51000	29.4	7.9
	22	65.0	5.0	51.4	10	±0.75	±1.20	±0.020	330	2.70	77200	29.4	15.3
	32	65.0	5.0	51.4	10	±0.66	±1.10	±0.018	530	4.30	110100	29.4	18.8
	50	65.0	5.0	51.4	10	±0.60	±1.00	±0.018	950	7.80	158500	29.4	27.6
	75	-	-	51.4	10	±0.50	±0.90	±0.017	1270	10.00	168900	29.4	31.7
	110	-	-	51.4	10	±0.47	±0.80	±0.016	1630	13.50	173300	29.6	46.5
	145	-	-	51.4	10	±0.45	±0.70	±0.014	2100	17.50	202300	29.9	56.0
56	9	72.3	5.0	56.1	10	±0.95	±1.40	±0.023	140	1.35	38800	34.8	8.5
	22	72.3	5.0	56.1	10	±0.90	±1.35	±0.025	270	2.70	55200	34.8	16.8
	30	72.3	5.0	56.2	10	±0.72	±1.20	±0.021	480	4.60	94800	34.8	20.3
	50	-	-	56.2	10	±0.65	±1.10	±0.020	880	8.50	152300	34.7	30.5
	65	-	-	56.2	10	±0.62	±1.00	±0.015	1200	11.50	178000	34.7	40.6
	83	-	-	56.2	10	±0.57	±0.90	±0.013	1600	15.50	205000	34.7	51.5
60	8	77.3	5.0	60.0	10	±1.10	±1.50	±0.025	125	1.40	35000	39.6	9.1
	18	77.3	5.0	60.0	10	±1.00	±1.40	±0.025	250	2.80	54300	39.6	18.2
	22	77.3	5.0	60.0	10	±0.80	±1.10	±0.022	440	4.70	92400	39.6	22.0
	42	-	-	60.0	10	±0.65	±0.90	±0.018	700	7.60	147000	39.6	33.0
	65	-	-	60.0	10	±0.60	±0.80	±0.016	1100	12.10	185300	39.6	44.0

HYDRA® STAINLESS STEEL METAL BELLOWS PREFERRED SERIES



B-end



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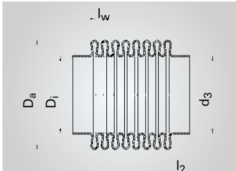


I cuff

06

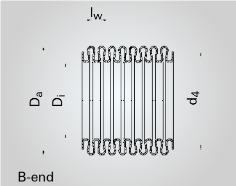
Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff Ø
	PN*	D_i	D_a	n_L	s		l_W		D_i	D_a	d_4
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm
60	8	60.0	82.0	6	0.30	1.4571	7.70	38	-1.0/+0.4	±1.0	76.0
	17	60.8	79.0	7	0.30	1.4571	7.20	41	-1.0/+0.4	±1.0	73.0
66	6	65.5	90.0	1	0.25	1.4571	5.30	47	-0.8/+0.3	±0.8	85.0
	15	65.5	90.0	2	0.25	1.4571	6.00	48	-0.8/+0.3	±0.8	85.0
	20	65.4	90.0	2	0.30	1.4571	6.10	51	-0.8/+0.3	±0.8	85.0
	32	65.4	90.0	3	0.30	1.4571	6.60	60	-0.8/+0.3	±0.8	82.0
	55	65.4	86.0	3	0.30	1.4571	6.40	63	-0.8/+0.3	±0.8	78.0
	90	65.4	90.0	6	0.30	1.4571	8.20	36	-1.0/+0.4	±1.0	82.0
	165	65.4	85.0	6	0.30	1.4571	7.10	36	-1.0/+0.4	±1.0	78.0
70	7	72.0	95.0	1	0.25	1.4571	4.50	52	-0.8/+0.3	±1.0	85.0
	18	70.5	95.0	2	0.30	1.4571	5.90	46	-0.8/+0.3	±1.0	85.0
	45	70.5	92.0	3	0.30	1.4571	6.10	55	-0.8/+0.3	±1.0	85.0
	60	70.5	92.0	4	0.30	1.4571	7.00	53	-1.0/+0.4	±1.0	85.0
77	7	77.5	101.0	1	0.25	1.4571	5.50	48	-0.8/+0.3	±1.0	95.0
	16	77.5	101.0	2	0.25	1.4571	6.30	49	-0.8/+0.3	±1.0	95.0
	20	77.4	101.0	2	0.30	1.4571	6.40	48	-0.8/+0.3	±1.0	95.0
	30	76.5	101.0	3	0.30	1.4571	7.20	48	-0.8/+0.3	±1.0	95.0
85	3	85.0	114.5	1	0.20	1.4571	7.00	38	-0.8/+0.3	±1.0	104.0
	8	85.0	110.0	1	0.30	1.4571	6.60	45	-0.8/+0.3	±1.0	104.0
	25	85.0	106.0	2	0.30	1.4571	6.00	54	-0.8/+0.3	±1.0	101.0
	45	85.0	106.0	3	0.30	1.4571	6.50	54	-0.8/+0.3	±1.0	101.0
	65	85.0	106.0	4	0.30	1.4571	6.90	52	-0.8/+0.3	±1.0	101.0
	80	85.0	108.0	5	0.30	1.4571	7.60	52	-1.0/+0.4	±1.0	101.0
93	18	93.0	120.0	2	0.30	1.4571	9.00	40	-0.8/+0.3	±1.0	110.0
96	8	96.0	122.0	1	0.30	1.4571	7.10	43	-0.8/+0.3	±1.0	113.0
	12	96.0	122.0	2	0.25	1.4571	6.50	45	-0.8/+0.3	±1.0	113.0
	18	96.0	122.0	3	0.30	1.4571	6.70	44	-0.8/+0.3	±1.0	113.0

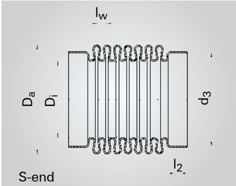
* Outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

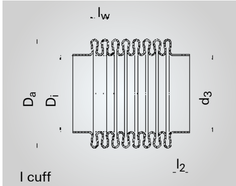
06

S-cuff		I-cuff		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per corrugation
Ø	Length	Ø	Length								
d_3	l_2	d_3	l_2	axial	angular	lateral	axial	angular	lateral		
inside		inside		$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	mm	mm	mm	mm	degree	mm	N/mm	Nm/degree	N/mm	cm²	g
-	-	60.0	10	±0.50	±0.65	±0.014	1800	19.80	229600	39.6	44.0
-	-	60.8	10	±0.35	±0.60	±0.012	4000	42.50	565500	38.4	64.0
84.3	5.0	65.5	10	±1.10	±1.40	±0.024	90	1.20	29100	47.5	11.2
84.3	5.0	65.5	10	±1.00	±1.35	±0.024	190	2.50	47900	47.5	22.4
84.3	5.0	65.4	10	±0.95	±1.20	±0.024	330	4.50	80300	47.4	26.9
-	-	65.4	10	±0.85	±1.10	±0.023	540	7.20	112300	47.4	40.4
-	-	65.4	10	±0.60	±0.85	±0.016	1075	13.40	225300	44.9	35.8
-	-	65.4	10	±0.65	±0.80	±0.018	1400	18.00	188500	47.4	81.0
-	-	65.4	10	±0.40	±0.60	±0.012	3300	41.00	554500	44.4	65.2
84.3	5.0	72.0	10	±1.00	±1.35	±0.017	150	2.30	77500	54.8	19
84.3	5.0	70.5	10	±1.00	±1.35	±0.023	360	5.40	106000	53.8	28
-	-	70.5	10	±0.70	±0.90	±0.017	900	12.80	239500	51.8	37
-	-	70.5	10	±0.67	±0.80	±0.012	1800	26.00	363000	51.8	50
95.3	5.0	77.5	10	±1.20	±1.30	±0.024	120	2.10	47400	62.5	13
95.3	5.0	77.5	10	±1.10	±1.20	±0.025	250	4.60	75300	62.5	26
95.3	5.0	77.4	10	±0.95	±1.10	±0.023	425	7.40	123800	62.5	31
-	-	76.5	10	±0.90	±0.95	±0.022	610	11.50	139000	61.7	46
-	-	85.1	10	±1.90	±1.40	±0.030	45	1.00	13800	78.2	10
103.5	5.0	85.0	10	±1.20	±1.20	±0.027	200	4.10	65500	74.6	10
99.0	5.0	85.0	10	±0.90	±1.00	±0.021	710	14.00	268500	71.3	34
-	-	85.0	10	±0.70	±0.80	±0.020	1150	22.50	370000	71.1	51
-	-	85.0	10	±0.60	±0.70	±0.017	1600	32.00	460000	71.6	68
-	-	85.0	10	±0.55	±0.60	±0.012	1700	34.50	411000	73.0	85
113.0	5.0	93.0	10	±1.40	±1.00	±0.035	360	9.00	75600	89.0	50
115.4	5.0	96.0	10	±1.20	±1.10	±0.026	180	4.70	63600	93.3	23
115.4	5.0	96.0	10	±1.25	±1.05	±0.024	220	5.70	92800	93.3	37
115.4	5.0	96.0	10	±1.00	±0.90	±0.020	385	10.00	152800	93.3	45

HYDRA® STAINLESS STEEL METAL BELLOWS PREFERRED SERIES







Reference diameter	Nominal pressure	Bellows profile				Material	Corrugation length	Max. number of corrugations	Ø Tolerances		B-cuff Ø
	PN*	D_i	D_a	n_L	s		l_W		D_i	D_a	d_4
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm	mm
96	30	96.0	122.0	3	0.30	1.4571	7.40	45	-0.8/+0.3	±1.0	113.0
	45	96.0	122.0	4	0.30	1.4571	7.80	43	-0.8/+0.3	±1.0	113.0
105	5	105.3	132.0	1	0.25	1.4571	6.80	42	-0.8/+0.3	±1.0	126.0
	8	105.2	132.0	1	0.30	1.4571	6.30	42	-0.8/+0.3	±1.0	126.0
	16	105.2	132.0	2	0.30	1.4571	7.30	50	-0.8/+0.3	±1.0	126.0
	25	105.2	132.0	3	0.30	1.4571	8.00	46	-0.8/+0.3	±1.0	126.0
110	5	110.3	138.0	1	0.25	1.4571	7.20	52	-0.8/+0.3	±1.5	132.0
	12	110.2	130.0	1	0.30	1.4571	5.50	55	-0.8/+0.3	±1.5	125.0
	25	110.2	130.0	2	0.30	1.4571	6.20	50	-0.8/+0.3	±1.5	125.0
	40	110.2	130.0	3	0.30	1.4571	7.00	48	-0.8/+0.3	±1.5	125.0
	60	110.2	132.0	4	0.30	1.4571	7.50	42	-0.8/+0.3	±1.5	125.0
	70	110.2	134.0	5	0.30	1.4571	8.00	40	-1.0/+0.4	±1.5	125.0
115	10	115.0	140.0	1	0.30	1.4571	6.80	38	-0.8/+0.3	±1.5	132.0
	18	115.0	133.0	1	0.30	1.4571	5.10	52	-0.8/+0.3	±1.5	127.5
	40	115.0	133.0	2	0.30	1.4571	5.30	40	-0.8/+0.3	±1.5	127.5
135	10	135.0	174.0	2	0.30	1.4571	13.00	42	-0.5/+1.5	-1.5/+0.5	158.0
	18	135.0	171.0	3	0.30	1.4571	14.00	39	-0.5/+1.5	-1.5/+0.5	157.0
	32	135.0	172.0	5	0.30	1.4571	14.00	39	-0.5/+1.5	-1.5/+0.5	157.0
	55	135.0	174.0	8	0.30	1.4571	16.00	34	-0.5/+1.5	-1.5/+0.5	158.0
164	10	164.0	203.0	2	0.30	1.4571	13.00	42	-0.5/+1.5	-1.5/+0.5	-
	16	164.0	202.0	3	0.30	1.4571	14.00	39	-0.5/+1.5	-1.5/+0.5	-
	25	164.0	203.0	5	0.30	1.4571	15.00	36	-0.5/+1.5	-1.5/+0.5	-
	40	164.0	205.0	8	0.30	1.4571	16.00	34	-0.5/+1.5	-1.5/+0.5	-
214	8	214.0	255.0	2	0.30	1.4571	15.00	36	-0.5/+1.5	-1.5/+0.5	-
	12	214.0	256.0	3	0.30	1.4571	16.00	34	-0.5/+1.5	-1.5/+0.5	-
	20	214.0	257.0	5	0.30	1.4571	17.00	32	-0.5/+1.5	-1.5/+0.5	-
	32	214.0	260.0	8	0.30	1.4571	18.00	30	-0.5/+1.5	-1.5/+0.5	-

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

S-end		I-cuff		Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per corrugation
Ø	Length	Ø	Length								
d_3	l_2	d_3	l_2	axial	angular	lateral	axial	angular	lateral		
inside		inside		$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	mm	mm	mm	mm	degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
115.4	5.0	96.0	10	±0.90	±0.80	±0.020	620	16.00	202000	93.3	66
-	-	96.0	10	±0.90	±0.80	±0.019	1100	28.50	322000	93.3	86
124.0	5.0	105.3	10	±1.50	±1.30	±0.028	150	4.60	68500	111	21
124.0	5.0	105.2	10	±1.20	±1.10	±0.021	240	7.40	127500	111	25
124.0	5.0	105.2	10	±1.20	±1.00	±0.024	465	14.20	183600	110	50
124.0	5.0	105.2	10	±1.10	±0.90	±0.024	760	23.20	250500	111	75
132.4	8.0	110.3	10	±1.70	±1.30	±0.032	140	4.70	62400	121	23
124.4	8.0	110.2	10	±0.75	±0.80	±0.013	460	14.70	329000	113	18
124.4	8.0	110.2	10	±0.75	±0.70	±0.012	950	30.00	535000	113	37
-	-	110.2	10	±0.70	±0.60	±0.012	1600	50.00	706000	113	55
-	-	110.2	10	±0.65	±0.55	±0.010	2050	65.00	802000	115	72
-	-	110.2	10	±0.60	±0.50	±0.008	2200	71.00	769000	117	90
-	-	115.0	10	±1.00	±0.80	±0.017	330	11.70	174000	128	26.0
-	-	115.0	10	±0.50	±0.40	±0.006	780	26.20	692000	121	19.0
-	-	115.0	10	±0.45	±0.40	±0.006	1550	52.00	1273000	121	37.4
-	-	135.0	16.5	±3.00	±2.00	±0.080	210	11.00	44500	188	95
-	-	135.0	16.5	±2.20	±1.50	±0.065	440	22.50	78800	184	131
-	-	135.0	16.5	±2.00	±1.40	±0.060	725	37.30	131000	185	222
-	-	135.0	16.5	±1.70	±1.20	±0.055	2500	130.00	350000	188	366
-	-	164.0	16.4	±3.00	±1.80	±0.070	250	18.40	74700	265	114
-	-	164.0	16.7	±2.60	±1.60	±0.065	425	31.00	109000	263	167
-	-	164.0	16.6	±2.40	±1.40	±0.065	750	33.00	168000	265	282
-	-	164.0	16.3	±2.10	±1.30	±0.060	1210	90.00	241000	267	466
-	-	214.0	17	±3.30	±1.60	±0.070	275	33.00	100800	432	158
-	-	214.0	17.2	±3.10	±1.50	±0.070	415	50.00	134000	434	241
-	-	214.0	17.2	±3.00	±1.40	±0.070	685	83.00	197000	436	407
-	-	214.0	16.8	±2.80	±1.30	±0.070	1075	132.00	280000	441	685

HYDRA® METAL BELLOWS FOR ANSI/ASME VALVES

06

In addition to the reference diameter, the maximum possible valve shaft diameter is also indicated for HYDRA metal bellows which are especially configured for ANSI/ASME standard valves.
The bellows are designed to tolerate a test pressure of 1.5 times the design pressure (compare Table 6.4.1.).
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

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

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

Bellows description:
(example)

BAT		60.0	x	82.0	x	6	x	0.3	x	15W	x	1.4571
Bellows with connectors		Inside diameter d_i = 60 mm		Outside diameter D_A = 82.0 mm		Individual number of layers n_L = 6		Individual layer thickness s = 0.3 mm		15 corrugations		Material 1.4571

Pressure stages according to ANSI/ASME 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.

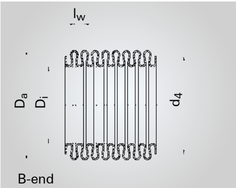
06

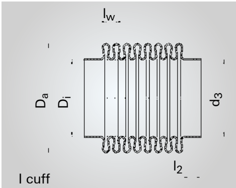
Load cycle numbers as per MSS SP-117

Nominal valve diameter	ANSI/ASME pressure stage class 800 and below		ANSI/ASME pressure stage greater than class 800	
	GATE valve	GLOBE valve	GATE valve	GLOBE valve
smaller than 2½"	2,000	5,000	2,000	2,000
2½" up 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.

HYDRA® METAL BELLOWS FOR ANSI/ASME VALVES



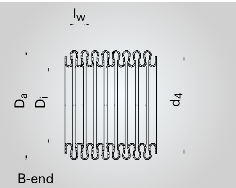


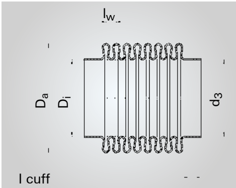
Reference diameter	Maximum Spindle diameter	ASME Class	Nominal pressure	Bellows profile				Material	Max. number of corrugations	Corrugation length
			PN*	D_i	D_a	n_L	s			l_W
mm	mm	–	bar	mm	mm	–	mm	–	–	mm
9	7.5	150	25	9.0	14.0	1	0.10	1.4541 / 1.4571	235	1.30
		300	50	9.0	14.5	2	0.10	1.4541 / 1.4571	214	1.75
		600	100	9.0	14.0	3	0.10	1.4541 / 1.4571	220	1.75
		800/900	150	9.0	14.0	4	0.10	1.4541 / 1.4571	191	2.00
		1500	250	9.0	13.0	4	0.10	1.4541 / 1.4571	258	1.50
16	14.5	150	25	16.6	24.0	2	0.10	1.4541 / 1.4571	104	2.00
		300	50	16.8	24.0	2	0.15	1.4541 / 1.4571	106	2.30
		600	100	16.4	24.0	3	0.15	1.4541 / 1.4571	104	2.50
		800/900	150	16.4	24.0	4	0.15	1.4541 / 1.4571	103	3.00
		1500	250	16.0	24.5	4	0.20	1.4541 / 1.4571	89	3.80
18	16.5	150	25	18.2	26.0	2	0.10	1.4541 / 1.4571	97	2.70
		300	50	18.0	26.0	2	0.15	1.4541 / 1.4571	93	2.60
		600	100	18.0	28.0	3	0.20	1.4541 / 1.4571	75	3.50
		800/900	150	18.0	28.0	3	0.25	1.4541 / 1.4571	75	3.80
		1500	250	18.0	28.0	4	0.25	1.4541 / 1.4571	82	3.50
22	20.5	150	25	22.0	32.5	2	0.15	1.4541 / 1.4571	73	2.80
		300	50	22.0	32.0	2	0.20	1.4541 / 1.4571	77	3.20
		600	100	22.0	32.0	3	0.20	1.4541 / 1.4571	77	3.30
		800/900	150	22.0	34.0	4	0.25	1.4541 / 1.4571	59	4.30
		1500	250	22.0	34.0	4	0.30	1.4541 / 1.4571	65	4.50
24	22.5	150	25	24.2	35.5	2	0.15	1.4541 / 1.4571	71	3.10
		300	50	24.2	36.5	2	0.25	1.4541 / 1.4571	63	3.30
		600	100	24.0	36.5	3	0.25	1.4541 / 1.4571	62	4.00
		800/900	150	24.0	36.0	4	0.25	1.4541 / 1.4571	64	4.60
		1500	250	24.0	36.5	5	0.25	1.4541 / 1.4571	66	4.80
27	25.0	150	25	27.0	38.0	2	0.15	1.4541 / 1.4571	111	2.80
		300	50	27.0	40.0	2	0.25	1.4541 / 1.4571	88	4.00

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

Ø Tolerances		B-end	I cuff		Nominal deflection per corrugation			Axial Spring rate per corrugation (±30 %)
		Ø	Ø	Length	1,000	2,000	5,000	
d_i	D_a	d_4	d_3	l_2	Load cycles	Load cycles	Load cycles	
			inside		$2_{dn,1000}$	$2_{dn,2000}$	$2_{dn,5000}$	
mm	mm	mm	mm	mm	–	–	–	N/mm
-0.4/+0.1	±0.3	12.5	9.0	5	0.26	0.23	0.19	115
-0.4/+0.1	±0.3	13.0	9.0	5	0.32	0.28	0.23	160
-0.4/+0.1	±0.5	12.5	9.0	5	0.22	0.19	0.16	450
-0.6/+0.2	±0.5	12.5	9.0	5	0.22	0.19	0.16	760
-0.6/+0.2	±0.5	11.7	9.0	5	0.13	0.11	0.09	1230
-0.4/+0.1	±0.5	21.5	16.6	6	0.47	0.41	0.34	126
-0.4/+0.1	±0.5	21.5	16.8	6	0.35	0.30	0.25	420
-0.6/+0.2	±0.5	21.5	16.4	6	0.35	0.30	0.25	680
-0.6/+0.2	±0.5	21.5	16.4	6	0.31	0.27	0.22	1000
-0.6/+0.2	±0.8	21.5	16.0	6	0.22	0.19	0.16	2150
-0.4/+0.1	±0.5	24.0	18.2	6	0.61	0.54	0.44	154
-0.6/+0.2	±0.5	24.0	18.0	6	0.43	0.38	0.31	405
-0.6/+0.2	±0.5	25.0	18.0	6	0.40	0.35	0.29	1000
-0.6/+0.2	±0.5	25.0	18.0	6	0.35	0.30	0.25	1700
-0.6/+0.2	±0.8	25.0	18.0	6	0.25	0.22	0.18	2840
-0.6/+0.2	±0.5	28.0	22.0	8	0.63	0.55	0.45	217
-0.6/+0.2	±0.5	28.0	22.0	8	0.45	0.39	0.32	660
-0.6/+0.2	±0.5	28.0	22.0	8	0.38	0.33	0.27	1020
-0.6/+0.2	±0.8	30.0	22.0	8	0.38	0.33	0.27	1900
-0.6/+0.2	±0.8	30.0	22.0	8	0.29	0.26	0.21	3600
-0.6/+0.2	±0.5	34.0	24.2	8	0.75	0.66	0.54	200
-0.6/+0.2	±0.5	34.0	24.2	8	0.51	0.45	0.37	590
-0.6/+0.2	±0.5	34.0	24.0	8	0.49	0.43	0.35	860
-0.6/+0.2	±0.8	34.0	24.0	8	0.39	0.34	0.28	2060
-0.6/+0.2	±0.8	34.0	24.0	8	0.31	0.27	0.22	3650
-0.6/+0.2	±0.5	34.5	27.0	8	0.67	0.58	0.48	220
-0.6/+0.2	±0.5	37.5	27.0	8	0.56	0.49	0.40	660

HYDRA® METAL BELLOWS FOR ANSI/ASME VALVES



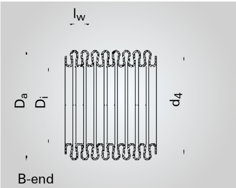


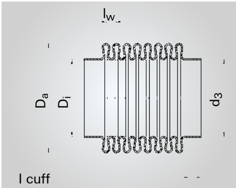
Reference diameter	Maximum Spindle diameter	ASME Class	Nominal pressure PN*	Bellows profile D_i	D_a	n_L	s	Material	Max. number of corrugations	Corrugation length l_W
mm	mm	–	bar	mm	mm	–	mm	–	–	mm
27	25.0	600	100	27.0	39.5	3	0.25	1.4541 / 1.4571	93	4.00
		800/900	150	27.0	41.0	3	0.30	1.4541 / 1.4571	87	5.20
29	27.0	150	25	29.0	43.0	2	0.20	1.4541 / 1.4571	83	3.80
		300	50	29.0	42.0	2	0.25	1.4541 / 1.4571	88	3.80
		600	100	29.0	43.0	4	0.25	1.4541 / 1.4571	82	5.00
		800/900	150	29.0	41.5	4	0.25	1.4541 / 1.4571	88	4.80
		1500	250	29.0	43.0	5	0.30	1.4541 / 1.4571	70	5.80
34	32.0	150	25	34.0	49.0	2	0.20	1.4541 / 1.4571	73	4.20
		300	50	34.0	50.0	2	0.30	1.4541 / 1.4571	73	4.60
		600	100	34.0	49.0	3	0.30	1.4541 / 1.4571	75	5.10
		800/900	150	34.0	48.0	4	0.30	1.4541 / 1.4571	78	5.20
		1500	250	34.0	48.0	5	0.30	1.4541 / 1.4571	70	5.60
38	36.2	150	25	38.8	53.5	2	0.20	1.4541 / 1.4571	83	4.50
		300	50	39.0	54.0	2	0.30	1.4541 / 1.4571	73	4.40
		600	100	38.2	56.0	4	0.30	1.4541 / 1.4571	70	5.50
		800/900	150	38.2	55.0	5	0.30	1.4541 / 1.4571	67	6.00
		1500	250	38.2	54.0	6	0.30	1.4541 / 1.4571	54	6.40
42	40.0	150	25	42.0	60.0	2	0.20	1.4541 / 1.4571	63	5.00
		300	50	42.0	58.0	2	0.30	1.4541 / 1.4571	73	4.80
		600	100	42.0	60.0	4	0.30	1.4541 / 1.4571	67	6.20
		800/900	150	42.0	61.0	6	0.30	1.4541 / 1.4571	59	7.40
		1500	250	42.0	60.0	7	0.30	1.4541 / 1.4571	53	8.00
47	45.4	150	25	47.8	66.0	2	0.20	1.4541 / 1.4571	63	5.10
		300	50	47.4	63.0	2	0.30	1.4541 / 1.4571	78	5.00
		600	100	47.4	65.0	4	0.30	1.4541 / 1.4571	61	6.30
		800/900	150	47.4	64.0	6	0.30	1.4541 / 1.4571	58	7.10
		1500	250	47.4	64.0	8	0.30	1.4541 / 1.4571	51	7.70

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

Ø Tolerances d_i	Ø Tolerances D_a	B-end Ø d_4	I-cuff Ø d_3 inside	I-cuff Length l_2	Nominal deflection per corrugation 1,000 Load cycles $2_{dn,1000}$	2,000 Load cycles $2_{dn,2000}$	5,000 Load cycles $2_{dn,5000}$	Axial Spring rate per corrugation (±30 %)
mm	mm	mm	mm	mm	–	–	–	N/mm
-0.6/+0.2	±0.5	36.5	27.0	8	0.45	0.39	0.32	1250
-0.6/+0.2	±0.8	37.5	27.0	8	0.36	0.32	0.26	2450
-0.6/+0.2	±0.5	39.0	29.0	8	0.83	0.73	0.60	260
-0.6/+0.2	±0.5	39.0	29.0	8	0.63	0.55	0.45	690
-0.6/+0.2	±0.8	39.0	29.0	8	0.56	0.49	0.40	1360
-0.6/+0.2	±0.8	39.0	29.0	8	0.49	0.43	0.35	2100
-0.6/+0.2	±0.8	39.0	29.0	8	0.42	0.37	0.30	4020
-0.6/+0.2	±0.5	47.0	34.0	10	1.00	0.88	0.72	270
-0.6/+0.2	±0.5	47.0	34.0	10	0.74	0.65	0.53	700
-0.6/+0.2	±0.8	47.0	34.0	10	0.61	0.54	0.44	1560
-0.6/+0.2	±0.8	45.0	34.0	10	0.49	0.43	0.35	2850
-0.6/+0.2	±0.8	45.0	34.0	10	0.40	0.35	0.29	3500
-0.6/+0.2	±0.8	47.0	38.8	10	0.97	0.85	0.70	310
-0.6/+0.2	±0.8	47.0	39.0	10	0.67	0.58	0.48	1000
-0.6/+0.2	±0.8	47.0	38.2	10	0.65	0.57	0.47	1400
-0.6/+0.2	±0.8	47.0	38.2	10	0.58	0.51	0.42	2570
-0.8/+0.3	±0.8	47.0	38.2	10	0.45	0.39	0.32	4550
-0.6/+0.2	±0.8	57.0	42.0	10	1.14	1.00	0.82	380
-0.6/+0.2	±0.8	50.5	42.0	10	0.75	0.66	0.54	880
-0.6/+0.2	±0.8	50.5	42.0	10	0.72	0.63	0.52	1500
-0.8/+0.3	±0.8	55.0	42.0	10	0.61	0.54	0.44	2900
-0.8/+0.3	±0.8	55.0	42.0	10	0.46	0.40	0.33	4830
-0.6/+0.2	±0.8	62.5	47.8	10	1.21	1.06	0.87	320
-0.6/+0.2	±0.8	56.5	47.4	10	0.72	0.63	0.52	1025
-0.6/+0.2	±0.8	57.0	47.4	10	0.70	0.61	0.50	1850
-0.8/+0.3	±1.0	57.0	47.4	10	0.51	0.45	0.37	4400
-0.8/+0.3	±1.0	57.0	47.7	10	0.36	0.32	0.26	7000

HYDRA® METAL BELLOWS FOR ANSI/ASME VALVES



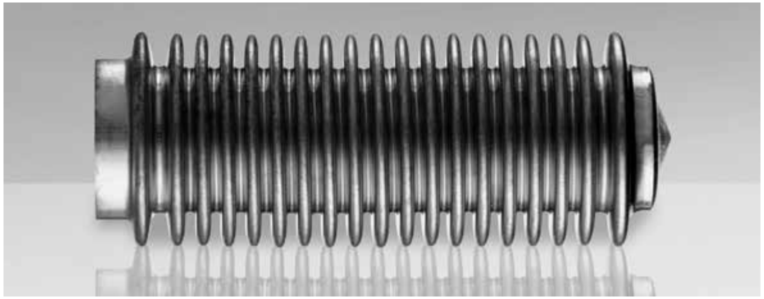


Reference diameter	Maximum Spindle diameter	ASME Class	Nominal pressure PN*	Bellows profile D_i	D_a	n_L	s	Material	Max. number of corrugations	Corrugation length l_W
mm	mm	–	bar	mm	mm	–	mm	–	–	mm
56	54.0	150	25	56.1	74.5	2	0.25	1.4541 / 1.4571	60	5.40
		300	50	56.2	76.0	3	0.30	1.4541 / 1.4571	56	6.10
		600	100	56.2	77.0	5	0.30	1.4541 / 1.4571	55	7.20
60	58.0	800/900	150	60.0	79.0	6	0.30	1.4541 / 1.4571	52	7.50
53	51.0	1500	250	53.0	70.0	8	0.30	1.4541 / 1.4571	51	7.70
66	63.4	150	25	65.4	87.0	2	0.30	1.4541 / 1.4571	52	5.80
		300	50	65.4	86.0	3	0.30	1.4541 / 1.4571	56	6.40
		600	100	65.4	88.0	6	0.30	1.4541 / 1.4571	53	8.10
		800/900	150	65.4	85.0	6	0.30	1.4541 / 1.4571	54	7.10
70	68.5	150	25	70.5	92.0	2	0.30	1.4541 / 1.4571	53	6.00
		300	50	70.5	90.0	3	0.30	1.4541 / 1.4571	61	5.50
85	83.0	150	25	85.0	106.0	2	0.30	1.4541 / 1.4571	54	6.00
		300	50	85.0	105.0	3	0.30	1.4541 / 1.4571	58	6.20
		600	100	85.0	105.0	5	0.30	1.4541 / 1.4571	51	7.20
96	94.0	800/900	150	96.0	116.0	8	0.30	1.4541 / 1.4571	44	8.20
110	108.2	150	25	110.2	130.0	2	0.30	1.4541 / 1.4571	50	6.20
		300	50	110.2	129.0	3	0.30	1.4541 / 1.4571	58	7.00

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

Ø Tolerances d_i	D_a	B-end Ø d_4	I-cuff Ø d_3 inside	I-cuff Length l_2	Nominal deflection per corrugation 1,000 Load cycles $2_{dn,1000}$	2,000 Load cycles $2_{dn,2000}$	5,000 Load cycles $2_{dn,5000}$	Axial Spring rate per corrugation (±30 %)
mm	mm	mm	mm	mm	–	–	–	N/mm
-1.0/+0.4	±1.0	68.0	56.1	10	1.25	1.10	0.90	425
-0.6/+0.2	±0.8	68.0	56.2	10	1.00	0.88	0.72	990
-0.8/+0.3	±0.8	73.0	56.2	10	0.90	0.79	0.65	1600
-0.8/+0.3	±1.0	73.0	60.0	10	0.58	0.51	0.42	3300
-1.0/+0.4	±1.0	64.0	53.0	10	0.45	0.39	0.32	7700
-0.8/+0.3	±0.8	75.0	65.4	10	1.25	1.10	0.90	530
-0.8/+0.3	±0.8	82.0	65.4	10	0.97	0.85	0.70	985
-1.0/+0.4	±1.0	82.0	65.4	10	1.04	0.91	0.75	2010
-1.0/+0.4	±1.0	80.0	65.4	10	0.63	0.55	0.45	3300
-0.8/+0.3	±1.0	85.0	70.5	10	1.25	1.10	0.90	565
-0.8/+0.3	±1.0	85.0	70.5	10	0.97	0.85	0.70	1220
-0.8/+0.3	±1.0	101.0	85.0	10	1.39	1.22	1.00	710
-0.8/+0.3	±1.0	101.0	85.0	10	1.04	0.91	0.75	1300
-1.0/+0.4	±1.0	101.0	85.0	10	0.92	0.80	0.66	2590
-1.0/+0.4	±1.0	108.0	96.0	10	0.68	0.60	0.49	6100
-0.8/+0.3	±1.5	125.0	110.2	10	1.20	1.05	0.86	950
-0.8/+0.3	±1.5	125.0	110.2	10	0.99	0.86	0.71	1875

HYDRA® METAL BELLOWS MADE OF BRONZE



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).

The dimensions of the possible bronze bellows are available on request.

HYDRA® DIAPHRAGM BELLOWS WITH NORMAL PROFILES

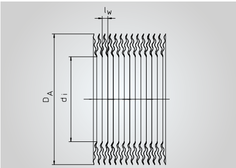
Flexibility for small installation spaces
HYDRA diaphragm bellows with normal profiles have a very high range of movement. They are particularly suited for applications in which large movements must be implemented in very little installation space.
Standard material is 1.4571. Bellows which are subject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

MO: Bellows without connecting pieces
MM: Bellows with connecting pieces

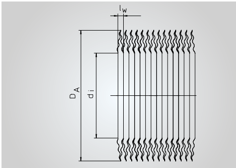
Bellows description:
(example)

MO	26.0	x	57.0	x	1	x	0.1	x	8MP	x	1.4571
Bellows without connectors	Inside diameter d_i = 26.0 mm		Outside diameter D_A = 57.0 mm		Individual number of layers n_L = 6		Individual layer thickness s = 0.1 mm		8 diaphragm pairs		Material 1.4571

HYDRA DIAPHRAGM BELLOWS WITH NORMAL PROFILES PREFERRED SERIES



Connection - outside of bellows



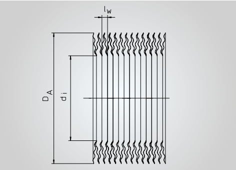
Connection - bellows interior

Reference diameter	Nominal pressure	Diaphragm contour				Material	Length per diaphragm pair	Maximum number of membrane pairs	Ø Tolerances	
	PN*	d_i	D_A	n_L	s		l_W		d_i	D_a
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm
11	5.0	11.0	22.0	1	0.10	1.4541	1.2	120	±0.3	±0.3
	8.0	11.0	22.0	1	0.15	1.4571	1.2	120	±0.3	±0.3
	4.0	11.0	27.0	1	0.10	1.4541	1.4	100	±0.3	±0.3
	6.0	11.0	27.0	1	0.15	1.4571	1.5	95	±0.3	±0.3
	2.0	11.0	31.0	1	0.10	1.4541	2.2	65	±0.3	±0.3
	5.2	11.0	31.0	1	0.15	1.4571	2.2	65	±0.3	±0.3
12	8.0	12.0	22.0	1	0.10	1.4541	1.0	145	±0.3	±0.3
	12.0	12.0	22.0	1	0.15	1.4571	1.0	145	±0.3	±0.3
17	2.1	17.0	37.0	1	0.10	1.4541	2.1	67	±0.3	±0.3
	3.6	17.0	37.0	1	0.15	1.4571	2.1	67	±0.3	±0.3
21	1.3	21.0	42.5	1	0.10	1.4541	2.0	140	±0.3	±0.3
	2.8	21.0	42.5	1	0.15	1.4571	2.0	140	±0.3	±0.3
	5.2	21.0	42.5	1	0.20	1.4571	2.0	140	±0.3	±0.3
	1.0	21.0	49.0	1	0.10	1.4541	3.2	45	±0.3	±0.3
	2.2	21.0	49.0	1	0.15	1.4571	3.1	45	±0.3	±0.3
	4.0	21.0	49.0	1	0.20	1.4571	3.1	45	±0.3	±0.3
26	2.0	25.5	50.0	1	0.10	1.4541	1.9	145	±0.3	±0.3
	3.0	25.5	50.0	1	0.15	1.4571	1.9	145	±0.3	±0.3
	0.8	26.0	57.0	1	0.10	1.4541	3.6	75	±0.3	±0.3
	1.8	26.0	57.0	1	0.15	1.4571	3.7	75	±0.3	±0.3
	3.2	26.0	57.0	1	0.20	1.4571	3.5	80	±0.3	±0.3
29	0.7	29.0	61.0	1	0.10	1.4541	3.8	72	±0.3	±0.3
	1.6	29.0	61.0	1	0.15	1.4571	3.7	75	±0.3	±0.3
	2.9	29.0	61.0	1	0.20	1.4571	3.6	75	±0.3	±0.3
33	0.6	33.0	67.0	1	0.10	1.4541	3.7	75	±0.3	±0.3
	1.4	33.0	67.0	1	0.15	1.4571	3.7	75	±0.3	±0.3
	2.6	33.0	67.0	1	0.20	1.4571	3.7	75	±0.3	±0.3

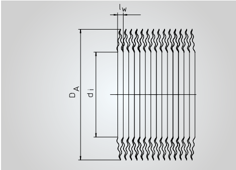
* Outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per diaphragm pair
axial	angular	lateral	axial	angular	lateral		
$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
0.80 = +0.16 / -0.64	±1.11	±0.0038	100	0.06	28000	2.2	0.46
0.70 = +0.14 / -0.56	±0.97	±0.0033	210	0.12	59000	2.2	0.68
1.00 = +0.20 / -0.80	±1.21	±0.0049	77	0.06	21000	3.0	0.76
0.80 = +0.16 / -0.64	±0.96	±0.0042	160	0.13	38000	3.0	1.15
1.20 = +0.24 / -0.96	±1.31	±0.0083	52	0.05	7100	3.7	1.06
1.00 = +0.20 / -0.80	±1.09	±0.0069	107	0.10	15000	3.7	1.58
0.60 = +0.12 / -0.48	±0.81	±0.0023	180	0.11	78000	2.0	0.32
0.60 = +0.12 / -0.48	±0.81	±0.0023	390	0.25	169000	2.0	0.48
1.70 = +0.34 / -1.36	±1.44	±0.0088	60	0.10	15000	6.0	1.36
1.40 = +0.28 / -1.12	±1.19	±0.0072	110	0.17	27000	6.0	2.04
1.60 = +0.32 / -1.28	±1.15	±0.0067	50	0.11	19000	8.1	1.72
1.50 = +0.30 / -1.20	±1.08	±0.0062	90	0.20	34000	8.1	2.57
1.40 = +0.28 / -1.12	±1.01	±0.0058	136	0.30	51400	8.1	3.43
2.40 = +0.48 / -1.92	±1.57	±0.0146	35	0.09	6300	10.1	2.46
2.20 = +0.44 / -1.76	±1.44	±0.0129	64	0.17	12200	10.1	3.69
2.00 = +0.40 / -1.60	±1.31	±0.0118	106	0.28	20300	10.1	4.93
1.00 = +0.20 / -0.80	±0.61	±0.0033	40	0.12	23700	11.6	2.32
0.90 = +0.18 / -0.72	±0.55	±0.0030	95	0.30	56000	11.6	3.49
2.70 = +0.54 / -2.16	±1.49	±0.0156	34	0.13	6800	14.2	3.23
2.50 = +0.50 / -2.00	±1.38	±0.0148	66	0.25	12400	14.2	4.85
2.30 = +0.46 / -1.84	±1.27	±0.0129	101	0.38	21300	14.2	6.47
2.90 = +0.58 / -2.32	±1.48	±0.0163	32	0.14	6700	16.6	3.62
2.70 = +0.54 / -2.16	±1.38	±0.0148	58	0.26	12900	16.6	5.43
2.50 = +0.50 / -2.00	±1.27	±0.0133	95	0.42	22300	16.6	7.24
3.10 = +0.62 / -2.48	±1.42	±0.0152	30	0.16	8200	20.4	4.27
2.90 = +0.58 / -2.32	±1.33	±0.0143	55	0.30	15100	20.4	6.41
2.70 = +0.54 / -2.16	±1.24	±0.0133	94	0.51	25700	20.4	8.55

HYDRA DIAPHRAGM BELLOWS WITH NORMAL PROFILES PREFERRED SERIES



Connection - outside of bellows



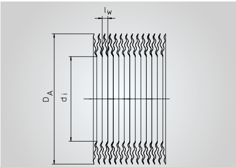
Connection - bellows interior

Reference diameter	Nominal pressure	Diaphragm contour				Material	Length per diaphragm pair	Maximum number of membrane pairs	Ø Tolerances	
	PN*	d_i	D_A	n_L	s		l_W		d_i	D_a
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm
36	0.5	36.0	72.0	1	0.10	1.4541	3.8	72	±0.3	±0.3
	1.3	36.0	72.0	1	0.15	1.4571	3.8	72	±0.3	±0.3
	2.4	36.0	72.0	1	0.20	1.4571	4.0	70	±0.3	±0.3
38	0.7	38.0	66.0	1	0.10	1.4541	2.5	110	±0.3	±0.3
	1.6	38.0	66.0	1	0.15	1.4571	2.6	105	±0.3	±0.3
	3.0	38.0	66.0	1	0.20	1.4571	2.7	100	±0.3	±0.3
42	0.5	42.0	81.0	1	0.10	1.4541	4.1	42	±0.3	±0.3
	1.1	42.0	81.0	1	0.15	1.4571	4.0	45	±0.3	±0.3
	1.9	42.0	81.0	1	0.20	1.4571	4.4	40	±0.3	±0.3
44	0.4	44.0	84.0	1	0.10	1.4541	4.2	35	±0.3	±0.3
	1.0	44.0	84.0	1	0.15	1.4571	4.2	35	±0.3	±0.3
	1.8	44.0	84.0	1	0.20	1.4571	4.2	35	±0.3	±0.3
47	0.4	47.0	88.0	1	0.10	1.4541	4.4	32	±0.3	±0.3
	1.0	47.0	88.0	1	0.15	1.4571	4.4	32	±0.3	±0.3
	1.8	47.0	88.0	1	0.20	1.4571	4.3	34	±0.3	±0.3
52	1.0	52.0	80.0	1	0.10	1.4541	3.2	45	±0.3	±0.3
	2.1	52.0	80.0	1	0.15	1.4571	3.2	45	±0.3	±0.3
	4.0	52.0	80.0	1	0.20	1.4571	3.2	45	±0.3	±0.3
	0.4	52.0	95.0	1	0.10	1.4541	4.6	38	±0.3	±0.3
	0.9	52.0	95.0	1	0.15	1.4571	4.5	40	±0.3	±0.3
	1.5	52.0	95.0	1	0.20	1.4571	4.6	38	±0.3	±0.3
57	0.7	57.0	102	1	0.15	1.4571	4.8	32	±0.3	±0.3
	1.4	57.0	102	1	0.20	1.4571	4.8	32	±0.3	±0.3
	2.1	57.0	102	1	0.25	1.4571	5.0	32	±0.3	±0.3
62	0.7	62.0	109	1	0.15	1.4571	4.9	32	±0.3	±0.3
	1.2	62.0	109	1	0.20	1.4571	4.9	32	±0.3	±0.3
	1.9	62.0	109	1	0.25	1.4571	4.9	32	±0.3	±0.3

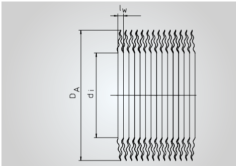
* Outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per diaphragm pair
axial	angular	lateral	axial	angular	lateral		
$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
3.30 = +0.66 / -2.64	±1.40	±0.0154	29	0.18	8800	23.8	4.89
3.10 = +0.62 / -2.48	±1.32	±0.0145	51	0.32	15500	23.8	7.33
2.90 = +0.58 / -2.32	±1.23	±0.0143	89	0.57	24300	23.8	9.77
2.70 = +0.54 / -2.16	±1.19	±0.0086	35	0.21	22700	21.8	3.66
2.50 = +0.50 / -2.00	±1.10	±0.0083	60	0.35	36000	21.8	5.49
2.30 = +0.46 / -1.84	±1.01	±0.0079	100	0.59	55600	21.8	7.32
3.60 = +0.72 / -2.88	±1.34	±0.0160	27	0.22	9100	30.7	6.03
3.40 = +0.68 / -2.72	±1.27	±0.0147	48	0.40	17000	30.7	9.04
3.20 = +0.64 / -2.56	±1.19	±0.0152	75	0.62	22000	30.7	12.1
3.70 = +0.74 / -2.96	±1.32	±0.0161	26	0.23	9100	33.2	6.43
3.50 = +0.70 / -2.80	±1.25	±0.0153	47	0.42	16400	33.2	9.65
3.20 = +0.64 / -2.56	±1.15	±0.0140	75	0.67	26000	33.2	12.9
3.80 = +0.76 / -3.04	±1.29	±0.0165	26	0.26	9200	36.9	6.96
3.60 = +0.72 / -2.88	±1.22	±0.0156	47	0.47	16600	36.9	10.4
3.30 = +0.66 / -2.64	±1.12	±0.0140	78	0.78	28800	36.9	13.9
2.40 = +0.48 / -1.92	±0.83	±0.0077	70	0.67	44700	34.0	4.64
2.20 = +0.44 / -1.76	±0.76	±0.0071	128	1.22	82000	34.0	6.97
2.00 = +0.40 / -1.60	±0.69	±0.0064	212	2.01	135000	34.0	9.29
4.00 = +0.80 / -3.20	±1.25	±0.0166	24	0.28	9200	43.6	7.94
3.80 = +0.76 / -3.04	±1.18	±0.0155	50	0.59	20000	43.6	11.9
3.50 = +0.70 / -2.80	±1.09	±0.0146	70	0.83	26800	43.6	15.9
4.10 = +0.82 / -3.28	±1.18	±0.0165	42	0.58	17300	51.0	13.5
3.90 = +0.78 / -3.12	±1.12	±0.0156	65	0.90	26700	51.0	18.0
3.60 = +0.72 / -2.88	±1.04	±0.0150	91	1.25	34500	51.0	22.5
4.30 = +0.86 / -3.44	±1.15	±0.0164	43	0.69	19700	58.9	15.1
4.10 = +0.82 / -3.28	±1.10	±0.0156	61	0.97	27900	58.9	20.2
3.80 = +0.76 / -3.04	±1.02	±0.0145	89	1.42	40600	58.9	25.2

HYDRA DIAPHRAGM BELLOWS WITH NORMAL PROFILES PREFERRED SERIES



Connection - outside of bellows



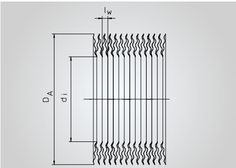
Connection - bellows interior

Reference diameter	Nominal pressure	Diaphragm contour				Material	Length per diaphragm pair	Maximum number of membrane pairs	Ø Tolerances	
	PN*	d_i	D_A	n_L	s		l_W		d_i	D_a
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm
67	1.0	67.0	102	1	0.15	1.4571	4.5	36	±0.3	±0.3
	1.8	67.0	102	1	0.20	1.4571	4.5	36	±0.3	±0.3
	3.0	67.0	102	1	0.25	1.4571	4.5	36	±0.3	±0.3
	0.6	67.0	116	1	0.15	1.4571	4.9	32	±0.3	±0.3
	1.1	67.0	116	1	0.20	1.4571	4.7	32	±0.3	±0.3
	1.8	67.0	116	1	0.25	1.4571	5.1	30	±0.3	±0.3
72	0.6	72.0	123	1	0.15	1.4571	5.3	250	±0.3	±0.3
	1.0	72.0	123	1	0.20	1.4571	5.3	250	±0.3	±0.3
	1.6	72.0	123	1	0.25	1.4571	5.2	250	±0.3	±0.3
	0.7	77.0	107	1	0.10	1.4541	3.4	250	±0.3	±0.3
	0.5	77.0	130	1	0.15	1.4571	5.2	250	±0.3	±0.3
	1.0	77.0	130	1	0.20	1.4571	5.3	250	±0.3	±0.3
	1.5	77.0	130	1	0.25	1.4571	5.4	250	±0.3	±0.3
82	0.5	82.0	136	1	0.15	1.4571	5.4	250	±0.3	±0.3
	0.9	82.0	136	1	0.20	1.4571	5.6	250	±0.3	±0.3
	1.4	82.0	136	1	0.25	1.4571	5.7	250	±0.3	±0.3
87	0.8	87.0	143	1	0.20	1.4571	5.7	250	±0.3	±0.3
	1.3	87.0	143	1	0.25	1.4571	5.8	250	±0.3	±0.3
	1.9	87.0	143	1	0.30	1.4571	5.9	250	±0.3	±0.3
92	0.6	92.0	134	1	0.15	1.4571	4.0	250	±0.3	±0.3
	0.8	92.0	134	1	0.20	1.4571	4.1	250	±0.3	±0.3
	1.3	92.0	134	1	0.25	1.4571	4.1	250	±0.3	±0.3
	1.9	92.0	134	1	0.30	1.4571	4.2	250	±0.3	±0.3
	0.8	92.0	149	1	0.20	1.4571	6.0	250	±0.3	±0.3
	1.2	92.0	149	1	0.25	1.4571	6.2	250	±0.3	±0.3
	1.8	92.0	149	1	0.30	1.4571	6.2	250	±0.3	±0.3

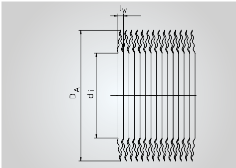
* Outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per diaphragm pair
axial	angular	lateral	axial	angular	lateral		
$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
3.00 = +0.60 / -2.40	±0.81	±0.0106	69	1.07	36500	56.9	11.1
2.50 = +0.50 / -2.00	±0.68	±0.0088	123	1.92	65000	56.9	14.9
2.10 = +0.42 / -1.68	±0.57	±0.0074	192	2.99	101500	56.9	18.6
4.50 = +0.90 / -3.60	±1.13	±0.0160	40	0.73	21000	67.3	16.9
4.30 = +0.86 / -3.44	±1.08	±0.0147	59	1.08	33500	67.3	22.5
4.00 = +0.80 / -3.20	±1.00	±0.0148	88	1.61	42500	67.3	28.2
4.70 = +0.94 / -3.76	±1.10	±0.0170	43	0.89	22000	76.4	18.7
4.50 = +0.90 / -3.60	±1.06	±0.0163	54	1.12	27400	76.4	25.0
4.20 = +0.84 / -3.36	±0.99	±0.0149	76	1.58	40000	76.4	31.2
2.70 = +0.54 / -2.16	±0.67	±0.0066	52	0.96	57000	67.1	6.9
4.90 = +0.98 / -3.92	±1.09	±0.0164	38	0.89	22500	86.0	20.7
4.70 = +0.94 / -3.76	±1.04	±0.0160	52	1.22	30000	86.0	27.6
4.40 = +0.88 / -3.52	±0.97	±0.0153	75	1.75	41300	86.0	34.5
5.00 = +1.00 / -4.00	±1.05	±0.0165	38	0.98	23200	95.2	22.2
4.80 = +0.96 / -3.84	±1.01	±0.0164	52	1.35	30000	95.2	29.6
4.50 = +0.90 / -3.60	±0.95	±0.0156	74	1.92	40600	95.2	37.0
5.20 = +1.04 / -4.16	±1.04	±0.0171	54	1.56	33000	106	32.4
5.00 = +1.00 / -4.00	±1.00	±0.0168	75	2.16	44200	106	40.5
4.70 = +0.94 / -3.76	±0.94	±0.0160	101	2.91	57600	106	48.6
3.90 = +0.78 / -3.12	±0.79	±0.0092	46	1.28	55000	101	17.9
3.20 = +0.64 / -2.56	±0.65	±0.0077	64	1.78	72900	101	23.9
3.00 = +0.60 / -2.40	±0.61	±0.0072	85	2.36	96700	101	29.8
2.80 = +0.56 / -2.24	±0.57	±0.0069	112	3.13	121600	101	35.8
5.30 = +1.06 / -4.24	±1.01	±0.0175	56	1.77	33900	116	34.5
5.10 = +1.02 / -4.08	±0.97	±0.0174	77	2.44	43600	116	43.2
4.80 = +0.96 / -3.84	±0.91	±0.0164	102	3.23	57800	116	51.8

HYDRA DIAPHRAGM BELLOWS WITH NORMAL PROFILES PREFERRED SERIES



Connection - outside of bellows



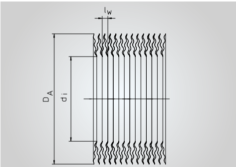
Connection - bellows interior

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

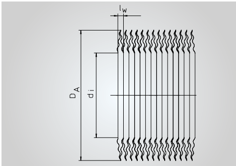
Reference diameter	Nominal pressure	Diaphragm contour				Material	Length per diaphragm pair	Maximum number of membrane pairs	Ø Tolerances	
	PN*	d_i	D_A	n_L	s		l_W		d_i	D_a
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm
97	1.7	97.0	134	1	0.20	1.4571	4.0	250	±0.3	±0.3
	2.7	97.0	134	1	0.25	1.4571	4.2	250	±0.3	±0.3
	3.9	97.0	134	1	0.30	1.4571	4.2	250	±0.3	±0.3
	0.8	97.0	156	1	0.20	1.4571	6.0	250	±0.3	±0.3
	1.1	97.0	156	1	0.25	1.4571	6.2	250	±0.3	±0.3
	1.7	97.0	156	1	0.30	1.4571	6.2	250	±0.3	±0.3
102	0.7	102	163	1	0.20	1.4571	6.0	250	±0.3	±0.3
	1.1	102	163	1	0.25	1.4571	6.5	250	±0.3	±0.3
	1.6	102	163	1	0.30	1.4571	6.5	250	±0.3	±0.3
112	0.6	112	173	1	0.20	1.4571	6.2	250	±0.3	±0.3
	1.0	112	173	1	0.25	1.4571	6.4	250	±0.3	±0.3
	1.4	112	173	1	0.30	1.4571	6.4	250	±0.3	±0.3
121	0.9	121	173	1	0.20	1.4571	6.0	250	±0.3	±0.3
	1.4	121	173	1	0.25	1.4571	6.2	250	±0.3	±0.3
	2.0	121	173	1	0.30	1.4571	6.2	250	±0.3	±0.3
127	0.7	127	185	1	0.15	1.4571	5.6	250	±0.3	±0.3
	0.9	127	185	1	0.20	1.4571	5.6	250	±0.3	±0.3
	1.3	127	185	1	0.25	1.4571	5.6	250	±0.3	±0.3
	1.6	127	185	1	0.30	1.4571	6.0	250	±0.3	±0.3
	0.5	127	195	1	0.20	1.4571	6.7	250	±0.3	±0.3
	0.9	127	195	1	0.25	1.4571	6.8	250	±0.3	±0.3
	1.2	127	195	1	0.30	1.4571	6.9	250	±0.3	±0.3

Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per diaphragm pair
axial	angular	lateral	axial	angular	lateral		
$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	degree	mm	N/mm	Nm/degree	N/mm	cm²	g
2.80 = +0.56 / -2.24	±0.56	±0.0064	142	4.13	178000	106	21.5
2.40 = +0.48 / -1.92	±0.48	±0.0058	221	6.43	251000	106	26.9
2.20 = +0.44 / -1.76	±0.44	±0.0053	318	9.26	361000	106	32.2
5.50 = +1.10 / -4.40	±1.00	±0.0173	59	2.06	39300	128	37.5
5.30 = +1.06 / -4.24	±0.96	±0.0173	76	2.65	47500	128	46.9
5.00 = +1.00 / -4.00	±0.91	±0.0163	103	3.60	64300	128	56.3
5.70 = +1.14 / -4.56	±0.99	±0.0172	50	1.92	36500	140	40.6
5.50 = +1.10 / -4.40	±0.95	±0.0179	77	2.95	48000	140	50.8
5.20 = +1.04 / -4.16	±0.90	±0.0170	103	3.95	64200	140	60.9
5.60 = +1.12 / -4.48	±0.90	±0.0162	40	1.77	31600	162	43.7
5.30 = +1.06 / -4.24	±0.85	±0.0158	61	2.70	45400	162	54.6
5.00 = +1.00 / -4.00	±0.80	±0.0149	81	3.59	60200	162	65.5
5.20 = +1.04 / -4.16	±0.81	±0.0141	65	3.06	58000	172	38.4
4.80 = +0.96 / -3.84	±0.75	±0.0134	101	4.76	85200	172	48.0
4.50 = +0.90 / -3.60	±0.70	±0.0126	146	6.88	123000	172	57.6
4.90 = +0.98 / -3.92	±0.72	±0.0117	40	2.12	46500	192	34.1
4.80 = +0.96 / -3.84	±0.71	±0.0114	60	3.19	70000	192	45.5
4.60 = +0.92 / -3.68	±0.68	±0.0110	78	4.14	91000	192	56.9
4.40 = +0.88 / -3.52	±0.65	±0.0112	96	5.10	97000	192	68.2
6.10 = +1.22 / -4.88	±0.87	±0.0169	42	2.38	36400	207	55.0
5.80 = +1.16 / -4.64	±0.83	±0.0163	64	3.62	54000	207	68.8
5.40 = +1.08 / -4.32	±0.77	±0.0154	90	5.09	73500	207	82.5

HYDRA DIAPHRAGM BELLOWS WITH NORMAL PROFILES PREFERRED SERIES



Connection - outside of bellows



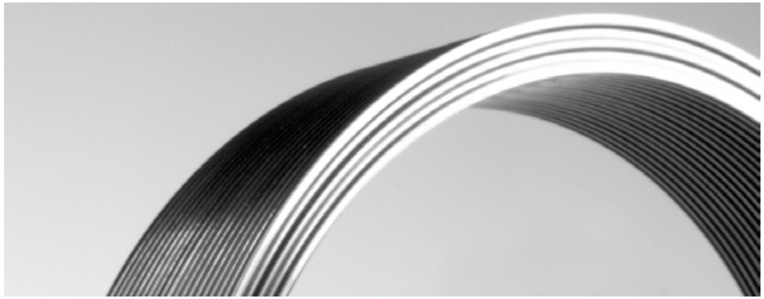
Connection - bellows interior

Reference diameter	Nominal pressure	Diaphragm contour				Material	Length per diaphragm pair	Maximum number of membrane pairs	Ø Tolerances	
	PN*	d_i	D_A	n_L	s		l_W		d_i	D_a
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm
152	0.5	152	226	1	0.20	1.4571	6.8	250	±0.3	±0.3
	0.7	152	226	1	0.25	1.4571	6.5	250	±0.3	±0.3
	1.0	152	226	1	0.30	1.4571	7.9	250	±0.3	±0.3
177	0.4	177	257	1	0.20	1.4571	8.9	250	±0.3	±0.3
	0.6	177	257	1	0.25	1.4571	8.9	250	±0.3	±0.3
	0.9	177	257	1	0.30	1.4571	7.5	250	±0.3	±0.3
202	0.4	202	287	1	0.20	1.4571	8.5	250	±0.3	±0.3
	0.5	202	287	1	0.25	1.4571	8.6	250	±0.3	±0.3
	0.8	202	287	1	0.30	1.4571	8.6	250	±0.3	±0.3

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

Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per diaphragm pair
axial	angular	lateral	axial	angular	lateral		
$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
6.70 = +1.34 / -5.36	±0.81	±0.0160	38	2.96	44000	284	70.3
6.40 = +1.28 / -5.12	±0.78	±0.0146	60	4.68	76000	284	87.9
6.10 = +1.22 / -4.88	±0.74	±0.0169	80	6.23	67000	284	105
7.20 = +1.44 / -5.76	±0.76	±0.0196	34	3.49	30300	374	87.3
6.80 = +1.36 / -5.44	±0.72	±0.0185	56	5.75	50000	374	109
6.30 = +1.26 / -5.04	±0.67	±0.0145	75	7.70	94000	374	131
7.80 = +1.56 / -6.24	±0.73	±0.0180	30	3.91	37200	474	104
7.40 = +1.48 / -5.92	±0.69	±0.0173	52	6.78	63000	474	131
6.90 = +1.38 / -5.52	±0.65	±0.0161	70	9.13	85000	474	157

HYDRA® DIAPHRAGM BELLOWS WITH NARROW PROFILES



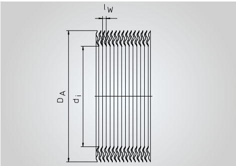
Diaphragm bellows with increased pressure resistance
HYDRA diaphragm bellows with narrow profiles are more pressure resistant and also have a higher spring rate than diaphragm bellows with normal profiles. The range of movement is somewhat smaller. For this reason they are well suited for static applications,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

MO: Bellows without connecting pieces
MM: Bellows with connectors

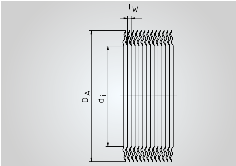
Bellows description:
(example)

MO	25.5	x	36.5	x	1	x	0.1	x	8MP	x	1.4571
MO: Bellows without connectors	Inside diameter d_i = 26.0 mm		Outside diameter D_A = 57.0 mm		Individual number of layers n_L = 6		Individual layer thickness s = 0.1 mm		8 diaphragm pairs		Material 1.4571

HYDRA® DIAPHRAGM BELLOWS WITH NARROW PROFILES



Connection - outside of bellows



Connection - bellows interior

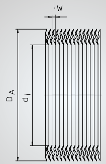
Reference diameter	Nominal pressure	Diaphragm contour				Material	Length per diaphragm pair	Maximum number of membrane pairs	Ø Tolerances	
	PN*	d_i	D_A	n_L	s		l_W		d_i	D_a
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm
12	8	12.0	20.0	1	0.10	1.4571	1.0	145	±0.3	0.3
	12	12.0	20.0	1	0.15	1.4571	1.0	145	±0.3	0.3
17	3.6	17.0	31.0	1	0.10	1.4571	1.5	95	±0.3	0.3
	6.1	17.0	31.0	1	0.15	1.4571	1.5	95	±0.3	0.3
25	8	25.5	36.5	1	0.10	1.4571	1.2	230	±0.3	0.3
	12	25.5	36.5	1	0.15	1.4571	1.2	230	±0.3	0.3
29	6	29.5	42.5	1	0.10	1.4571	1.4	200	±0.3	0.3
	9	29.5	42.5	1	0.15	1.4571	1.4	200	±0.3	0.3
34	6	33.5	46.5	1	0.10	1.4571	1.4	200	±0.3	0.3
	9	33.5	46.5	1	0.15	1.4571	1.5	185	±0.3	0.3
	6	34.5	47.5	1	0.10	1.4571	1.3	215	±0.3	0.3
	9	34.5	47.5	1	0.15	1.4571	1.4	200	±0.3	0.3
36	4	36.0	53.0	1	0.10	1.4571	1.9	145	±0.3	0.3
	6	36.0	53.0	1	0.15	1.4571	1.9	145	±0.3	0.3
37	6	37.0	50.0	1	0.10	1.4571	1.5	185	±0.3	0.3
	9	37.0	50.0	1	0.15	1.4571	1.5	185	±0.3	0.3
39	6	39.5	52.5	1	0.10	1.4571	1.5	185	±0.3	0.3
	9	39.5	52.5	1	0.15	1.4571	1.5	185	±0.3	0.3
42	6	42.5	55.5	1	0.10	1.4571	1.5	185	±0.3	0.3
	9	42.5	55.5	1	0.15	1.4571	1.5	185	±0.3	0.3
44	6	44.5	57.5	1	0.10	1.4571	1.5	185	±0.3	0.3
	9	44.5	57.5	1	0.15	1.4571	1.6	175	±0.3	0.3
47	6	47.0	60.0	1	0.10	1.4571	1.6	175	±0.3	0.3
	9	47.0	60.0	1	0.15	1.4571	1.7	160	±0.3	0.3
52	6	52.5	65.5	1	0.10	1.4571	1.6	175	±0.3	0.3
	9	52.5	65.5	1	0.15	1.4571	1.7	160	±0.3	0.3
57	6	57.0	70.0	1	0.10	1.4571	1.6	165	±0.3	0.3
	9	57.0	70.0	1	0.15	1.4571	1.7	145	±0.3	0.3

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

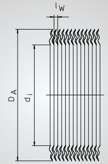
06

Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per diaphragm pair
axial	angular	lateral	axial	angular	lateral		
$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
0.50 = +0.10 /-0.40	±0.72	±0.0021	200	0.11	76800	2.1	0.42
0.40 = +0.08 /-0.32	±0.57	±0.0017	500	0.28	192000	2.1	0.63
0.90 = +0.18 /-0.72	±0.86	±0.0038	100	0.13	38400	4.65	0.84
0.80 = +0.16 /-0.64	±0.76	±0.0033	190	0.24	72900	4.65	1.27
0.60 = +0.12 /-0.48	±0.44	±0.0015	105	0.22	105000	7.6	0.85
0.50 = +0.10 /-0.40	±0.37	±0.0013	280	0.59	280000	7.6	1.27
0.70 = +0.14 /-0.56	±0.45	±0.0018	110	0.31	109000	10.3	1.16
0.60 = +0.12 /-0.48	±0.38	±0.0016	265	0.75	263000	10.3	1.74
0.70 = +0.14 /-0.56	±0.40	±0.0016	105	0.37	129000	12.7	1.29
0.60 = +0.12 /-0.48	±0.34	±0.0015	247	0.86	263000	12.7	1.94
0.70 = +0.14 /-0.56	±0.39	±0.0015	100	0.37	149000	13.3	1.32
0.60 = +0.12 /-0.48	±0.34	±0.0014	250	0.92	322000	13.3	1.98
0.80 = +0.16 /-0.64	±0.41	±0.0023	70	0.30	57600	15.6	1.88
0.70 = +0.14 /-0.56	±0.36	±0.0020	150	0.65	123000	15.6	2.82
0.70 = +0.14 /-0.56	±0.37	±0.0016	103	0.43	130000	15	1.40
0.60 = +0.12 /-0.48	±0.32	±0.0014	310	1.28	391000	15	2.11
0.70 = +0.14 /-0.56	±0.35	±0.0015	97	0.45	137000	16.7	1.48
0.60 = +0.12 /-0.48	±0.30	±0.0013	300	1.38	423000	16.7	2.23
0.70 = +0.14 /-0.56	±0.33	±0.0014	92	0.48	147000	19	1.58
0.60 = +0.12 /-0.48	±0.28	±0.0012	310	1.62	497000	19	2.37
0.70 = +0.14 /-0.56	±0.31	±0.0014	100	0.57	173000	20.5	1.65
0.60 = +0.12 /-0.48	±0.27	±0.0013	250	1.42	381000	20.5	2.47
0.70 = +0.14 /-0.56	±0.30	±0.0014	100	0.62	168000	22.6	1.73
0.60 = +0.12 /-0.48	±0.26	±0.0013	250	1.56	371000	22.6	2.59
0.70 = +0.14 /-0.56	±0.27	±0.0013	108	0.82	220000	27.4	1.90
0.60 = +0.12 /-0.48	±0.23	±0.0012	286	2.17	517000	27.4	2.86
0.70 = +0.14 /-0.56	±0.25	±0.0012	102	0.90	241000	31.8	2.05
0.60 = +0.12 /-0.48	±0.22	±0.0011	270	2.38	565000	31.8	3.07

HYDRA® DIAPHRAGM BELLOWS WITH NARROW PROFILES



Connection - outside of bellows



Connection - bellows interior

06

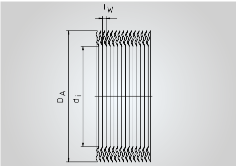
Reference diameter	Nominal pressure	Diaphragm contour				Material	Length per diaphragm pair	Maximum number of membrane pairs	Ø Tolerances	
	PN*	d_i	D_A	n_L	s		l_W		d_i	D_a
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm
62	6	62.5	75.5	1	0.10	1.4571	1.5	95	±0.3	0.3
	9	62.5	75.5	1	0.15	1.4571	1.5	95	±0.3	0.3
	1.1	62.0	88.0	1	0.15	1.4571	1.9	75	±0.3	0.3
	1.8	62.0	88.0	1	0.20	1.4571	1.9	75	±0.3	0.3
	2.5	62.0	88.0	1	0.25	1.4571	1.9	95	±0.3	0.3
67	9	67.0	80.0	1	0.15	1.4571	1.5	90	±0.3	0.3
	12	67.0	80.0	1	0.20	1.4571	1.6	90	±0.3	0.3
	7	67.0	83.0	1	0.15	1.4571	1.6	90	±0.3	0.3
	10	67.0	83.0	1	0.20	1.4571	1.7	85	±0.3	0.3
72	7	72.0	88.0	1	0.15	1.4571	1.6	110	±0.3	0.3
	10	72.0	88.0	1	0.20	1.4571	1.7	105	±0.3	0.3
77	7	77.0	93.0	1	0.15	1.4571	1.6	110	±0.3	0.3
	10	77.0	93.0	1	0.20	1.4571	1.7	105	±0.3	0.3
82	7	82.0	98.0	1	0.15	1.4571	1.6	95	±0.3	0.3
	10	82.0	98.0	1	0.20	1.4571	1.7	90	±0.3	0.3
84	7	84.0	100	1	0.15	1.4571	1.6	95	±0.3	0.3
	10	84.0	100	1	0.20	1.4571	1.7	90	±0.3	0.3
87	7	87.0	103	1	0.15	1.4571	1.6	95	±0.3	0.3
	10	87.0	103	1	0.20	1.4571	1.7	90	±0.3	0.3
92	7	92.0	108	1	0.15	1.4571	1.4	110	±0.3	0.3
	10	92.0	108	1	0.20	1.4571	1.6	95	±0.3	0.3
97	7	97.0	113	1	0.15	1.4571	1.6	95	±0.3	0.3
	10	97.0	113	1	0.20	1.4571	1.7	90	±0.3	0.3
102	7	102	118	1	0.15	1.4571	1.5	100	±0.3	0.3
	10	102	118	1	0.20	1.4571	1.7	90	±0.3	0.3
106	7	106	122	1	0.15	1.4571	1.5	100	±0.3	0.3
	10	106	122	1	0.20	1.4571	1.6	95	±0.3	0.3

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

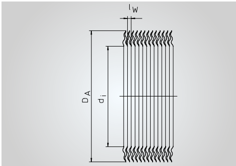
06

Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per diaphragm pair
axial	angular	lateral	axial	angular	lateral		
$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	degree	mm	N/mm	Nm/degree	N/mm	cm²	g
0.70 = +0.14 /-0.56	±0.23	±0.0010	100	1.04	318000	37.5	2.23
0.60 = +0.12 /-0.48	±0.20	±0.0009	260	2.70	825000	37.5	3.34
1.50 = +0.30 /-1.20	±0.46	±0.0025	148	1.82	346000	44	7.35
1.40 = +0.28 /-1.12	±0.43	±0.0024	248	3.04	579000	44	9.80
1.30 = +0.26 /-1.04	±0.40	±0.0022	380	4.66	888000	44	12.25
0.70 = +0.14 /-0.56	±0.22	±0.0010	200	2.36	720000	42	3.56
0.60 = +0.12 /-0.48	±0.19	±0.0009	500	5.89	1583000	42	4.74
0.80 = +0.16 /-0.64	±0.24	±0.0011	225	2.76	74000	44.3	4.47
0.70 = +0.14 /-0.56	±0.21	±0.0011	560	6.87	1635000	44.3	5.96
0.80 = +0.16 /-0.64	±0.23	±0.0011	190	2.65	712500	50.4	4.77
0.70 = +0.14 /-0.56	±0.20	±0.0010	530	7.40	1760000	50.4	6.35
0.80 = +0.16 /-0.64	±0.22	±0.0010	200	3.15	847000	56.9	5.06
0.70 = +0.14 /-0.56	±0.19	±0.0009	540	8.51	2025000	56.9	6.75
0.80 = +0.16 /-0.64	±0.20	±0.0009	213	3.76	1011000	63.8	5.36
0.70 = +0.14 /-0.56	±0.18	±0.0009	550	9.72	2312000	63.8	7.15
0.80 = +0.16 /-0.64	±0.20	±0.0009	220	4.06	1091000	66.6	5.48
0.70 = +0.14 /-0.56	±0.17	±0.0009	560	10.3	2460000	66.6	7.31
0.80 = +0.16 /-0.64	±0.19	±0.0009	245	4.82	1300000	71	5.66
0.70 = +0.14 /-0.56	±0.17	±0.0008	710	13.98	3325000	71	7.55
0.80 = +0.16 /-0.64	±0.18	±0.0007	315	6.87	2410000	78.1	5.96
0.70 = +0.14 /-0.56	±0.16	±0.0007	730	15.9	4277000	78.1	7.94
0.80 = +0.16 /-0.64	±0.17	±0.0008	320	7.70	2070000	86.8	6.25
0.70 = +0.14 /-0.56	±0.15	±0.0008	740	17.8	4234000	86.8	8.34
0.80 = +0.16 /-0.64	±0.17	±0.0007	330	8.71	2660000	95.2	6.55
0.70 = +0.14 /-0.56	±0.15	±0.0007	750	19.8	4710000	95.2	8.74
0.80 = +0.16 /-0.64	±0.16	±0.0007	330	9.36	2859000	102.2	6.79
0.70 = +0.14 /-0.56	±0.14	±0.0007	750	21.3	5710000	102.2	9.05

HYDRA® DIAPHRAGM BELLOWS WITH NARROW PROFILES



Connection - outside of bellows



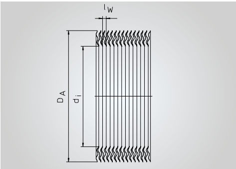
Connection - bellows interior

Reference diameter	Nominal pressure	Diaphragm contour				Material	Length per diaphragm pair	Maximum number of membrane pairs	Ø Tolerances	
	PN*	d_i	D_A	n_L	s		l_W		d_i	D_a
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm
112	7	112	128	1	0.15	1.4571	1.6	95	±0.3	0.3
	10	112	128	1	0.20	1.4571	1.7	90	±0.3	0.3
127	7	127	143	1	0.15	1.4571	1.6	95	±0.3	0.3
	10	127	143	1	0.20	1.4571	1.7	90	±0.3	0.3
142	7	142	158	1	0.15	1.4571	1.8	20	±0.3	0.3
	10	142	158	1	0.20	1.4571	1.9	20	±0.3	0.3
	4	142	168	1	0.15	1.4571	2.8	20	±0.3	0.3
	6	142	168	1	0.20	1.4571	3.0	20	±0.3	0.3
147	6	147	167	1	0.15	1.4571	1.8	20	±0.3	0.3
	8	147	167	1	0.20	1.4571	2.0	20	±0.3	0.3
158	8	158	178	1	0.20	1.4571	1.8	20	±0.3	0.3
	12	158	178	1	0.25	1.4571	2.0	20	±0.3	0.3
168	6	168	188	1	0.15	1.4571	2.1	20	±0.3	0.3
	8	168	188	1	0.20	1.4571	2.2	20	±0.3	0.3
176	9	176	196	1	0.25	1.4571	2.1	20	±0.3	0.3
	12	176	196	1	0.30	1.4571	2.2	20	±0.3	0.3
186	3	186	212	1	0.15	1.4571	3.0	20	±0.3	0.3
191	7	191	211	1	0.20	1.4571	2.0	20	±0.3	0.3
	10	191	211	1	0.25	1.4571	2.1	20	±0.3	0.3
205	10	205	225	1	0.25	1.4571	2.1	20	±0.3	0.3
	12	205	225	1	0.30	1.4571	2.2	20	±0.3	0.3
223	10	223	243	1	0.25	1.4571	2.1	20	±0.3	0.3
	12	223	243	1	0.30	1.4571	2.2	20	±0.3	0.3
240	10	240	260	1	0.25	1.4571	2.1	20	±0.3	0.3
	12	240	260	1	0.30	1.4571	2.2	20	±0.3	0.3

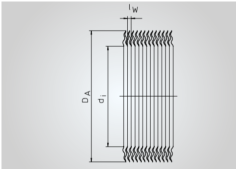
* Outside pressure; in the event of inside pressure loads, column stability must also be guaranteed (buckle resistance)

Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per diaphragm pair
axial	angular	lateral	axial	angular	lateral		
$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	degree	mm	N/mm	Nm/degree	N/mm	cm²	g
0.80 = +0.16 / -0.64	±0.15	±0.0007	340	10.7	2870000	110	7.15
0.70 = +0.14 / -0.56	±0.13	±0.0007	760	23.9	5680000	110	9.53
0.80 = +0.16 / -0.64	±0.14	±0.0006	350	13.9	3740000	143	8.04
0.70 = +0.14 / -0.56	±0.12	±0.0006	770	30.6	7280000	143	10.72
0.80 = +0.16 / -0.64	±0.12	±0.0006	350	17.2	3650000	177	8.94
0.70 = +0.14 / -0.56	±0.11	±0.0006	770	37.8	7200000	177	11.91
1.00 = +0.20 / -0.80	±0.15	±0.0012	220	11.5	1010000	189	15.00
0.80 = +0.16 / -0.64	±0.12	±0.0010	570	29.9	2280000	189	20.00
0.90 = +0.18 / -0.72	±0.13	±0.0007	450	24.2	5130000	192	11.69
0.80 = +0.16 / -0.64	±0.12	±0.0007	850	45.7	7860000	192	15.59
0.80 = +0.16 / -0.64	±0.11	±0.0006	870	53.3	11300000	221	16.63
0.70 = +0.14 / -0.56	±0.10	±0.0006	1370	83.9	14400000	221	20.79
0.90 = +0.18 / -0.72	±0.12	±0.0007	520	35.9	5600000	249	13.25
0.80 = +0.16 / -0.64	±0.10	±0.0007	930	64.3	9130000	249	17.67
0.70 = +0.14 / -0.56	±0.09	±0.0005	1530	115	18000000	272	23.08
0.60 = +0.12 / -0.48	±0.07	±0.0005	2200	166	23600000	272	27.70
1.20 = +0.24 / -0.96	±0.14	±0.0012	280	24.2	1850000	311	19.26
0.80 = +0.16 / -0.64	±0.09	±0.0005	1050	92.5	15900000	315	19.96
0.70 = +0.14 / -0.56	±0.08	±0.0005	1650	145	22600000	315	24.94
0.70 = +0.14 / -0.56	±0.07	±0.0005	1800	182	28300000	363	26.68
0.60 = +0.12 / -0.48	±0.06	±0.0004	2900	292	41500000	363	32.02
0.70 = +0.14 / -0.56	±0.07	±0.0004	1850	219	34160000	427	28.92
0.60 = +0.12 / -0.48	±0.06	±0.0004	2950	349	49630000	427	34.70
0.70 = +0.14 / -0.56	±0.06	±0.0004	1900	259	40390000	488	31.03
0.60 = +0.12 / -0.48	±0.06	±0.0004	3000	409	58100000	488	37.23

HYDRA® DIAPHRAGM BELLOWS WITH NARROW PROFILES



Connection - outside of bellows



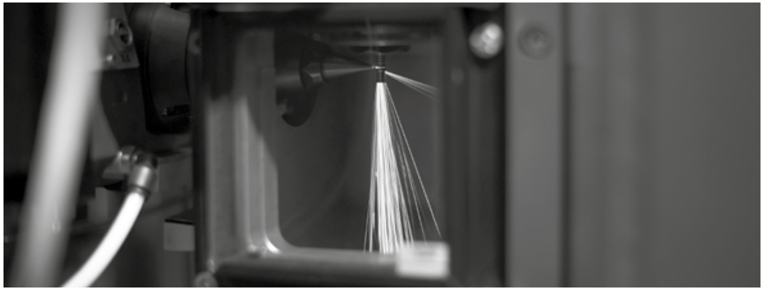
Connection - bellows interior

Reference diameter	Nominal pressure	Diaphragm contour				Material	Length per diaphragm pair	Maximum number of membrane pairs	Ø Tolerances	
	PN*	d_i	D_A	n_L	s		l_W		d_i	D_a
mm	bar	mm	mm	–	mm	–	mm	–	mm	mm
250	6	250	275	1	0.25	1.4571	2.6	20	±0.3	0.3
	8	250	275	1	0.30	1.4571	2.7	20	±0.3	0.3
268	6	268	292	1	0.25	1.4571	2.6	20	±0.3	0.3
	8	268	292	1	0.30	1.4571	2.7	20	±0.3	0.3
280	5	280	300	1	0.25	1.4571	2.6	20	±0.3	0.3
	7	280	300	1	0.30	1.4571	2.7	20	±0.3	0.3

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

Nominal deflection per corrugation (for 10,000 load cycles)			Spring rate per corrugation (±30 %)			Effective cross-section	Weight per diaphragm pair
axial	angular	lateral	axial	angular	lateral		
$2\delta_{n,0}$	$2\alpha_{n,0}$	$2\lambda_{n,0}$	c_δ	c_α	c_λ	A	
mm	degree	mm	N/mm	Nm/degree	N/mm	cm^2	g
0.90 = +0.18 / -0.72	±0.08	±0.0006	1400	210	21400000	537	40.72
0.80 = +0.16 / -0.64	±0.07	±0.0005	2200	331	31200000	537	48.86
0.90 = +0.18 / -0.72	±0.07	±0.0006	1600	274	27800000	611	41.70
0.80 = +0.16 / -0.64	±0.07	±0.0005	2500	428	40300000	611	50.04
0.70 = +0.14 / -0.56	±0.06	±0.0004	2000	367	37300000	656	35.99
0.60 = +0.12 / -0.48	±0.05	±0.0004	3100	569	53600000	656	43.19

GEOMETRY OF THE CONNECTORS FOR METAL AND DIAPHRAGM BELLOWS



Metal bellows with B-end

The design of the weld area of the connection parts and the selection of the welding method are determined by the total wall thickness t 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 technical tables.

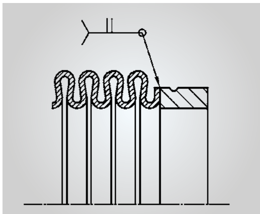


Figure 6.8.1

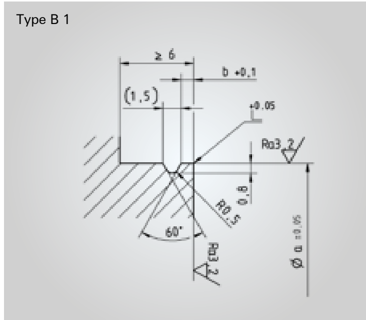
The following applies to the total wall thickness of the bellows:

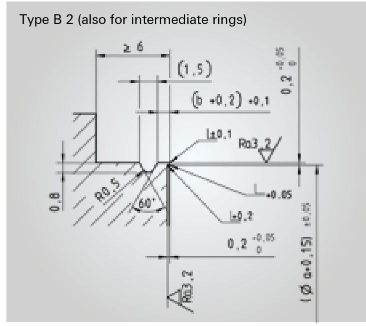
$$t = n_L \cdot s \qquad 6.8.1.$$

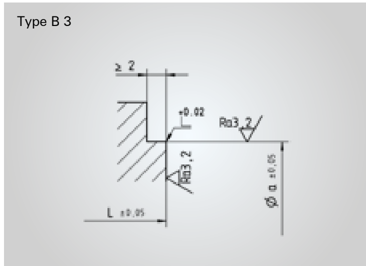
Total wall thickness t	Welding method	Version	Weld diameter a	Width of weld lip w
mm	–	–	mm	mm
d ≤ 0.10	Laser	B 3	$a = d_4^{\pm 0.05}$ d_4: Cuff diameter	–
0.10 < t ≤ 0.20	Laser / Microplasma	B 1, B 2, B 4, B 5		b = t 0.40 ≤ b
0.20 < t ≤ 0.30				
0.30 < t ≤ 0.45	Laser / Microplasma / WIG			
0.45 < t ≤ 0.90	Microplasma / WIG			
0.90 < t ≤ 2.40	TIG with weld accessory			b = 2t but b_{max} = 2.4

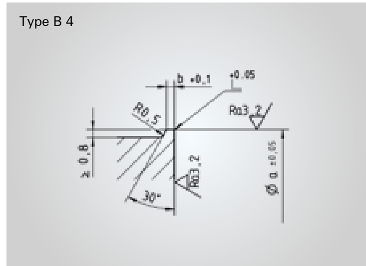
Table 6.8.1

Geometry designs in the seam area









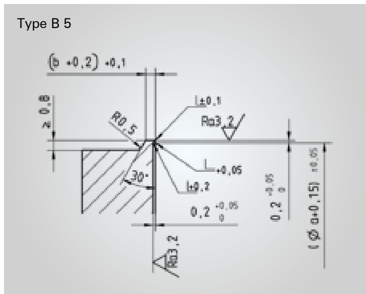


Figure 6.8.2. (values a and b in accordance with Table 6.8.1.)

Metal bellows with S-cuff

The design of the connecting piece is mainly determined by the welding method.
The dimensions for d_3 and t can be found in the bellows technical tables.

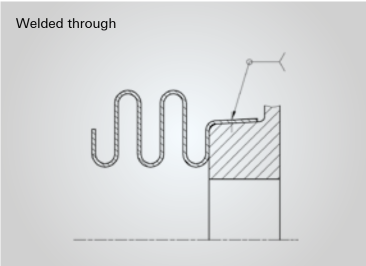


Figure 6.8.3.a

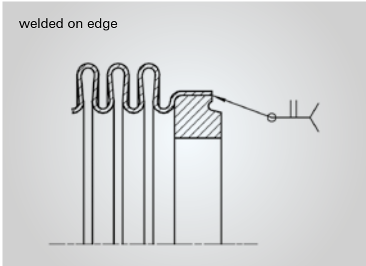


Figure 6.8.3.b

Total wall thickness t	Welding method	Version	Cuff diameter d_3	Weld diameter a
mm	–	–	mm	mm
d ≤ 0.45	Laser, pressed on and welded through	S 1	$d_3 \leq 16$	$a = (d_3 + 0.1)^{\pm 0.05}$
			$16 < d_3 \leq 40$	$a = (d_3 + 0.3)^{\pm 0.05}$
			$40 < d_3 \leq 85$	$a = (d_3 + 0.5)^{\pm 0.05}$
d ≤ 0.10	Laser	S 2	$d_3 \leq 55$ $55 < d_3 \leq 105$ $105 < d_3 \leq 125$	$a = (d_3 + 0.1)^{\pm 0.05}$ $a = (d_3 + 0.3)^{\pm 0.05}$ $a = (d_3 + 0.5)^{\pm 0.05}$
0.10 < t ≤ 0.30	Laser/Microplasma	S 2 / 3		
0.30 < t ≤ 0.45	Laser / Microplasma and WIG	S 2 / 3		
0.45 < t ≤ 0.90	Microplasma and WIG	S 3		
0.90 < t ≤ 2.40	TIG with weld accessory			

Table 6.8.2.

Total wall thickness t	Width of weld lip b
mm	mm
d ≤ 0.4	0.4
0.4 < t ≤ 0.9	b = t
0.9 < t ≤ 1.2	b = 2t
1.2 < t ≤ 2.4	2.4

Radius R			
d3	t = 0.3	0.3 ≤ t < 0.8	0.8 ≤ t < 2.4
<55	1.5	1.8	2
55 – 105	2	2.3	2.5
105 – 125	2.5	2.8	3.0

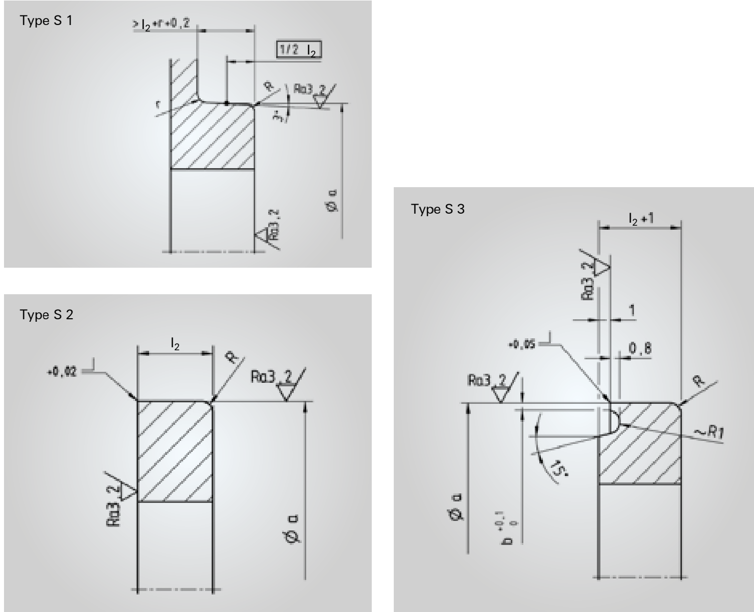


Figure 6.8.4. (values a, b and R in accordance with Table 6.8.2., l2 in accordance with Table 6.3. or 6.4.)

Metal bellows with I-cuff

The welding method determines the connection geometry for J-cuffs (with or without weld lip). The dimensions for d_3 and t can be found in the bellows technical tables.

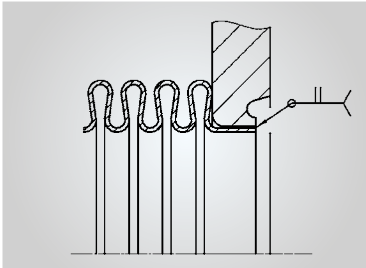


Figure 6.8.5

Total wall thickness t	Welding method	Version	Weld diameter a
mm	–	–	mm
d ≤ 45	Laser	I 1	$a = (d_3 + 2 \cdot t)$
0.10 < t ≤ 0.45	Microplasma	I 2	
0.30 < t ≤ 0.90	Microplasma / WIG	I 2	
0.90 < t ≤ 2.40	TIG with weld accessory	I 2	

Total wall thickness t	Width of weld lip b
mm	mm
d ≤ 0.4	0.4
0.4 < t ≤ 0.9	b = t
0.9 < t ≤ 1.2	b = 2t
1.2 < t ≤ 2.4	2.4

Table 6.8.3.

Radius R			
d3	t = 0.3	0.3 ≤ t < 0.8	0.8 ≤ t < 2.4
<55	1.5	1.8	2
55 – 105	2	2.3	2.5
105 – 125	2.5	2.8	3.0

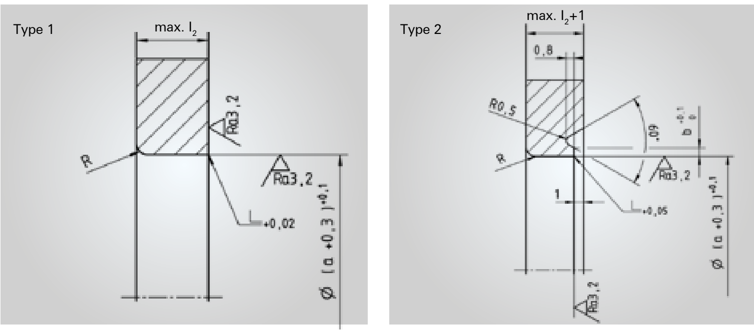


Figure 6.8.6. (values a, b and R in accordance with Table 6.8.3., l2 in accordance with Table 6.3. or 6.4.)

Diaphragm bellows

Connection part for diaphragm bellows (normal profile) can be welded at the outside or inside diameter with the microplasma welding method. The dimensions for D_a, D_i, and l_W can be found in the bellows technical tables. Diaphragm bellows with narrow profile can only be welded at the outside diameter.

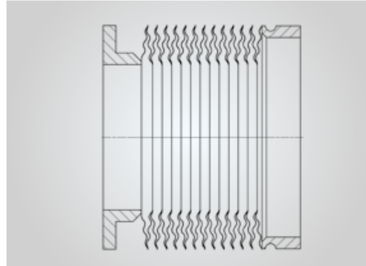


Figure 6.8.7.

Welding position	Bellows inside diameter	Weld diameter	Width of weld lip	Edge dimensions	Chamfer depth
–	mm	mm	mm	mm	mm
at inside diameter	$D_i \le 60$	$a = D_i^{+0.1}$	b = 0.4	$k = \max \begin{cases} 0.9 \\ \frac{D_a - D_i}{24} - 0.2 \end{cases}$	–
	$60 < D_i \le 100$	$a = D_i^{+0.15}$	b = 0.5		
	$100 < D_i$	$a = D_i^{+0.2}$	b = 0.6		
at outside diameter	$D_a \le 80$	$a = (D_a - 0.1)^{+0.1}$	b = 0.4		z = 2 ±0.1
	$80 < D_a \le 140$	$a = (D_a - 0.15)^{+0.15}$	b = 0.5		z = 3 ±0.1
	$140 < D_a$	$a = (D_a - 0.15)^{+0.15/-0.05}$	b = 0.6		z = 4 ±0.1

Table 6.8.4.

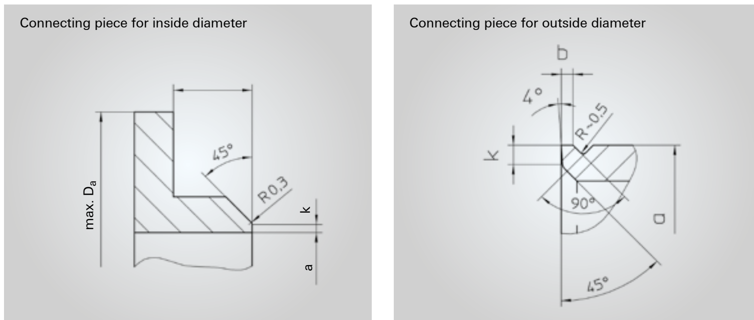


Figure 6.8.8. (values a, b and k in accordance with Table 6.8.4., since in accordance with Table 6.6. or 6.7.)

HYDRA® PRECISION TUBES

06

HYDRA precision tubes are sorted by diameter and wall thickness. The maximum production length of a tube is 6.50 meters; shorter pieces are available in any length. Tolerances for tube diameter and length are in the range of ±0.1 mm. Standard material is 1.4571; other materials available on request.

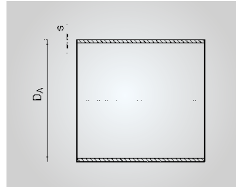
Tube designation
(example)

HWE | 35.8 x 0.2 x 300 | 1.4571

- HWE – Precision tube
- 35.8 – Outside diameter D_A = 35.8 mm
- 0.2 – Wall thickness 0.2 mm
- 300 – Length 300 m
- 1.4571 – Material 1.4571

HYDRA® PRECISION TUBES

Thin-walled stainless steel tubes
Standard material: 1.4571



06

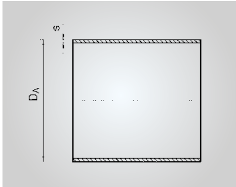
Outside diameter D_A mm	Wall thickness s mm
7.30	0.10
8.00	0.10
8.20	0.10
8.50	0.10
8.80	0.10
9.10	0.10
9.20	0.10
9.50	0.10
9.80	0.10
10.10	0.10
10.20	0.10
10.40	0.10
10.50	0.10
10.80	0.10
11.10	0.10
11.40	0.10
11.90	0.10
12.00	0.10
12.20	0.10
12.30	0.10
12.40	0.10
12.50	0.10
12.60	0.10
12.80	0.10
13.00	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

Outside diameter D_A mm	Wall thickness s 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

Outside diameter D_A mm	Wall thickness s 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

HYDRA® PRECISION TUBES

Thin-walled stainless steel tubes
Standard material: 1.4571



06

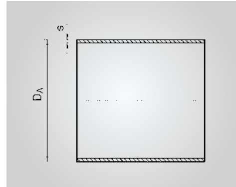
Outside diameter	Wall thickness
D_A	s
mm	mm
16.70	0.15
16.90	0.15
17.10	0.15
17.50	0.15
17.90	0.15
18.00	0.15
18.30	0.15
18.50	0.15
18.70	0.15
18.90	0.15
19.10	0.15
19.30	0.15
19.50	0.15
19.70	0.15
20.00	0.15
20.10	0.15
20.50	0.15
20.90	0.15
21.30	0.15
21.70	0.15
22.10	0.15
22.30	0.15
22.50	0.15
22.70	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

Outside diameter	Wall thickness
D_A	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

Outside diameter	Wall thickness
D_A	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

HYDRA® PRECISION TUBES

Thin-walled stainless steel tubes
Standard material: 1.4571



06

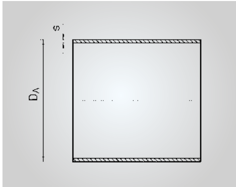
Outside diameter	Wall thickness
D_A	s
mm	mm
18.60	0.20
18.70	0.20
18.90	0.20
19.40	0.20
19.90	0.20
20.10	0.20
20.20	0.20
20.40	0.20
20.70	0.20
20.90	0.20
21.00	0.20
22.40	0.20
22.60	0.20
22.90	0.20
23.10	0.20
23.20	0.20
23.40	0.20
23.90	0.20
24.00	0.20
24.40	0.20
24.50	0.20
24.60	0.20
24.90	0.20
25.10	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

Outside diameter	Wall thickness
D_A	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

Outside diameter	Wall thickness
D_A	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
1050	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® PRECISION TUBES

Thin-walled stainless steel tubes
Standard material: 1.4571



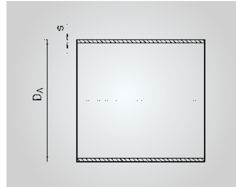
Outside diameter	Wall thickness
D_A	s
mm	mm
16.20	0.25
16.90	0.25
17.00	0.25
17.60	0.25
18.50	0.25
19.15	0.25
19.80	0.25
20.45	0.25
21.10	0.25
21.75	0.25
22.40	0.25
22.50	0.25
22.70	0.25
23.10	0.25
23.70	0.25
24.30	0.25
24.50	0.25
25.10	0.25
25.40	0.25
25.70	0.25
26.30	0.25
26.90	0.25
27.50	0.25
28.00	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

Outside diameter	Wall thickness
D_A	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

Outside diameter	Wall thickness
D_A	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® PRECISION TUBES

Thin-walled stainless steel tubes
Standard material: 1.4571



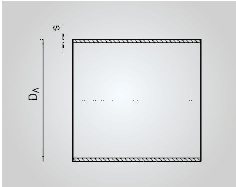
Outside diameter	Wall thickness
D_A	s
mm	mm
61.60	0.25
65.90	0.25
66.00	0.25
66.70	0.25
68.90	0.25
69.60	0.25
69.70	0.25
70.50	0.25
70.90	0.25
71.00	0.25
71.70	0.25
72.50	0.25
72.60	0.25
77.90	0.25
78.00	0.25
78.70	0.25
78.80	0.25
87.90	0.25
88.00	0.25
88.80	0.25
89.70	0.25
96.50	0.25
97.20	0.25
99.90	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

Outside diameter	Wall thickness
D_A	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

Outside diameter	Wall thickness
D_A	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

HYDRA® PRECISION TUBES

Thin-walled stainless steel tubes
Standard material: 1.4571



Outside diameter	Wall thickness
D_A	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

Outside diameter	Wall thickness
D_A	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

Outside diameter	Wall thickness
D_A	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 tube sizes listed in the tables. Other sizes, wall thickness and materi-als are available on request.

MATERIALS

07

In chapter 07 you will find the basic characteristics and quality of the materials used. Apart from the respective delivery form, this includes the limiting temperatures as well as strength characteristic values of the room temperature.
The chemical composition of the materials as well as their strength at increased temperatures are described below. Finally, you will find a list of the material descriptions acc. to international specifications.

All information is supplied without guarantee.

07

DESCRIPTIONS, FORMS OF DELIVERY, LIMITING TEMPERATURES

Material group	Material no. acc. to DIN EN 10027	Designation acc. to DIN EN 10027	Semi-finished	Documentation	Upper limiting tempera-ture °C
Unalloyed steel	1.0254	P235TR1	Welded tubes	DIN EN 10217-1	300
			seamless tubes	DIN EN 10216-1	
	1.0255	P235TR2	Welded tubes	DIN EN 10217-1	
			seamless tubes	DIN EN 10216-1	
	1.0427	C22G1	Flanges	VdTÜV-WB 364	350
General construction steel	1.0038	S235JRG2	Steel bars/rods, flat products, wire rod profiles	DIN EN 10025 AD W1	300
	1.0050	E295			
	1.0570	S355J2G3			
Heat resisting unalloyed steel	1.0460	C22G2	Flanges	VdTÜV-WB 350	450
Heat-resisting steel	1.0345	P235GH	Sheet metal	DIN EN 10028-2	480
			Seamless tube	DIN EN 10216	450
	1.0425	P265GH	Sheet metal	DIN EN 10028-2	480
	1.0481	P295GH	Sheet metal	DIN EN 10028-2	500
	1.5415	16Mo3	Sheet metal	DIN EN 10028-2	530
			Seamless tube	DIN EN 10216-2	
	1.7335	13CrMo4-5	Sheet metal	DIN EN 10028-2	570
			Seamless tube	DIN EN 10216-2	
	1.7380	10CrMo9-10	Sheet metal	DIN EN 10028-2	600
			Seamless tube	DIN EN 10216-2	
Fine-grain structural steel					
Normal	1.0562	P355N	Sheet metal, metal strip, Steel bars/rods	DIN EN 10028-3	
Heat resisting	1.0565	P355NH			400
Tough when cold	1.0566	P355NL1			(-50) [1]
Special	1.1106	P355NL2			(-60) [1]

[1] Lower limiting temperature

STRENGTH VALUES AT AMBIENT TEMPERATURE (GUARANTEED VALUES [2])

Material no. acc. to DIN EN 10027	Yield strength min.	Tensile strength	Elongation at break min.		Impact work min. KV [3]	Remarks
	R_{eH}	R_m	A_5	A_{80}		
	MPa	MPa	%	%	J	
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 20 °C: 31	s ≤ 70
1.0038	235	340 - 470	21 - 26 [4]	17 - 21 [4]	at 20 °C: 27	3 ≤ s ≤ 100 (R_m)
1.0050	295	470 - 610	16 - 20 [4]	12 - 16 [4]		10 ≤ s ≤ 150 (KV)
1.0570	355	490 - 630	18 - 22 [4]	14 - 18 [4]	at -20 °C: 27	s < 16 (R_{eH})
1.0460	240	410 - 540	20		at 20 °C: 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
1.5415	275	440 - 590	22		at 20 °C: 31	s ≤ 16
	280	450 - 600	20		at 20 °C: 27	
1.7335	300	440 - 600	20		at 20 °C: 31	s ≤ 16
	290	440 - 590			at 20 °C: 27	
1.7380	310	480 - 630	18		at 20 °C: 31	s ≤ 16
	280		20		at 20 °C: 27	
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

[2] Smallest value from lateral and transverse test piece
[3] acc. to DIN EN 10045; average of 3 tests with DIN EN standards
[4] depending on product thickness

DESCRIPTIONS, FORMS OF DELIVERY, LIMITING TEMPERATURES

Material group	Material no. acc. to DIN EN 10027	Designation acc. to DIN EN 10027	Semi-finished	Documentation	Upper limiting temperature
					°C
Stainless ferritic steel	1.4511	X3CrNb17	Metal strip, sheet metal	DIN EN 10088	
				VdTÜV-WB 422	200
	1.4512	X2CrTi12	Metal strip, sheet metal	DIN EN 10088	350
				SEW 400	
Stainless austenitic steel	1.4301	X5CrNi18-10	Metal strip, sheet metal	DIN EN 10088-2	550 / 300 [5)]
	1.4306	X2CrNi19-11	Metal strip, sheet metal	DIN EN 10088-2	550 / 350 [5)]
	1.4541	X6CrNiTi18-10	Metal strip, sheet metal	DIN EN 10088-2	550 / 400 [5)]
	1.4571	X6CrNiMoTi17-12-2	Metal strip, sheet metal	DIN EN 10088-2	550 / 400 [5)]
	1.4404	X2CrNiMo17-12-2	Metal strip, sheet metal	DIN EN 10088-2	550 / 400 [5)]
	1.4435	X2CrNiMo18-14-3	Metal strip, sheet metal	DIN EN 10088-2	550 / 400 [5)]
	1.4565	X2CrNiMnMoNbN25-18-5-4	Metal strip, sheet metal	SEW 400	550 / 400 [5)]
	1.4539	X1NiCrMoCu25-20-5	Sheet metal, metal strip,	DIN EN 10088-2	550 / 400 [5)]
			Seamless tube	VdTÜV-WB 421	400
	1.4529	X1NiCrMoCuN25-20-7	Sheet metal, metal strip	DIN EN 10088-2	400
			Seamless tube	VdTÜV-WB 502	
Highly heat-resistant austenitic steel	1.4948	X6CrNi18-10	Sheet metal, metal strip	DIN EN 10028-7	600
			Forging	DIN EN 10222-5	
			Seamless tube	DIN EN 10216-5	400 [5)]
	1.4958	X5NiCrAlTi31-20	Sheet metal, metal strip	DIN EN 10028-7	600
			Seamless tube	DIN EN 10216-5	400 [5)]

[5)] Limiting temperature where there is a risk of intercrystalline corrosion

STRENGTH VALUES AT ROOM TEMPERATURE (GUARANTEED VALUES [2)])

Material no. acc. to DIN EN 10027	Elongation limit min.			Tensile strength	Elongation at break min. > 3 mm	Elongation at break min. < 3mm	Impact work > 10 mm thickness, transverse min.	Remarks
		$R_{p0.2}$	$R_{p1.0}$	R_m	Thickness A_5	Thickness A_{80}	KV	
		MPa	MPa	MPa	%	%	J	
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 20 °C: 60	s ≤ 6
	l	215	245		43	40		
1.4306	q	220	250	520 - 670	45	45	at 20 °C: 60	s ≤ 6
	l	205	235		43	40		
1.4541	q	220	250	520 - 720	40	40	at 20 °C: 60	s ≤ 6
	l	205	235		38	35		
1.4571	q	240	270	540 - 690	40	40	at 20 °C: 60	s ≤ 6
	l	225	255		38	35		
1.4404	q	240	270	530 - 680	40	40	at 20 °C: 60	s ≤ 6
	l	225	255		38	35		
1.4435	q	240	270	550 - 700	40	40	at 20 °C: 60	s ≤ 6
	l	225	255		38	35		
1.4565	q	420	460	800 - 1000	30	25	at 20 °C: 55	s ≤ 30
1.4539	q	240	270	530 - 730	35	35	at 20 °C: 60	s ≤ 6
	l	225	255		33	30		
		220	250	520 - 720	40	40		
1.4529	q	300	340	650 - 850	40	40	at 20 °C: 60	s ≤ 50
	l	285	325		38	35		
		300	340	600 - 800	40	40	at 20 °C: 84	
1.4948	q	230	260	530 - 740	45	45	at 20 °C: 60	s ≤ 6
	q	195	230	490 - 690	35		at 20 °C: 60	s ≤ 250
	q	185	225	500 - 700	30		at 20 °C: 60	
1.4958	q	170	200	500 - 750	30	30	at 20 °C: 80	s ≤ 75
	q	170	200	500 - 750	30		at 20 °C: 80	

[2)] Smallest value from lateral and transverse test piece
q = Test piece, transverse
l = Test piece, lateral

DESCRIPTIONS, FORMS OF DELIVERY, LIMITING TEMPERATURES

Material group	Material no. acc. to DIN EN 10027[6]	Designation acc. to DIN EN 10027	Trade name	Semi-finished	Documentation	Upper limiting temperature °C
Heat resistant steel	1.4828	X15CrNiSi20-12		Sheet metal, metal strip	DIN EN 10095 (SEW470)	900
	1.4876	X10NiCrAlTi32-20	INCOLOY 800	Metal strip, sheet metal, rod, seamless Tube, forging	SEW470	600
					VdTÜV-WB 412	
		X10NiCrAlTi32-20 H	INCOLOY 800 H		VdTÜV-WB 434	950
					DIN EN 10095	900
Nickel-base alloys	2.4858	NICr21Mo	INCOLOY 825	Metal strip, sheet metal	DIN 17750	
					VdTüV-WB 432	450
					DIN 17744 [7]	
	2.4816	NiCR15Fe	INCONEL 600	Metal strip, sheet metal	DIN EN 10095	1000
					VdTÜV-WB 305	450
			INCONEL 600 H		DIN 17750	
					VdTÜV-WB 305	450
					DIN 17742 [7]	
	2.4819	NiMo16Cr15W	HASTELLOY C-276	Metal strip, sheet metal	DIN 17750	
					VdTÜV-WB 400	450
					DIN 17744 [7]	
	2.4856	NiCr22Mo9Nb	INCONEL 625	Flat products, Metal strip, sheet metal	DIN EN 10095	900
					VdTÜV-WB 499	450
			INCONEL 625 H		DIN 17750	
					DIN 17744 [7]	
	2.4610	NiMo16Cr16Ti	HASTELLOY C-4	Metal strip, sheet metal	DIN 17750	
					VdTÜV-WB 424	400
					DIN 17744 [7]	
	2.4360	NiCu30Fe	MONEL	Metal strip, sheet metal	DIN 17750	
				Metal strip, sheet metal, Seamless tube, Forging	VdTÜV-WB 263	425
					DIN 17743 [7]	

[6] The material number DIN 17007 is valid for nickel-base alloys
[7] Chemical composition

STRENGTH VALUES AT ROOM TEMPERATURE (GUARANTEED VALUES [2])

Material no. acc. to DIN EN 10027[6]	Yield points min.		Tensile strength	Elongation at break min.		Impact work min.	Remarks
	$R_{p0.2}$	$R_{p1.0}$	R_m	A_5	A_{80}	KV	
	MPa	MPa	MPa	%	%	J	
1.4828	230	270	500 - 750		28		Solution-annealed (+AT), s ≤ 3 mm
1.4876	210		500 - 750	22			soft-annealed (+A)
	210	240	500 - 750	30		at 20 °C: 150 [8]	
	170	200	450 -700	30			solution-annealed (+AT)
	170	210	450 - 680		28		
2.4858	240	270	≥ 550	30			soft-annealed (+A), F55,
	235	265	550 - 750		30	at 20 °C: 80	s ≤ 30 mm
2.4816	240		500 - 850		30		soft-annealed (+A), F55
	200	230	550 - 750	30		at 20 °C: 150 [8]	
	180	210	≥ 550		30		solution-annealed (+AT), (+AT), F50
	180	210	500 - 700	35		at 20 °C: 150 [8]	
2.4819	310	330	≥ 690	30			solution-annealed (+AT), F69,
	310	330	730 - 1000	30		at 20 °C: 96	s ≤ 5 mm
2.4856	415		820 - 1050		30		soft-annealed (+A), s ≤ 3 mm
	400	440	830 - 1000	30			soft-annealed (+A)
	275	305	≥ 690		30	at 20 °C: 100	solution annealed (+AT), F69
2.4610	305	340	≥ 690	40		at 20 °C: 96	solution-annealed (+AT), s ≤ 5
	280	315	700 - 900	40		at 20 °C: 96	5 < s ≤ 30
2.4360	175	205	≥ 450	30			soft-annealed (+A), F45, s ≤ 50
	175		450 - 600	30		at 20 °C: 120	soft-annealed (+A), F45

[2] Smallest value from lateral and transverse test piece
[6] The material number DIN 17007 is valid for nickel-base alloys
[8] Value a_k in J/cm²

DESCRIPTIONS, FORMS OF DELIVERY, LIMITING TEMPERATURES

Material group	Material no.	Designation	Semi-finished	Documentation	Upper limiting temperature
	as per DIN EN 1652				°C
Cop-per-based alloys	CW354H	CuNi30Mn1Fe	Metal strip, sheet metal	DIN-EN 1652 AD-W 6/2	350
Copper	CW024A	Cu-DHP	Metal strip, sheet metal	DIN-EN 1652 AD-W 6/2	250
Copper-tin alloys	CW452K	CuSn6	Metal strip, sheet metal	DIN-EN 1652	
Copper-zinc alloys	CW503L	CuZn20	Metal strip, sheet metal	DIN-EN 1652	
	CW508L	CuZn37	Metal strip, sheet metal	DIN-EN 1652	
	2.0402[9] (CW617N)	CuZn40Pb2	Metal strip, sheet metal	DIN 17670 DIN 17660	
	acc. to DIN EN 485-2				
Wrought aluminium alloys	EN AW-5754	EN AW-Al Mg3	Metal strip, sheet metal	DIN EN 485-2	
				DIN EN 575-3	
				AD-W 6/1	150 (AD-W)
	EN AW-6082	EN AW-Al Si1MgMn	Metal strip, sheet metal	DIN-EN 485-2	
				DIN-EN 573-3	
	acc. to DIN 17007				
Pure nickel	2.4068	LC-Ni 99	Metal strip, sheet metal	VdTÜV-WB 345	600
Titanium	3.7025	Ti 1	Metal strip, sheet metal	DIN 17 850	250
				DIN 17 860	
				VdTÜV-WB 230	
Tantalum		Ta	Metal strip, sheet metal	VdTÜV-WB 382	250

[9] acc. to DIN 17670

STRENGTH VALUES AT ROOM TEMPERATURE (GUARANTEED VALUES [2])

Material no.	Yield points min.		Tensile strength	Elongation at break min.	Impact work min.	Remarks
	$R_{p0.2}$	$R_{p1.0}$	R_m	A_5	KV	
	MPa	MPa	MPa	%	J	
CW354H	≥ 120		350 - 420	35 [13]		R350 (F35) [11] 0.3 ≤ s ≤ 15
CW024A	≤ 100		200 - 250	42 [13]		R200 (F20) [11] s > 5 mm
	≤ 140		220 - 260	33 [14] / 42 [13]		R220 (F22) [11] 0.2 ≤ s ≤ 5 mm
CW452K	≤ 300		350 - 420	45 [14]		R350 (F35) [11] 0.1 ≤ s ≤ 5 mm
				55 [13]		
CW503L	≤ 150		270 - 320	38 [14]		R270 (F27) [11] 0.2 ≤ s ≤ 5 mm
				48 [13]		
CW508L	≤ 180		300 - 370	38 [14]		R300 (F30) [11] 0.2 ≤ s ≤ 5 mm
				48 [13]		
2.0402	≤ 300		≥ 380	35		- (F38) [12] 0.3 ≤ s ≤ 5 mm
EN AW-5754	≥ 80		190 - 240	14 (A50)		0.5 < s ≤ 1.5 mm Status: O / H111 DIN EN values
EN AW-6082	≤ 85		≤ 150	14 (A50)		0.4 ≤ s ≤ 1.5 mm Status: O ; DIN EN values
2.4068	≥ 80	≥ 105	340 - 540	40		
3.7025	≥ 180	≥ 200	290 - 410	30 / 24 [15]	62	0.4 < s ≤ 8 mm
TANTAL-ES	≥ 140		≥225	35 [10]		0.1 ≤ s ≤ 5.0, smelted with electronic beam
TANTALUM-GS	≥ 200		≥ 280	30 [10]		0.1 ≤ s ≤ 5.0, sintered in vacuum

[2] Smallest value from lateral and transverse test piece
[10] Gauge length lo = 25 mm
[11] Status description acc. to DIN EN 1652 or. (--) acc. to DIN
[12] Acc. to DIN, material not contained in the DIN EN
[13] Details in DIN EN for s > 2.5 mm
[14] Elongation at break A50, details in DIN EN for s ≤ 2.5 mm
[15] A50 for thicknesses ≤ 5 mm

CHEMICAL COMPOSITION (PERCENTAGE BY MASS)

Material group	Material no.	Designation	C [16]	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			Alges ≥ 0.015
General construction 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 resisting unalloyed steel	1.0460	C22G2	0.18 - 0.23	0.15 - 0.35	0.4 - 0.90	0.035	0.030	≤ 0.30			
Heat-resisting steel	1.0345	P236GH	≤ 0.16	0.35	0.4 - 1.20	0.03	0.025	≤ 0.30	≤ 0.08	≤ 0.30	Nb,Ti,V Alges ≥ 0.020 Cu ≤ 0.30 Cr+Cu+Mo+Ni ≤ 0.70
	1.0425	P265GH	≤ 0.20	0.4	≤ 0.5	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				

[16] The C content is dependent on the thickness. The values are for a thickness of ≤ 16 mm.

07

CHEMICAL COMPOSITION (PERCENTAGE BY MASS)

Material group	Material no.	Designation	C max.	Si max.	Mn	P max.	S max.	Cr	Mo	Ni	Other Elements
Fine grain construction 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			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		8.0 - 10.5	
	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	X2CrNiMnMoNbN2 5-18-5-4	0.04	1.00	4.50 - 6.5	0.030	0.015	21.0 - 25	3.0 - 4.5	15.0 - 18	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: 1.20- 2.00 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

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CHEMICAL COMPOSITION (PERCENTAGE BY MASS)

Material group	Material no.	Designation	C	Si	Mn	P max.	S max.	Cr	Mo	Ni	Other Elements
Highly heat-resistant austenitic steel	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: ≤ 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-base 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	Residue	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 C-4	≤ 0.015	≤ 0.08	≤ 1.0	0.025	0.015	14.0 - 18.0	14.0 - 17.0	Residue	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	CW354H	CuNi 30 Mn1 Fe CUNIFER 30	≤ 0.05		0.5 - 1.50		0.050			30.0 -32.0	Cu: residue, Pb, Zn

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CHEMICAL COMPOSITION (PERCENTAGE BY MASS)

Material group	Material no.	Designation	Cu	Al	Zn	Sn	Pb	Ni	Ti	Ta	Other Elements
Copper	CW024A	Cu DHP	≥ 99.9								P: 0.015 - 0.04
Copper-tin alloy	CW452K	CuSn 6	Residue		≤ 0.2	5.5 - 7.0	≤ 0.2	≤ 0.2			P: 0.01 - 0.4, Fe: ≤ 0.1
Copper-Zinc alloy	CW503L	CuZn 20	79.0 - 81.0	≤ 0.02	Residue	≤ 0.1	≤ 0.05				
	CW508L	CuZn 37 Brass	62.0 - 64.0	≤ 0.05	Residue	≤ 0.1	≤ 0.1	≤ 0.3			
	2.0402	CuZn 40 Pb 2	57.0 - 59.0	≤ 0.1	Residue	≤ 0.3	1.5 - 2.5	≤ 0.4			
Wrought aluminium alloy	EN AW-5754	EN AW-Al Mg3	≤ 0.1	Residue	≤ 0.1				≤ 0.15		Si, Mn, Mg
	EN AW-6082	EN AW-Al Si1MgMn	≤ 0.1	Residue	≤ 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							Residue		N ≤ 0.05 H ≤ 0.013 C ≤ 0.06 Fe ≤ 0.15
Tantalum	-	Ta						≤ 0.01	≤ 0.01	Residue	

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STRENGTH VALUES AT ELEVATED TEMPERATURES

Material no. acc. to DIN	Type of value	RT [17]	100	150	200	250	300	350	400	450	500	550	600	700	800	900
		Strength parameters in MPa – Temperatures in °C														
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 acc. to AD W1)			
1.0570	$R_{p\,0.2}$	315	254		226	206	186						(values acc. to AD W1)			
1.0460	$R_{p\,0.2}$	240	230	210	185	165	145	125	100	80			( ) = values at 480 °C			
	$R_{p\,1/10000}$								136	80	(53)					
	$R_{p\,1/100000}$								95	49	(30)					
	$R_{m\,10000}$								191	113	(75)					
	$R_{m\,100000}$								132	69	(42)					
1.0345	$R_{p\,0.2}$	206	190	180	170	150	130	120	110				( ) = values at 480 °C			
	$R_{p\,1/10000}$								136	80	(53)					
	$R_{p\,1/100000}$								95	49	(30)					
	$R_{m\,10000}$								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				( ) = values at 480 °C			
	$R_{p\,1/10000}$								136	80	(53)					
	$R_{p\,1/100000}$								95	49	(30)					
	$R_{m\,10000}$								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	264	250	233	213	194	175	159	147	141		( ) = values at 530 °C			
	$R_{p\,1/10000}$									216	132	(84)				
	$R_{p\,1/100000}$									167	73	(36)				
	$R_{m\,10000}$									298	171	(102)				
	$R_{m\,100000}$									239	101	(53)				
	$R_{m\,200000}$									217	84	(45)				
1.7335	$R_{p\,0.2}$				230	220	205	190	180	170	165		( ) = values at 570 °C			
	$R_{p\,1/10000}$									245	157	(53)				
	$R_{p\,1/100000}$									191	98	(24)				
	$R_{m\,10000}$									370	239	(76)				
	$R_{m\,100000}$									285	137	(33)				
	$R_{m\,200000}$									260	115	(26)				

[17] Room temperature values valid to 50 °C

STRENGTH VALUES AT ELEVATED TEMPERATURES

Material no. acc. to DIN	Type of value	RT [17]	100	150	200	250	300	350	400	450	500	550	600	700	800	900
		Strength parameters in MPa – Temperatures in °C														
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			( ) = values at 480 °C			
	$R_{p\,1/10000}$								136	80	(53)					
	$R_{p\,1/100000}$								95	49	(30)					
	$R_{m\,10000}$								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				
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				
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							

[17] Room temperature values valid to 50 °C

STRENGTH VALUES AT ELEVATED TEMPERATURES

Material no. acc. to DIN	Type of value	Strength parameters in MPa – Temperatures in °C: RT [17]	100	150	200	250	300	350	400	450	500	550	600	700	800	900
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		
1.4958	$R_{p\,0.2}$	170	140	127	115	105	95	90	85	82	80	75	75			
	$R_{p\,1}$	200	160	147	135	125	115	110	105	102	100	95	95			
	R_m	500	465	445	435	425	420	418	415	415	415					
	$R_{p\,1/10000}$												115	58		
	$R_{p\,1/100000}$	Values in brackets were determined by enhanced extrapolation											(85)	(40)		
	$R_{m\,10000}$										290	225	140	69		
	$R_{m\,100000}$										215	160	95	44		
	$R_{m\,200000}$										(196)	(143)	(83)	(38)		
1.4828	$R_{p\,0.2}$	230	205		180		160		150		140		130	DIN EN 14917		
	$R_{p\,1}$	270	245		220		205		190		180		170			
	R_m	550	470		430		410		400		370		320			
	$R_{p\,1/1000}$	DIN EN 10095											120	50	20	8
	$R_{p\,1/10000}$												80	25	10	4
	$R_{m\,1000}$												190	75	35	15
	$R_{m\,100000}$												120	36	18	8.5
	$R_{m\,100000}$												65	16	7.5	3.0
1.4876 solution-annealed (+AT)	$R_{p\,0.2}$	170	140		115		95		85		80		75	DIN EN 14917		
	$R_{p\,1}$	200	160		135		115		105		100		95			
	R_m	450	425		400		390		380		360		300			
	$R_{p\,1/1000}$	DIN EN 10095											130	70	30	13
	$R_{p\,1/10000}$												90	40	15	5
	$R_{m\,1000}$												200	90	45	20
	$R_{m\,100000}$												152	68	30	10
	$R_{m\,100000}$	DIN EN 14917											114	47	19	4
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						

[17] Room temperature values valid to 50 °C

STRENGTH VALUES AT ELEVATED TEMPERATURES

Material no. acc. to DIN	Type of value	Strength parameters in MPa – Temperatures in °C: RT [17]	100	150	200	250	300	350	400	450	500	550	600	700	800	900
2.4816 DIN EN 10095	$R_{p\,0.2}$	200	180		165		155		150	145			soft-annealed (+A)			
	R_m	550	520		500		485		480	475						
		-750														
	$R_{p\,0.2}$	180	170		160		150		150	145			solution-annealed (+AT)			
	R_m	500	480		460		445		440	435						
		-700														
	$R_{p\,1/10000}$	soft-annealed (+A)									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
2.4819 VdTÜV-WB 400	$R_{p0,2}$	310	280		240		220		195							
	R_{p1}	330	305		275		215		200							
2.4856	$R_{p\,0.2}$	400	350		320		300		280	270		soft-annealed (+A), VdTÜV-WB 499				
	$R_{p\,1/100000}$	solution-annealed (+AT), manufacturer's figures for Inconel 625 H											250	90	30	10
	$R_{m\,100000}$												290	135	45	18
	$R_{m\,1000}$	soft-annealed (+A), DIN EN 10095												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 for 425 °C			
	R_m	450	420	400	390	385	380	375	370	(370)						
CW354H	$R_{p\,1}$	140	130	126	123	120	117	112								
	$R_{p\,1/10000}$				107	99	92	84								
	$R_{p\,1/100000}$				102	94	86	78								
	K/S [18]		93	87	84	82	80	78	75							
CW024A AD-W 6/2	$R_{p\,1}$	60	55	55									State R200			
	R_m	200	200	175	150	125										
	K/S [18]	57	57	50	43	36										
	$R_{p\,1}$	65	58	58									State R220			
	R_m	220	220	195	170	145										
	K/S [18]	63	63	56	49	41										
	$R_{p\,2/10000}$		58	53	46	37							State R200 + R220			
	$R_{p\,2/100000}$		56	49	40	30										
EN-AW 5754	$R_{p\,0.2}$	80	70													
	$R_{m\,100000}$		(80)	45												

[17] Room temperature values valid to 50 °C
[18] K/S = Permissible tension in accordance with AD-W 6/2 for 10^5 h

STRENGTH VALUES AT ELEVATED TEMPERATURES

Material no. acc. to DIN	Strength parameters in MPa															
	Type of value	Temperatures in °C														
		RT [17]	100	150	200	250	300	350	400	450	500	550	600	700	800	900
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 titanium	$R_{p\,1}$	200	180	150	110	90										
	$R_{m\,10000}$	220	160	150	130	110										
	$R_{m\,100000}$	200	145	130	120	90										
Tantalum	$R_{p\,0,2}$	140	100	90	80	70							Tantalum-ES Smelted with electronic beam			
	R_m	225	200	185	175	160	150									
	$A_{30[\%]}$	35														
	$R_{p\,0,2}$	200	160	150	140	130							Tantalum-GS Sintered in vacuum			
	R_m	280	270	260	240	230										
	$A_{30[\%]}$	25														

[17] Room temperature values valid to 50 °C

PERMISSIBLE OPERATING PRESSURES AND TEMPERATURES FOR MALLEABLE IRON THREADED CONNECTIONS

Threaded connections made of malleable iron can be used at up to the operating pressures in the following table, depending on the flow media and operating temperature.

Permissible operating pressure for the flow media

DN	d	Water and gas up to max. 120 °C	Gases and vapours up to max. 150 °C	Gases and vapours up to max. 300 °C	Oils up to 200 °C
–	Inch	–	–	–	–
Nipple, flat sealing screw connections					
6-50	¼ - 2	65 bar	50 bar	40 bar	35 bar
Conical sealing screw connections					
6 - 32	¼ - 1¼	65 bar	40 bar	40 bar	35 bar
40	1½	50 bar	50 bar	40 bar	30 bar
50	2	55 bar	40 bar	32 bar	24 bar

Particular care is required with the seal. The sealing materials are to be adjusted to the operating conditions. Only permitted sealants may be used to seal threaded connections in drinking water and gas installations.

Only the highest quality connecting threads are suitable for demanding operating requirements.

MATERIAL DESCRIPTIONS ACCORDING TO INTERNATIONAL SPECIFICATIONS

Material no. acc. to DIN EN	USA			Japan		
	Standard	UNS designation	Semi-finished product/ application/title	Standard	Designation	Semi-finished product/ application/title
1.0254	ASTM A 53	K02504 Grade A, type S	Welded and seamless black-oxidised and hot-dip galvanised steel tubes	JIS G 3445	STKM12A	Tube for mechanical engineering
	ASTM A 519	K02504 Grade 1020	Seamless tube	JIS G 3454	STPG370	Tube for pressure tanks
	ASTM A 523	K02504 Grade B	Seamless, resistance welded tube	JIS G 3457	STPY400	Welded tube
1.0255	ASTM A106	Grade A	Seamless heat resisting tube	JIS G 3455	STS 370	Tube for pressure vessels
1.0038	ASTM A 500	K03000	Welded and seamless molded parts made of unalloyed steel			
1.0050	ASTM A 573	Grade 70	Sheet metal with improved toughness	JIS G 3101	SS490	General construction steels
1.0570	ASTM A105		Forging for tubelines	JIS G 3106	SM490YB	Steels for welded structures
	ASTM A 662	Grade C	Sheet metal for pressure tanks	JIS G 3106	SM520B	Steels for welded structures
1.0345	ASTM A 414	K02201 Grade A	Sheet metal for pressure tanks	JIS G 3115	SPV450	Sheet metal for pressure tanks
1.0425	ASTM A 414	K02505 Grade D	Sheet metal for pressure tanks	JIS G 3115	SPV355	Sheet metal for pressure tanks
1.0481	ASTM A 414	K02704 Grade F	Sheet metal for pressure tanks	JIS G 3118	SGV410	Sheet metal for pressure tanks
1.5415	ASTM A 204	K12320 Grade A	Sheet metal for pressure tanks	JIS G 3458	STPA12	tubes,
1.7335	ASTM A 387	K11789 Grade 12	Sheet metal made of Cr-Mo alloy steel for pressure tanks	JIS G 3462	STBA22	Boiler and heat exchanger tubes
1.7380	ASTM A 387	K21590 Grade 22	Sheet metal made of Cr-Mo alloy steel for pressure tanks	JIS G 4109	SCMV4	Sheet metal for pressure tanks
1.0305	ASTM A 106	K02501 Grade A	Seamless heat resisting tube	JIS G 3461	STB340	Tube, boiler tube
1.0562	ASTM A 299	K02803 Grade A	Sheet metal for pressure tanks	JIS G 3106	SM490 A;B;C	Steels for welded structures
	ASTM A 714	K12609 Grade II	Welded and seamless tubes made of high tensile, low-alloy steel	JIS G 3444	STK490	Tubes for general use
1.0565	ASTM A 633	K12037 Grade D	Sheet, high-strength			
	ASTM A 662	K12037 Grade C	Sheet metal for pressure tanks			
1.0566	ASTM A 662	K02701 Grade C	Sheet metal for pressure tanks	JIS G 3126	SLA365	Sheet for pressure vessels, low temperature

MATERIAL DESCRIPTIONS ACCORDING TO INTERNATIONAL SPECIFICATIONS

Material no. acc. to DIN EN	Korea			China		
	Standard	Designation	Semi-finished product/ application/title	Standard	Designation	Semi-finished product/ application/title
1.0254	KS D 3583	SPW 400	Welded tubes made of carbon steel			
1.0255	KS D 3562	SPPS 410	Carbon steel, tubelines for high-pressure applications	GB/T 5312	410	Seamless tube for shipbuilding
1.0038				GB/T 700	Q235B U12355	(unalloyed construction steels)
1.0050	KS D 3503	SS 490	General construction steels	GB/T 700	Q275 U12752	(unalloyed construction steels)
1.0570	KS D 3517	STKM 16C	Unalloyed steel tubes for general mechanical engineering	GB 6654	16MnR L20162	Sheet metal for pressure tanks
				GB/T 8164	16Mn L20166	Metal strip for welded tubes
1.0345	KS D 3521	SPPV 450	Steel plates for pressure vessels for medium working temperatures	GB 6654	20R	Sheet metal for pressure tanks
1.0425	KS D 3521	SPPV 315	Steel plates for pressure vessels for medium working temperatures	GB/T 713	22Mng	Steel sheets for boilers and pressure vessels
1.0481						
1.5415	KS D 3572	STHA 12	Tubes for boilers and heat exchangers	GB 5310	15MoG A65158	Seamless tubes for pressure tanks
1.7335	KS D 3572	STHA 22	Tubes for boilers and heat exchangers	YB/T 5132	12CrMo A30122	Sheet metal for alloy construction steels
1.7380	KS D 3543	SCMV 4	Cr-Mo steel for pressure vessels	GB 5310	12Cr2MoG A30138	Seamless tubes for pressure tanks
1.0305				GB/T 5312	360	Seamless tube for shipbuilding
1.0562						
1.0565						
1.0566	KS D 3541	SLA 1 360	Steel plates for pressure vessels (low temperature)	GB/T 714	Q420q-D L14204	Steels for bridge building

MATERIAL DESCRIPTIONS ACCORDING TO INTERNATIONAL SPECIFICATIONS

Material no. acc. to DIN EN	USA			Japan		
	Standard	UNS designation	Semi-finished product/ application/title	Standard	Designation	Semi-finished product/ application/title
1.1106	ASTM A 707	K12510 Grade L3	Forged flanges made of alloyed and unalloyed steel for use at low temperatures	JIS G 3444	STK490	Tubes for general use
1.4511				JIS G 4305	SUS430LX	Cold-rolled sheet metal, steel plates and metal strip
1.4512	ASTM A 240	S40900 409	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks	JIS G 4312	SUH409L	Sheet metal, rust-resistant, heat resistant
1.4301	ASTM A 240	S30400 304	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks	JIS G 4305	SUS304	Cold-rolled sheet metal, steel plates and metal strip
1.4306	ASTM A 240	S30403 304L	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks	JIS G 4305	SUS304L	Cold-rolled sheet metal, steel plates and metal strip
1.4541	ASTM A 240	S32100 321	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks	JIS G 4305	SUS321	Cold-rolled sheet metal, steel plates and metal strip
1.4571	ASTM A 240	S31635 316Ti	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks	JIS G 4305	SUS316Ti	Cold-rolled sheet metal, steel plates and metal strip
1.4404	ASTM A 240	S31603 316L	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks	JIS G 4305	SUS316L	Cold-rolled sheet metal, steel plates and metal strip
1.4435	ASTM A 240	S31603 316L	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks	JIS G 4305	SUS316L	Cold-rolled sheet metal, steel plates and metal strip
1.4565	ASTM A 240	S34565	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks			
1.4539	ASTM A 240	N08904 904L	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks	JIS G 4305	SUS890L	Cold-rolled sheet metal, steel plates and metal strip
1.4529	ASTM A 240	N08925	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks			

MATERIAL DESCRIPTIONS ACCORDING TO INTERNATIONAL SPECIFICATIONS

Material no. acc. to DIN EN	Korea			China		
	Standard	Designa-tion	Semi-finished product/ application/title	Standard	Designation	Semi-finished product/ application/title
1.1106				GB 6654	16MnR L20163	Sheet metal for pressure tanks
1.4511	KS D 3698	STS 430LX	Cold-rolled sheet metal, steel plates and metal strip			
1.4512				GB /T 3280	022Cr11NbTi S11168	Hot-rolled sheet metal made of heat-resistant steel, ferritic
1.4301	KS D 3698	STS 304	Cold-rolled sheet metal, steel plates and metal strip	GB /T 3280	06Cr19Ni10 S30408	Cold-rolled sheet metal and metal strips, austenitic
1.4306	KS D 3698	STS 304L	Cold-rolled sheet metal, steel plates and metal strip	GB /T 3280	022Cr19Ni10 S30403	Cold-rolled sheet metal and metal strips, austenitic
1.4541	KS D 3698	STS 321	Cold-rolled sheet metal, steel plates and metal strip	GB /T 3280	06Cr18Ni11Ti S32168	Cold-rolled sheet metal and metal strips, austenitic
1.4571	KS D 3698	STS 316Ti	Cold-rolled sheet metal, steel plates and metal strip	GB /T 3280	06Cr17Ni12Mo2Ti S31668	Cold-rolled sheet metal and metal strips, austenitic
1.4404	KS D 3698	STS 316L	Cold-rolled sheet metal, steel plates and metal strip	GB /T 3280	022Cr17Ni12Mo2 S31603	Cold-rolled sheet metal and metal strip, austenitic
1.4435	KS D 3698	STS 316L	Cold-rolled sheet metal, steel plates and metal strip	GB /T 3280	022Cr17Ni12Mo2 S31603	Cold-rolled sheet metal and metal strips, austenitic
1.4565				GB /T 3280	022Cr24Ni-17Mo5Mn6NbN	Cold-rolled sheet metal and metal strips, austenitic
1.4539				GB /T 3280	015Cr21Ni-26Mo5Cu2	Cold-rolled sheet metal and metal strips, austenitic
1.4529	KS D 3698	STS 317J5L	Cold-rolled sheet metal, steel plates and metal strip			

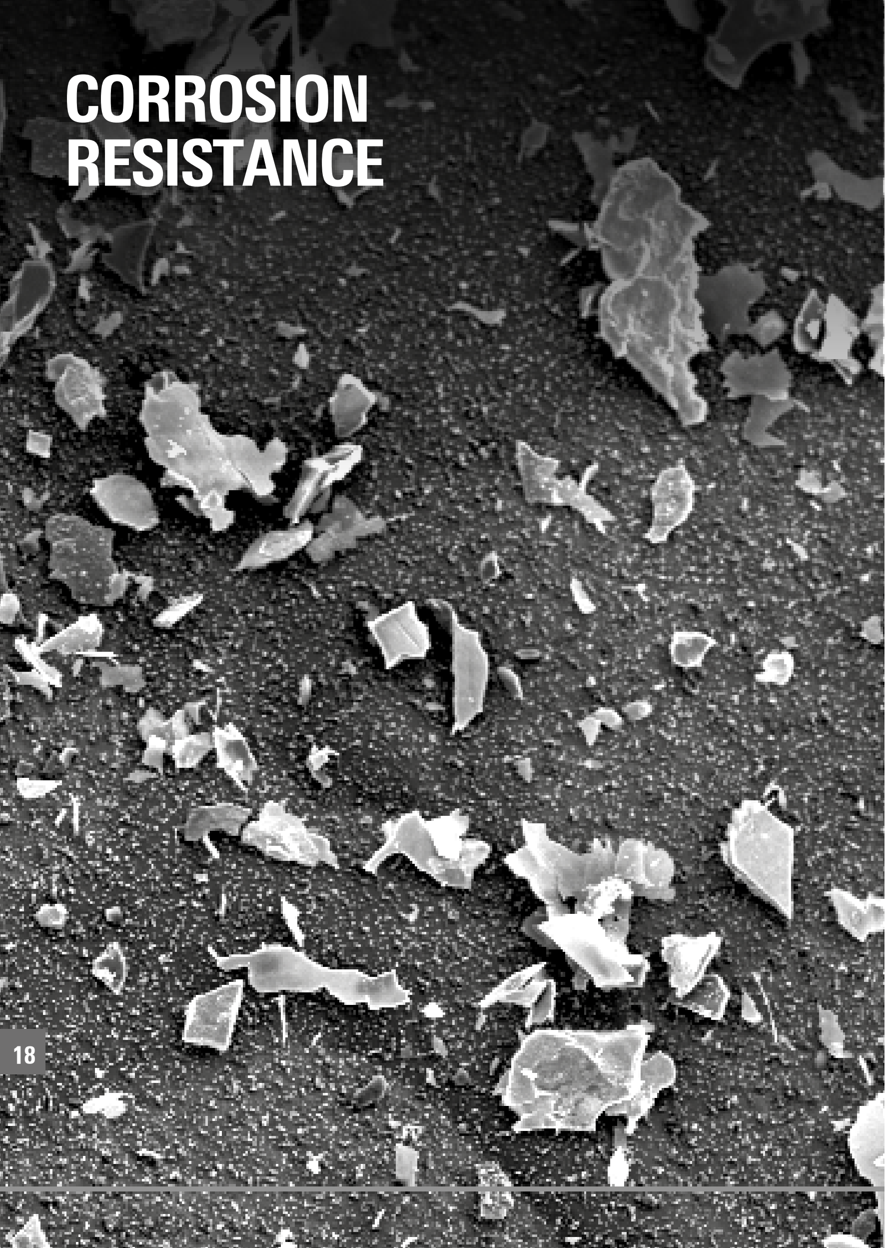
MATERIAL DESCRIPTIONS ACCORDING TO INTERNATIONAL SPECIFICATIONS

Material no. acc. to DIN EN	USA			Japan		
	Standard	UNS designation	Semi-finished product/ application/title	Standard	Designation	Semi-finished product/ application/title
1.4948	ASTM A 240	S30409 304H	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks			
1.4919	ASTM A 240	S31609 316H	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks			
1.4958	ASTM A 240	N08810	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks			
1.4828	ASTM A 167	S30900 309	Sheet metal and metal strip made of non-rusting, heat-resistant Cr-Ni steel	JIS G 4312	SUH309	Heat-resistant sheet metals and steel plates
1.4876	ASTM A 240	N08800 800H	Sheet metal and metal strip made of heat-resistant, non-rusting Cr and Cr-Ni steel for pressure tanks	JIS G 4902	NCF800	Special alloys in sheet metals
2.4858	ASTM B 424	N08825	Sheet metal and metal strips made of Ni-Fe-Cr-Mo-Cu alloys (UNS N08825 and N08221)	JIS G 4902	NCF825	Special alloys in sheet metals
2.4816	ASTM B 168	N06600	Sheet metal and metal strips made of Ni-Cr-Fe, and Ni-Cr-Co-Mo alloys (UNS N06600 and N06690)			
2.4819	ASTM B 575	N10276	Sheet metal and metal strips made of low Ni-Mo-Cr alloys			
2.4856	ASTM B 443	N06625	Sheet metal and metal strips made of Ni-Cr-Mo-Nb alloy (UNS N06625)	JIS G 4902	NCF625	Special alloys in sheet metals
2.4610	ASTM B 575	N06455	Sheet metal and metal strips made of low Ni-Mo-Cr alloys			
2.4360	ASTM B 127	N04400	Sheet metal and metal strips made of Ni-Cu alloy (UNS N04400)	JIS H 4551	NW4400	Sheet metals and metal strips made of nickel and nickel alloy

MATERIAL DESCRIPTIONS ACCORDING TO INTERNATIONAL SPECIFICATIONS

Material no. acc. to DIN EN	Korea			China		
	Standard	Designation	Semi-finished product/ application/title	Standard	Designation	Semi-finished product/ application/title
1.4948				GB /T 3280	07Cr19Ni10	Cold-rolled sheet metal and metal strips, austenitic
1.4919						
1.4958						
1.4828	KS D 3732	STR 309	Heat-resistant sheet metals and steel plates	GB/T 4238	16Cr23Ni13 S38210	Heat-resistant steels; austenitic
1.4876	KS D 3532	NCF 800	Special alloys in sheet metal and steel plates	GB/T 15007	NS 111 H01110	Rustproof alloys
2.4858	KS D 3532	NCF 825	Special alloys in sheet metal and steel plates	GB/T 15007	NS 142 H01402	Rustproof alloys
2.4816				GB/T 15007	NS 3102 H06600	Rustproof alloys
2.4819				GB/T 15007	NS 3304 H10276	Rustproof alloys
2.4856	KS D 3532	NCF 625	Special alloys in sheet metal and steel plates	GB/T 15007	NS 3306 H06625	Rustproof alloys
2.4610				GB/T 15007	NS 3305 H06455	Rustproof alloys
2.4360				GB/T 15007	NS6400 H04400	Rustproof alloys

CORROSION RESISTANCE



18

Basic principles

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).

08

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 briefly described below.

Uniform surface 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

Under certain conditions, attacks in limited areas can be described as pitting corrosion due to their appearance. The attack occurs from the effect of chlorine, bromine or iodine ions, particularly when present in watery solutions. This form of corrosion or the resulting selective attack is not calculable in comparison with surface corrosion and for that reason it can only be mastered using an appropriate selection of materials. With non-rusting steels, the stability relating to pitting corrosion increases with rising molybdenum content in the chemical composition of the material. The so-called cumulated reaction value (WS = Cr % + 3.3 · Mo % + 30 N %) can be used to compare roughly the stability of the materials in relation to pitting corrosion; the higher the cumulated reaction value, the greater the stability.

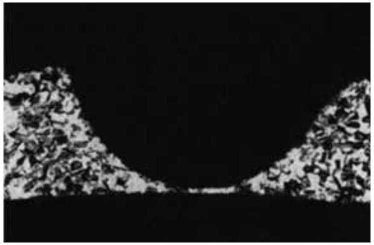


Fig. 18.1 Pitting corrosion on a cold strip made of austenitic steel. Sectional view (50-fold enlargement).

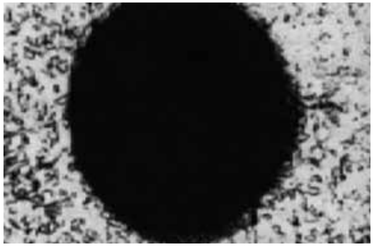


Figure 18.2 Sectional view (50-fold enlargement).

Intercrystalline corrosion

Intercrystalline corrosion is a localised, selective corrosion, which primarily attacks the grain boundaries. This type of corrosion is caused by separation in the material structure, which leads to a reduction in corrosion resistance in the areas near to the grain boundaries. With non-rusting steels, this form of corrosion can increase the disintegration of the grain bond (intergranular attack).

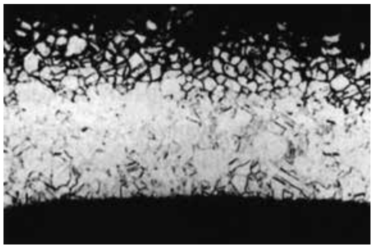


Figure 18.3 Intercrystalline corrosion (intergranular attack) in material 1.4828. Sectional view (100-fold enlargement).

These deposit processes are dependent on temperature and time in CrNi alloys, 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-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 our rust-products made of rust-resistant steels, 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 crack configuration can be transgranular or intercrystalline. 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 ambient temperature in austenitic materials in a neutral solutions containing chloride.

At temperatures above 100 °C stress corrosion cracking (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. 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.

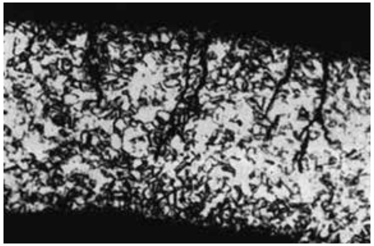


Figure 18.4 Transgranular stress corrosion cracking on a cold strip made of austenitic steel. Sectional view (50-fold enlargement).

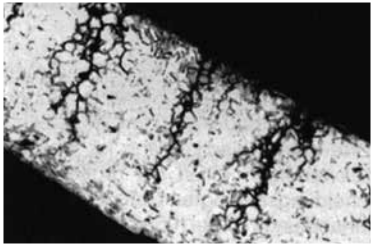


Figure 18.5 Intergranular stress corrosion cracking on a cold strip made of austenitic steel. Sectional view (50-fold enlargement).

Crevice corrosion

Owing to 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 assessing the resistance to crevice corrosion.

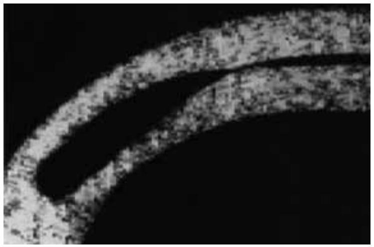


Figure 18.6 Crevice corrosion on a cold strip made from austenitic steel. Sectional view (50-fold enlargement).

Dezincification

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 dezincification 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 dezincification.

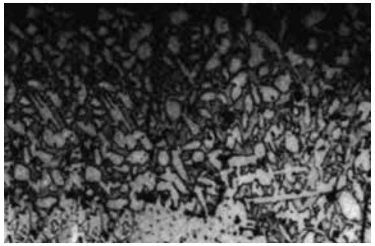


Figure 18.7 Dezincification on a Copper-Zinc alloy (CuZn37). Sectional view (100-fold enlargement).

Dissimilar metal corrosion

A type of corrosion which may result from a combination of different materials. In practice, so-called "practical galvanic potentials" are used, for example in seawater, to assess the risk of dissimilar metal corrosion. 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.

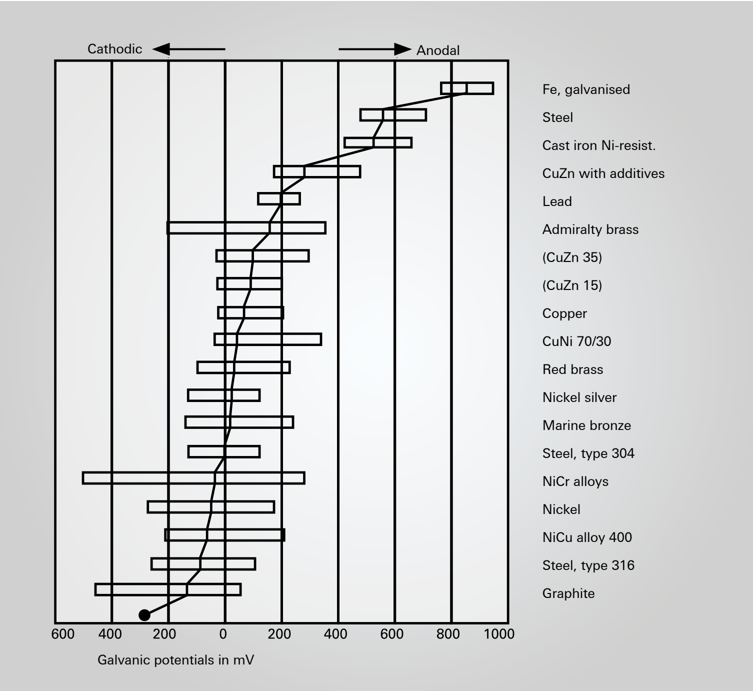


Figure 18.9 Galvanic potential in seawater

Source: DECHEMA material tables.

RESISTANCE TABLES

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 no claims to completeness The data constitutes recommendations only, for which no liability can be accepted

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

Table keys

Assessment	Corrosion behaviour	Suitability
0	resistant	suitable
1	uniform corrosion with reduction in thickness of up to 1 mm/year	restricted suitability
L	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

dc: damp condition
hs: hydrous solution (at boiling point)
cs: cold saturated (ambient temperature)
me: melt
bp: boiling point
adp: acid dew point
dsr dry condition
ws: watery solution

Medium: Designation / Chemical formula		Concentration	Temperature		Stainless steels			Nickel alloys					Copper alloys			Pure metals					
		%	°C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Cunifer 30 2.0882	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
1,3 Butadiene $CH_2=CHCH=CH_2$								0	0	0		0				0	0			0	
Acetaldehyde CH_3 - CHO		100	SP	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetanilide = Antifebrin			<114	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
Acetic acid		5	20	3	0	0	0	0	1	0	0	1				0	3	0	0	0	
CH_3-COOH		5	SP	3	3	0	0	0	1	0	0	1						0	0		
		50	20	3	3	0	0	0	1	0	0	1				0	3	1	0	0	0
		50	SP	3	3	3	0	0	1	0	0	1				3	3	0	0	3	1
		80	20	3	3	L	L	0	1	0	0	1					3	0	0	0	0
		96	20	3	3	3	L	0	1	0	0	1					3	0	0		
		98	SP	3	3	3	3	0	1	0	0	1						0	0		
Acetic acid alumina s. Aluminium acetate																					
Acetic acid butyl ether s. Butyl acetate																					
Acetic acid vapour		33	20		3	1	1														
		100	>50		3	3	3	0	1		0	1	3			3	3	0		1	
		100	<SP		3	3	3	0	3		0	3	3			3	3	0		3	
Acetic anhydride		All	20	1	0	0	0	0	1	0	0	1	1	3	0	0	1	0	0	0	0
$(CH_3\text{-}CO)_2O$		100	60	3		0	0				0				1	1	1	0	0	1	0
		100	SP	3		0	0		3		0						1	0	0	3	0
Acetone CH_3COCH_3		100	SP	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	tr		20	0	0	0	0	0	0	0	0	0	3	3	3	3	0	0	0	0	3
H-C≡C-H	tr		200	1	0	0	0	0	0	0	0	0	3	3	3	3	3	0	0	1	3
Acetylene dichloride	ws	5	20																	1	
$H_2C=CCl_2$	tr	100	20	0	L	L	L	0	0	0		0					0			0	
Acetylene tetrachloride $CHCL_2$ - $CHCL_2$ s. Tetrachloroethane																					

Medium: Designation / Chemical formula		Concentration	Temperature		Stainless steels			Nickel alloys					Copper alloys			Pure metals					
		%	°C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Cunifer 30 2.0882	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Adipine acid $HOOC(CH_2)_4COOH$		All	200	0	0	0	0	0	0	0	0	0					0	0	0	0	0
Alcohol s. Ethylene alcohol																					
Allyl alcohol CH_2CHCH_2OH		100	SP			0	0	0	0	0	1	0					0				
Allyl chloride $CH_2=CHCH_2Cl$		100	25				0	0	0	0		0					0				
Alum		100	20	1	1	0	0	0	1	0	0		1			1			0	1	
$KAl(SO_4)_2$	ws	10	20	1	0	0	0				1		1	1	1	1		0	0	1	
	ws	10	<80	1	1	0	0				1		1					0	0		
		hs			3	3	1				3		3								
Aluminium Al	Melt		750	3	3	3	3					3					3	3			
Aluminium acetate	ws	3	20	3	0	0	0				0						0	0			
$(CH_3\text{-}COO)_2Al(OH)$	ws	hs		3	0	0	0				1							0	1		
Aluminium chloride $AlCl_3$	ws	5	20	3	3	3	L	1	1	0	0	1	3	3	1	3	1	0	0	3	1
Aluminium fluoride AlF_3	ws	10	25	3	3	3	3				1	1				1	1	0	3	1	1
Aluminium formate $Al(HCOO)_3$				1	0	0	0	0	0	0	0				0	1	0	0	0	0	
Aluminium hydroxide $Al(OH)_3$	ws	10	20	1	3	0	0	0		0	0	1	0			0		0	0	1	
Aluminium nitrate $Al(NO_3)_3$				0	0	0	0	0	0	0	0	0						0	0	1	
Aluminium oxide Al_2O_3			20	1	1	0	0	0		0	0	3	0	0	0	0			0	3	
Aluminium sulphate	ws	10	<SP	3	3	3	0	0	1	0	1	3	3	3	3	3	1	0	0	3	
$Al_2(SO_4)_3$	ws	15	50	3	3	3	1		1	1	1	1	1	1	1	1	1	0	0	3	

08

Medium				Materials																			
Designation Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Ammonia	tr	10	20	0	0	0	0		0	0	0	1	0	S	S	0	3	0	0	0	0
NH_3	ws	2	20	0	0	0	0		0	0	0	0	3	S	S	3	3	0	0	1	0
	ws	20	40	0	0	0	0	0	1	1	1	3				3	3	0	0		
	ws	hs	SP	0	0	0	0	0	3	1	1	3						0	0		
Ammonium acetate				1	0	0	0												0	0	
CH_3-$COONH_4$																					
Ammonium alum	ws	kg	20			0	0											3	0		
$NH_4Al(SO_4)_2$																					
Ammonium bicarbonate	ws			0	0	0	0	1	3			3	3			3			0	0	
$(NH_4)HCO_3$																					
Ammonium bifluoride	ws	10	25	3	3	3	3				0							3	0		
NH_4HF_2	ws	100	20	3	3	0	0				0							3	0		
Ammonium bromide	ws	10	25	3	L	L	L	0		0	1								0	1	
NH_4Br																					
Ammonium carbonate	ws	1	20	0	0	0	0	0	0	0	1	0	1			1			0	0	0
$(NH_4)_2CO_3$		50	SP	0	0	0	0	0	0	0	1	0	1			1	1		0	0	0
Ammonium chloride	ws	1	20	1	L	L	L	0	0	0	0	0	1	S	S	1	1	0	0	1	1
NH_4Cl	ws	10	100	1	L	L	L	0	0	0	0	1	1	S	S	1	1	0	1	1	1
	ws	50	SP	1	L	L	L	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	ws	hs	70	3																	
	ws	20	80	3		3	3				0			3	3	3			0		
Ammonium fluorosilicate	ws	20	40	3		1	0	0	0	0	0	0					0				
$(NH_4)_2SiF_6$																					
Ammonium formate	ws	10	20	1	0	0	0	0	0	0	0	0						0	0	0	
$HCOONH_4$		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	ws	5	20	3	0	0	0	0	1	0	0	3	3			3			0	0	
NH_4NO_3	ws	100	SP	3	0	0	0	0			0	3		3	3	3			0	0	
Ammonium oxalate	ws	10	20	1	1	0	0		1	0	0	1	1			1		0	0		
$(COONH_4)_2$	ws	10	SP	3	3	1	0		1	0		1	1			1		1	0		
Ammonium perchlorate	ws	10	20		L	L	L				1							0			
NH_4ClO_4																					

Medium				Materials																			
Designation Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Stainless steels: Austenitic steels	Stainless steels: Austenitic + Mo	Nickel alloys: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	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 persulphate	ws	5	20		0	0	0	0	1	0	0	3	3			3	3	0	0	3	
$(NH_4)S_2O_8$	ws	10	25	3	1	1	1				0	3	3	3	3	3	3	0			3
Ammonium phosphate	ws	5	25	0	1	1	0	0	1	0	0	1	1			3	1	0	0	1	
$NH_4H_2PO_4$																					
Ammonium rhodanide			70		0	0	0											0		0	
NH_4CNS																					
Ammonium saltpetre																					
s. Ammonium nitrate																					
Ammonium sulphate	ws	1	20	0	0	0	0	0	1	0	0	1	3			3	1	0	0	L	
$(NH_4)_2SO_4$	ws	10	20	0	1	1	0	0	3		1	1	3	3	1	3	1	3	0	L	1
	ws	hs	SP	1		0					3	2	3					0	0		
Ammonium sulphite		kg	20		1	0	0	3	3			3	3			3	3	0	0		
$(NH4)_2SO_3$		hs	SP		3	1	1	3	3			3	3			3	3	0	0		
Ammonium sulphocyanide																					
s. Ammonium rhodanide																					
Amyl acetate		All	20					1	1	1	1	1	1			1	1		1	1	
CH_3-$COOC_5H_{11}$		100	SP	1		1	1		0	1	1	0	0				0			0	
Amyl alcohol		100	20	0	0	0	0		0	0	0	0	0	0	0	0	0		0		
$C_5H_{11}OH$ Pentanole		100	SP	1	0	0	0											0		1	
Amyl chloride		100	SP	1		L	L	0	1	0	0	1	0			0	1	0	0	3	
$CH_3(CH_2)_3CH_2Cl$																					
Amyl mercaptan		100	160			0	0				0										
Anilin		100	20			0	0	0	1	0	0	3	3	3	3	3	3	0		0	0
$C_6H_5NH_2$		100	180			1	1					1								3	0
Anilin chloride	ws	5	20		L	L	L				0		3			3	3	0	0	3	
$C_6H_5NH_2HCl$	ws	5	100		L	L	L				0							0			
Anilin hydrochloride																					
s. Anilin chloride																					
Anilin sulphate			20				0				0									1	
Aniline sulphite	ws	10	20				0		1		0										
	ws	kg	20				0				0										

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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	Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Cunifer 30 2.0882	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Antifreeze			20		0	0	0	0	0	0	0	0					0	0	0	0	
Glysantine																					
Antimony	Melt	100	650	3						0	0							3		3	
Sb																					
Antimony tric hloride	tr		20	0	3	3	3										0			3	
$SbCl_3$	ws		100	1	3	3	3										0			3	
Aqua regia			20	3	3	3	3		3		3		3	3	3	3		0	0		1
$3HCl+HNO_3$																					
Arsenic			65			0	0														
As			110			1	1														
Arsenious acid	ws		20	3		0	0														
H_3AsO_4	ws	90	110		3	3	3		3				3			3				3	
Asphalt			20	0	0	0	0						0	0	0	0	0			0	
Azobenzene			20		0	0	0	0	0	0	0	0						0	0	0	
C_6H_5-N=N-C_6H_5																					
Baking powder	dc			1	0	0	0	0	0	0	0	0				1				0	
Barium carbonate			20	3	0	0	0	0		0	0	0	0	0	0	0		0	0	1	
$BaCO_3$																					
Barium chloride	ws	5	20		L	L	L	1	1	0	0	1	3			3	1	0	0	3	
$BaCl_2$	ws	25	SP		L	L	L	1	1	0	0	1					1	0	0	L	
Barium hydroxide	solid	100	20	0	0	0	0	0	1		0	1	0	1	0	0	0	0		3	
$Ba(OH)_2$	ws	All	20	0	0	0	0	0	1		0	1	0	1	0	0	1	0		3	
	ws	All	SP	0	0	0	0				1		0					0			
	ws	100	815	0	0	0	0	0	1								1	0			
		kg	20	0	0	0	0				1		0	1	0	0	0	0		0	
	ws		SP	0	0	0	0				1						0	0		3	
		hs																			
		50	100	0	0	0	0	0	1			1					0	0			
Barium nitrate	ws	All	SP		0	0	0	0	1	0			3			3		0	0	0	
$Ba(NO_3)_2$																					
Barium sulphate			25	0	0	0	0	0		0		0	0	0	0	0	1	0	0	0	
$BaSO_4$																					
Barium sulphide			25		0	0	0						3	1	3	3					
BaS																					

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	Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Cunifer 30 2.0882	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Beer		100	20	3	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	
		100	SP	3	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	
Benzaldehyde	tr		SP		0	0	0											1	0	0	0
C_6H_5-CHO																					
Benzene[1)]		100	20	1	1	1	1	0	1	1	1	2		1	1	1	1	0	0	1	0
		100	SP	1	2	1	1		1	1	1	2	0	1	1	1	1	0	0	1	0
Benzenesulfonic acid	ws	5	40	3	0	0	0														
C_6H_5-SO_3H	ws	5	60	3	3	1	1														
Benzoic acid	ws	All	20	1	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
C_6H_5COOH	ws	All	SP	3	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	
Benzyl alcohol		All	20	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
C_6H_5-CH_2OH																					
Blood			20	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Borax	ws	kg		1	0	0	0						0	0	0	0		0	0	0	
$Na_2B_4O_7$	ws			3	0	0	0											0	0	1	
		hs																			
Boric acid	ws	50	100	3	0	0	0	0	1	0	0	1		1		1	1	0	0	1	1
H_3BO_3	ws	50	150	3	1	0	0	0	1	0	0	1		1		1	1	0	0	1	0
	ws	70	150	3	1	1	1	0	1	0	0	1	0	1	1	1	1	0	0	1	0
Boron			20	0	0	0	0														
OM			900	0																	
Brandy			20	1	0	0	0	0	0	0	0	0									
			SP	3	0	0	0	0	0	0	0	0									
Bromine	tr	100	20	L	L	L	L	1	0	0	0	0		0	0	0	0	3		3	0
Br	dc	100	20	L	L	L	L		3		3	0	1	3	1	3	0	0		3	0
Bromine water		0.03	20		L	L	L														
		1	20		L	L	L														
Bromoform	tr		20	0	0	0	0	0	0	0	0	0			0	0				3	
$CHBr_3$	dc		3	0	0	0	0	0	0	0	0			0	0				3		
Butane		100	20	0	0	0	0	0	0	0	0	0	0	0	0	1	0			1	
C_4H_{10}		100	120		1	0	0				1										
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	
Butyl acetate			20	1	0	0	0	0		0	0	1	0	0	0	0		0	0	0	0
$CH_3COOC_4H_9$			SP	1	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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Butyl alcohol		100	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CH_3-CH_2-CH_2-CH_2OH$		100	SP	0	0	0	0		0		0	0						0	0	0	
Butyric acid	ws	kg	20	3	0	0	0	1	3	0	0	1					3			0	
$CH_3-CH_2-CH_2-COOH$	ws		SP	3	3	3	0	1	3	0	0	1					3			1	
		hs																			
Cadmium	Melt					3	3														
Cd																					
Calcium			850	3		3	3														
Ca																					
Calcium bisulphite		kg	20	3	3	0	0						1	3	1	0		0			
$CaSO_3$			SP	3	3	3	0											0			
		hs																			
Calcium carbonate			20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
$CaCO_3$																					
Calcium chlorate	ws	10	20		L	L	L	1	1	1	1	1	3			1	1		0		
$Ca(ClO_3)_2$	ws	10	100		3	3	L	1	1	1	1	1	3			1	1		0		
Calcium chloride	ws	5	100	3	L	L	L				0							0	0	3	
$CaCl_2$	ws	10	20	3	L	L	L	0	0	0	0	0	0	3	1	1	0	0	0	3	
		kg		3	L	L	L	0	0	0	0	1	0	3		0	1	0	0	3	
				3	3	L	L	0	0	0	0	3	0	3				L	0	3	
		hs																			
Calcium hydroxide				0	0	0	0	1	1	0	0	1	0	0	0	1	1	0	0	3	
Ca(OH)2																					
Calcium hypochlorite	ws	2	20	3	3	3	L	0	3	0	0	3	3			3	3	0	0	3	
$Ca(OCl)_2$	ws	kg		3	3	3	L				1								0	3	
Calcium nitrate			20	3	0	0	0	0	0	0	0	0						0		0	
$Ca(NO_3)_2$		All	100	3	0	0	0	0		0	0	0						0		0	
Calcium oxalate	dc		20	1	0	0	0	0	0	0	0	0	0	0	0			0	0	3	
$(COO)_2Ca$																					
Calcium oxide			20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		3	
CaO																					
Calcium sulphate	dc		20	1	0	0	0	0		0	0	0	0	0	0	0	0	0	0	1	
$CaSO_4$	dc		SP	1	0	0	0	0		0	0	0	0	0	0	0	0	0	0	1	
Calcium sulphite	ws	kg		0	0	0	0									1		0	0	1	
$CaSO_3$	ws			0	0	0	0									1		0	0	1	
		hs																			

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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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Carbolic acid			20	0	0	0	0	0	1	0	0	1	0			0	1	0	0	0	
$C_6H_5(OH)$			SP	3	3	3	0				1	0					0	0	0	3	
	ws	90	SP	3	3	3	0				1	0					0	0	0	3	
Carbon dioxide	tr	100	<540	0	1	0	0	0	0	0	0	0				3	0		0		
CO_2	tr	100	1000	3					3										0		
	dc	20	25	1	1	0	0	0	0	0	0	0	0	3	1	1			0	3	
	dc	100	25	3	1	0	0	0	1	0	0	1	0			0	1	0	0	3	
Carbon monoxide		100	20	0	0	0	0		0	0	0	0				0	0	0	0	0	0
CO		100	<540	3	0	0	0		3		0	1				3	3	0	0	1	3
Carbon tetrachloride	tr		20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
CCl_4	tr		SP	1	0	0	0				0	0		0	0	0	0	0		3	
	dc		25	1	1	1	1	0	0	0	0	0	0			1	0	0		3	
	dc		SP	3			1													3	
Carbonic acid																					
CO_2																					
s. Carbon dioxide																					
Caustic potash																					
s. Potassium hydroxide																					
Caustic soda lye																					
s. Sodium hydroxide																					
Chloral			20								0								0	3	
CCl_3-CHO																					
Chloramines				3	3	1	0	0		0	0	0									
Chloric acid	ws		20	3	3	3	3	0			0							0	0	3	3
$HClO_3$																					
Chloride of lime																					
s. Calcium hypochlorite																					
Chlorine	tr	100	200	0	0	0	0		0	0	0	0	0	0	0	0	0	1	0	0	0
Cl_2	tr	100	300	3	3	3	0		0	0	0	0									
	tr	100	400	3	3	3	3		0	0	0	0									
	dc		20	3	3	3	3	0			0							0	0	3	
	dc		150	3	3	3	3				0							0	0	3	
Chlorine dioxide	ws	0.5	20	3	3	3	3				1				3			0	0		
ClO_2																					

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Medium				Materials																	
Designation Chemical formula					**Stainless steels**			**Nickel alloys**					**Copper alloys**			**Pure metals**					
		Concentration %	**Temperature** °C	**Non-/low- alloy steels**	**Ferritic steels**	**Austenitic steels**	**Austenitic + Mo**	**Incoloy 825 2.4858**	**Inconel 600 2.4816**	**Inconel 625 2.4856**	**Hastelloy-C 2.4610 / 2.4819**	**Monel 2.4360**	**Cunifer 30 2.0882**	**Tombac**	**Bronze**	**Copper**	**Nickel**	**Titanium**	**Tantalum**	**Aluminium**	**Silver**
Chloroacetic acid		All	20	3	3	3	L	3		1	1	3	3			3		0	0	3	
CH$_2$-Cl-COOH	ws	30	80	3	3	3	3		3		0			3	3	3	1	0	0	3	
Chlorobenzene	tr			0	0	0	0				0										
C_6H_5Cl	dc	100	20	0	L	L	L	0	0	0	0	0	0	0	0	1	1	0	0	1	
Chloroethane	tr		20	0	0	0	0				0				0					0	
CH_2=CHCl			<400	0	0	0	0				0						0	0			
Chloroethylene																					
C_2H_5Cl																					
s. Ethyl chloride																					
Chloroform	tr			1	1	1	1	0	0	0	0	0	0	0	0	0	0	0		0	
$CHCl_3$	dc			3	L	L	L	0	0	0		0						0		3	
Chloromethane	tr		20	0	L	L	L						0					0		0	
CH_2Cl_2	dc		20		L	L	L	0		1	1	1	0			0	1	0		3	
	dc		SP		L	L	L	1		1	1	1	1			0	1	0		3	
Chloromethane	tr	100	20	0	0	0	0		0	0	0	0		0	0	0	0	0		0	
CH_3Cl	dc		20	3	L	L	L		0	0								0		3	
	dc		100		L	L	L		0	0						1		0		3	
Chloronaphthalene				0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	
$C_{10}H_7Cl$																					
Chlorophenol				1	0	0	0				0										
$C_6H_4(OH)Cl$																					
Chlorosulphonic acid	tr	100	20	0	0	0	0	0	0	0	0	0				0	0	0	0	0	3
HSO_3Cl	dc		20	3	3	3	1	1	1	1						3	3	3	0	3	3
Chrome alum	ws	1	20	3	3	0	0					1						0		1	
$KCr(SO_4)_2$		kg		3	3	1	0		0			0		3			1	0		3	
				3	3	3	3		0			1		3			3	0		3	
		hs																			
Chromic acid	ws	5	20	3	3	0	0	1	3	0	0	3	3	3	3	3	3	0	0	1	0
Cr_2O_3 (H_2CrO_4)	ws	5	90	3	3	3	3				1	3	3	3	3	3	3	0	0		
	ws	10	20	3	0	0	0	1	3		0	3	3	3	3	3	3	0	0	1	
	ws	10	65	3	3	3	3				0	3	3	3	3	3	3	0	0		
	ws	10	SP	3	3	3	3	1	3		0	3	3	3	3	3	3	0	0	3	
	ws	50	SP	3	3	3	3	3	3		3	3	3	3	3	3	3	0	0	3	
	ws	60	20	3	3	3	3	1	3			3	3	3	3	3	3	0	0	3	

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Medium				Materials																	
Designation Chemical formula					**Stainless steels**			**Nickel alloys**					**Copper alloys**			**Pure metals**					
		Concentration %	**Temperature** °C	**Non-/low- alloy steels**	**Ferritic steels**	**Austenitic steels**	**Austenitic + Mo**	**Incoloy 825 2.4858**	**Inconel 600 2.4816**	**Inconel 625 2.4856**	**Hastelloy-C 2.4610 / 2.4819**	**Monel 2.4360**	**Cunifer 30 2.0882**	**Tombac**	**Bronze**	**Copper**	**Nickel**	**Titanium**	**Tantalum**	**Aluminium**	**Silver**
Chromic acid anhydride																					
CrO_3																					
s. Chromium oxide																					
Chromium oxide				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
CrO_3																					
Chromium sulphate		kg		3	0	0	0		0	0	0	0					0				
$Cr_2(SO_4)_3$				3	0	1	1		1	0	0	0					0				
		hs																			
Cider			20	3	0	0	0	0	0	0	0	0					0	0	0	1	0
			SP	3	0	0	0	0	0	0	0	0					0	0	0	1	0
Citric acid	ws	All	SP	3	3	3	0		0		0										
$CH_2COOH(COH)$	ws																				
COOH CH_2 COOH																					
Combustion gases																					
free of S or																					
H_2SO_4 and Cl			≤400	0	0	0	0				0										
with S or			>ADP																		
H_2SO_4 and Cl			and																		
			≤400	0	0	0	0				0										
Copper (II)-chloride	ws	1	20	3	3	L	L	0	3		1	3	3			3	3	0	0	3	
$CuCl_2$	ws	kg		3	3	3	3	3	3		0	3				3	3	0	0	3	
Copper (II)-nitrate	ws	1	20		0	0	0	0	3		0	3	3			3	3	0	0	3	
$Cu(NO_3)_2$	ws	50	SP		0	0	0		3		1	3					0	0	3		
	ws	kg			0	0	0	0	3		1	3	3			3	3	0	0	3	
Copper (II)-sulphate	ws	kg		3	0	0	0	0	3		0	3	3			3	3	0	0	3	
$CuSO_4$	ws			3	1	0	0	0	3		0	3				3	3	0	0	3	0
		hs																			
Copper acetate	ws		20	3	0	0	0	0	1	0	0	1	3		3	3	1	0	0	3	1
$(CH_3\text{-}COO)_2$	ws		SP	3	0	0	0								3			0		3	
Cresols		All	20	3	1	0	0		0	0		0					0	0		0	0
$C_6H_4(CH_3)OH$		All	SP	3	1	1	0		0	0	1	0					0	0		3	0
Crotonaldehyde			20	3		0	0	0	0	0	0	0	0	0		0				0	
CH_3-CH=CH-CHO			SP			1	0	0	0	0	0	0	0	0						0	

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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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Cyclohexane				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
$(CH_2)_6$																					
Diammonium phosphate																					
s. Ammonium phosphate																					
Dibromethane																					
s. Ethylene bromide																					
Dichlorethylene																					
$C_2H_2Cl_2$																					
s. Acetylene dichloride																					
Dichloroethane																					
$CH_2Cl\text{-}CH_2Cl$																					
s. Ethylene chloride																					
Difluorodichloromethane	tr		SP			0	0	0	0	0	0	0							0	0	
CF_2Cl_2	tr		20			0	0	0	0	0	0	0							0	0	
	dc		20			0	0	0	0	0	0	0							0	0	
Diphenyl		100	20	0	0	S	S	0	0	0	0	0	0	0	0	0	0	0	0	0	
$C_6H_5\text{-}C_6H_5$		100	400	0	0	S	S	0	0	0	0	0				0	0	0	0	0	
Ethane			20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH_3 - CH_3																					
Ether																					
$(C_2H_5)_2O$																					
s. Ethyl ether																					
Ethereal oils			20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ethyl alcohol		All	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C_2H_5OH		All	SP	1	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
Ethyl benzene				1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C_6H_5 - C_2H_5																					
Ethyl chloride			0	S	S	S	0	0	0	1	0	0	1	1	1	0		0	1	0	
C_2H_5Cl																					
Ethyl ether			0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	
$(C_2H_5)_2O$																					
Ethylene																					
$CH_2{=}CH_2$			20	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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Ethylene bromide																					
$CH_2Br\text{-}CH_2Br$				1		0	0										0			3	
Ethylene chloride	tr	100	20	0	L	L	L	1	0				0	1		1		0	0	0	1
CH_2CLCH_2CL	dc	100	20		L	L	L												0		1
Ethylene glycol		100	20	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	
$CH_2OH\text{-}CH_2OH$																					
Exhaust gases																					
s. Combustion gases																					
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
Ferric (II) chloride	ws	10	20	0		L	L				1		1	3	1	1		0	0	3	
$FeCl_2$	ws	kg						3	3		0	3	3			3	3	0	0	3	
Ferric (II) sulphate	ws	All	SP	0	0	0	0				0	0					3	0		3	
$FeSO_4$																					
Ferric (III) chloride	tr	100	20	0	L	L	L	1	3		0	3	3	3	3	3	3	0	0	3	
$FeCl_3$	ws	5	25	3	3	3	3	3	3		0	3	3	3	3	3	3	0	0	3	
	ws	10	65	3	1	1	1				3						0	0			
	ws	50	20	3	3	3	3		3		1		3	3	3	3		0	0		
Ferric (III) chloride	ws	10	20	3	0	0	0				0							0			
$Fe(NO_3)_3$	ws	All	SP	3	0	0	0	3	3	3	3	3				3	0				
Ferric (III) sulphate	ws	<30	20	3	0	0	0	0	3		0	1	3	3	3	3	3	0	0	3	
$Fe(SO_4)_3$	ws	All	SP	3	1	0	0				0							0	0	3	
Fixing salt																					
s. Sodium thiosulphate																					
Flue gases																					
s. Combustion gases																					
Fluoride	dc		20	3	3	3	3				0	0	3	3	3	3	0	3		3	0
F	tr	100	20	0	0	0	0				0	0	0	0	0	0	0	0		3	0
	tr	100	200	0	0	L	L				0	0				3	0	0		3	
	tr	100	500	3							0									3	

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Medium			Materials																		
Designation Chemical formula				Stainless steels			Nickel alloys					Copper alloys			Pure metals						
	Concentration %	Temperature °C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Cunifer 30 2.0882	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Fluosilicic acid s. Hexafluorosilicic acid																				
Formaldehyde ws	10	20	3	0	0	0	0	0	0	0	0	0	3	0	0	0	0		1	0
CH_2O ws	40	20	3	0	0	0	0	0	0	0	0	0	3	0	0	0	0		1	0
ws	All	SP	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	SP	3	3	3	1	0	1	0	0	1		0			3	0		3	3
	80	SP	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	
Frigene CF_2Cl_2 s. Dichlorodifluoromethane																				
Fuel s. Petrol																				
Fuels s. Petrol s. Benzene																				
Petrol-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	SP	3	1	1	1				0					3			0	0	
Gallic acid ws	1	20	1	0	0	0				0								0		
$C_6H_2(OH)_3COOH$	100	20	3	0	0	0												0		
	100	SP	3	0	0	0		3										0		
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 s. Acetic acid																				
Glas Melt		1200	1		1	1														
Glauber salt s. Sodium sulphate																				
Gluconic acid $CH_2OH(CHOH)_4$-COOH	100	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	

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Medium			Materials																		
Designation Chemical formula				Stainless steels			Nickel alloys					Copper alloys			Pure metals						
	Concentration %	Temperature °C	Non-/low- alloy steels	Ferritic steels	Austenitic steels	Austenitic + Mo	Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Cunifer 30 2.0882	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Glucose ws $C_6H_{12}O_6$		20		0	0	0						0	1	0	0		0		0	
Glutamic acid		20	1	L	L	0	0	1	0	0	1					1				
HOOC-CH_2-CH_2-$CHNH_2$-COOH		80	3	L	L	0		1		1										
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	SP	1	1	0	0		0	0	0			1		0	0		0	0	
Glycol CH_2OH-CH_2OH s. Ethylene glycol																				
Glycolic acid		20	3	1	1	1				0							0		1	
CH_2OH-COOH		SP	3	3	3	3				0							0		1	
	98	SP	3	3	3	3	0	1	0	0	1						0	0		
Glysantine s. Antifreeze																				
Hexachloroethane																				
CCl_3-CCl_3 tr		20			0	0	0	0		0	0						0		0	
= Perchloroethane dc		20			0	0	0	0		0	0						0		0	
Hexafluorosilicic acid s. hexafluorosilic hydrogen acid																				
Hexamethylenetetramine ws	20	60	1		0	0				0										1
$(CH_2)_6N_4$ ws	80	60	3		0	0				0										
Hydrazine H_2N-NH_2		20	0		0		3	3			3					3			1	
Hydrazine sulphate ws $(N_2H_6)SO_4$	10	SP	3		3	3														
Hydrobromic acid HBr		20	3	3	3	3	3	3	3	3	3	3	3	3	3			0	3	3

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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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Hydrochloric acid		0.2	20	3	3	L	L				0						L	0	0		
HCl		0.5	20	3	3	3	L				0							0	0		
		0.5	SP	3	3	3	3				3							1	0		
		1	20	3	3	3	L	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	SP	3	3	3	3				3							3	0	3	
Hydrochloric acid gas																					
s. Hydrochloric																					
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	SP								1	1						3	3	3	
		90	30					1	1			0					1	3	3	3	
Hydrofluoro-		100	20	3	3	L	L				1		1	3	1	1				3	
Hydrogen acid		25	20	3	3	3	3	1	1	1	1	3		3	1	1	1	3		3	
$H_2(SiF_6)$		70	20	3	3	3	3				1									3	
	Vapour			3	3	3	3				1							2		3	
Hydrogen			<300	0		0	0				0			0		0				0	
H			>300	3		0	0				0									0	
Hydrogen bromide	tr	100	20	0	0	0	0														
HBr	dc	30	20	3	3	3	3											0			
Hydrogen chloride	tr		20	0	3	1	1	0	0	0	0			3	3	3				1	0
HCl	tr		100	0	3	3	3	0	0	0	0			3		3				1	
	tr		250	1	3	3	3	0	0	0	0			3		3				3	3
	tr		500	3	3	3	3		1		0			3		3				3	3
Hydrogen cyanide	tr		20	3	0	0	0	0	1	0	0	1	3	3	3	1	0	0	0	0	
HCN	ws	20	20	3	1	0	0	0	1	0	0	1	3	3	3	1	0	0	0	0	
	ws	kg	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 iodide	tr		20	0	0	0	0														
/ acid	dc		20	3	3	3	3														
Hydrogen peroxide		All	20	3	3	0	0	0	1	0	0	1	3	3	3		3	1	3	0	0
H_2O_2																					

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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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	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	tr	100	20	1	S	0	0	0	1		0	1	0	0	0	0	0	0	0	0	1
H_2S	tr	100	100	3	S	0	0									0				0	
	tr	100	200	3	3	0	0												0		
	dc		20	3	3	0	0		0	0	0	0	3	3	3	3	1	0		0	3
Hydroquinone				3		0	0	0	0	0		1					1			0	
$HO\text{-}C_6H_4\text{-}OH$																					
Hypochlorus acid			20	3	3	3	3											0		3	
HOCl																					
Illuminating gas				0	0	0	0	0	0	0	0	1	1	0	0	1	1				
Indole			20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
Ink																					
s. Gallic acid																					
Iodine	tr	100	20	0	L	L	L				0	0	3	3	3	3		3		0	
J_2	dc		20	3	3	3	3				1	3					3	0		3	3
	dc		SP	3	3	3	3				1	3					3			3	3
Iodoform	tr		60	0	0	0	0													0	
CHJ_3	dc		20	3	3	L	L														
Isatin			20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
$C_8H_5NO_2$																					
Kalinite																					
s. Alum																					
Ketene			20		0	0	0	0	0	0	0						0	0	0	0	
$(CnH_2n+1)_2C{=}C{=}O$			SP		0	0	0	0	0	0	0						0	0	0	0	
Lactic acid	ws	1	20	3	3	0	0	0		0	0		0	3	1	0		0	0	0	
$C_3H_6O_3$	ws	All	20	3	3	1	0				0							0	0	3	
	ws	10	SP	3	3	3	3	0	3		0	3	1			1	3	0	0	3	
	ws	All	SP	3	3	3	1				0							0	0	3	
Lactose	ws		20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
$C_{12}H_{22}O_{11}$																					
Lead	Melt		388	3	1	1	1		0			3				3		0	0		
Pb			900	3	3	3	3				0										
Lead acetate	Melt			3	0	0	0				0	0			3	3				3	
$(CH_3\text{-}COO)_2Pb$																					
Lead acid		<20	<30					0	0	0		1					1				
$Pb(N_3)_2$																					

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Austenitic steels	Austenitic + Mo	Nickel alloys: Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Tombac	Bronze	Pure metals: Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Lead nitrate	ws		100	1	0	0	0	0	0	0	0	0						0	0	0	
$Pb(NO_3)_2$																					
Lime																					
CaO																					
s. Calcium oxide																					
Lime milk			20	0	1	0	0													0	
$Ca(OH)_2$			SP	0	1	0	0													0	
Liquid ammonia																					
s. Ammonium hydroxide																					
Lithium	Melt		300	0	0	0	0	0	0	0	0	3	3	3	3	3		0		3	
Li																					
Lithium chloride	ws	kg		3	3	3	L	0	0	0	0	1					0	0			
LiCl																					
Lithium hydroxide	ws	All	20	1	0	0	0	0	0	0		0					0	0			
LiOH																					
Magnesium	Melt		650		1	3	3	3	3		3	3	3	3	3	3	3	0	0	3	
Mg																					
Magnesium carbonate	ws		20	0	0	0	0	0	0	0	0	0	0			0	0	0	0	1	
$MgCO_3$	ws		SP	0	0	0	0	0	0	0	0	0	0			0	0	0	0	1	
Magnesium chloride	ws	5	20	3	3	L	L	0	0	0	0	0	3			3	0	0	0	3	
$MgCl_2$	ws	5	SP	3	3	3	3	0	0	0	0	0	3			3	0	0	0	3	
	ws	50	SP	3	3	3	3				0							0	0	3	
Magnesium hydroxide	ws	kg		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	
$Mg(OH)_2$	ws	hs		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	
Magnesium nitrate		kg		0	0	0	0	3	3		3	0	3	0	0	3	3	0	0	1	
$Mg(NO_3)_2$																					
Magnesium oxide																					
MgO																					
s. Magnesium hydroxide																					
Magnesium sulphate	ws	0.1	20	0	1	0	0				0							0	0	3	
$MgSO_4$	ws	5	20	3	1	0	0	0	1	0	0	1	0	3	0	0	1	0	0	0	
	ws	50	SP	3	1	0	0				1							0	0	0	
Maleic acid	ws	5	20	3	0	0	0	0	1	0	0	1	0				1			0	
HOOC-HC=CH-COOH	ws	50	100	3	0	0	0		1											0	

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels: Ferritic steels	Austenitic steels	Austenitic + Mo	Nickel alloys: Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Tombac	Bronze	Pure metals: Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Maleic acid hydride		100	285								0										
Malic acid	ws		20	3	3	0	0	0	1	0	0	1	3			3	3	0	0	0	
	ws	50	100	3	3	0	0	0	1	0	0	1	3	3	3	3	3	0	0	0	
Malonic acid			20			1	1	1	1	1	1	1					1	1		1	
$CH_2(COOH)_2$			50					1	1	1	1	1					1	1			
			100					3	3		3	3					3	3			
Manganese(II)-chloride	ws	5	100	3	L	L	L	1	1	1		1	3			3	1	0	0		
$MnCl_2$	ws	50	20	1	3	L	L	1	1	1		1	3			3	1	0	0		
Manganese(II)-sulphate		kg			0	0	0	0	0	0	0	0				0	0	0			
$MnSO_4$																					
Maritime climate	dc			2L	1L	1L	0	0	0	0	0	0	0	1	0	0	0	0	0	2	1
Mercury	tr	All	<500	1	1	1	0		0	0	0	3	3	3	3	3		0	0	3	
Hs																					
Menthol					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
$C_{10}H_{19}OH$																					
Methane			200	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	
CH_4			600								0						0				
Methanol																					
s. Methyl alcohol																					
Methyl acetate		60	20	0		0	0				0							0	0		
CH_3COOCH_3		60	SP	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	SP	1	3	1	1		0	0	0	0		0	0	0	0	0	0	1	0
Methylamine	ws	25	20	1	0	0	0	0		0	0	3	3	3	3	3		0		0	
CH_3-NH_2																					
Methyldehyde																					
s. Formaldehyde																					

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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	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		SP	3	3	3	1														
5 / 15 / 80		134		3	1	1														
Molasses		0	0	0	0	0	0	0	0					0	0	0	0			
Monochloroacetic acid s. Acetic acid																				
Naphthalene	100	20	0	0	0	0											0		1	
$C_{10}H_8$	100	390	0	0	0	0														
Naphthalene chloride	100	45								0										
	100	200								0										
Naphthalene sulphonic acid	100	20	0		0	0				0										
$C_{10}H_7SO_3H$	100	SP		3	3	3				0										
Naphthenic acid	100	20		L	L	L	0	0	0		0					1			0	
Nickel (II) chloride ws	10	20	3	L	L	L	0	1	0	0	1	1	3	1	3	1	0			0
$NiCl_2$ ws	10	SP	3	3	L	L				0							0			
	total	70				0				1										
Nickel (II) nitrate ws	10	25	3	0	0	0	0	0	0	0	3	3			3	3	0	0	3	
$Ni(NO_3)_2$ ws	<100	25	3	0	0	0	0	3		1	3				3	3	0	0	3	

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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Nickel (II) sulphate ws		20	3	0	0	0	0	1	1	1	1					3	0			
$NiSO_4$ ws		SP	3	0	0	0		0		1	1					3	0			
Nitric acid	1	20	3	0	0	0				0	0	1	3	3	3	0	0	0		
HNO_3	1	SP	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	SP	3	1	0	0				1							0	0		
	10	SP	3	1	0	0				1	3					3	0	0		
	15	SP	3	1	0	0				3							0	0		
	25	SP	3	3	0	0				3							1	0		
	50	SP	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	SP	3	3	3	3	0	3		3	3	3			3	3	0	0	3	
	99	SP	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			0	0	0	0	0	0	0	1	0	0	0	0	0	0	0		0	
$C_6Hx(NO_2)y$																				
Nitrobenzoic acid ws		20	1	0	0	0	0	0	0	0	0	0	0	0		0			0	
$C_6H_4(NO_2)COOH$																				
Nitrogen	100	20	0		0	0		0	0	0	0	0	0	0	0	0	0		0	0
N	100	900	1													3				
Nitroglycerine		20	0	0	0	0													0	
$C_3H_5(ONO_2)_3$																				
Nitrous acid HNO_2 similar to Nitric acid																				
Oil of turpentine	100	20	3	0	0	0						0	1	0	0		0		0	
	100	SP	3	0	0	0						0	1	0	0		0		0	
Oleic acid s. Fatty acid																				
Oleum s. Sulphur trioxide																				
Oxalic acid ws	All	20	3	3	0	0	1	1	0	0	1					3	0	0	0	
$C_2H_2O_4$ ws	10	SP	3	3	3	3	0	1	0	0	1	1			1	3	3	0	3	
ws	hs		3	3	3	3	1	1	1	1	1									

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	Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Cunifer 30 2.0882	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Oxygen			500	1	0	0	0					0			3	3				0	3
O																					
Ozone					0	0	0	0	0	0	0	0				1		0		0	
Paraffin			20	0	0	0	0											0		0	
CnH_2n_{+2}	Melt		120	0	0	0	0						0	0	0	0		0		0	
Perchloric acid		10	20	3	3	3	3											0		3	
$HClO_4$		100	20	3	3	3	3											0			
Perchloroethylene			20	0	0	0	0							0	0	0	0			0	
C_2Cl_4			SP	0	1	1	1							1	1	0	0			3	
	dc			3	L	L	L														
Perhydrol																					
s. Hydrogen peroxide																					
Petrol[1)]		100	25	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1		1	
		100	SP	1			0	0			0	1						1		1	
Petroleum			20	0	0	0	0		0	0	0	0	0	1	0	0	0	0		0	
			SP	0	0	0	0		0	0	0	0		1	0	0	3	0		0	
Phenol																					
s. Carbolic acid																					
Phloroglucinol																					
$C_6H_3(OH)_3$			20		0	0	0	0	0	0	0	0						0	0	0	
Phosgene	tr																				
$COCl_2$			20		0	0	0	0	0	0	0	0						0	0	0	
Phosphoric acid	ws	1	20	3	0	0	0	0	0	0	0	1	3			3	0	0	0	3	
H_3PO_4	ws	10	20	3	3	0	0				0							0	0		
	ws	30	SP	3	3	1	1				1	1	1	2	1	3	3	3	0	3	
	ws	60	SP	3	3	3	3				1							3	0		
	ws	80	20	3	3	1	0		0	0	0				0	1		3	0		0
	ws	80	SP	3	3	3	3		0		3				1		3	3	0		1
Phosphorous	tr																				
P			20	0	0	0	0														
Phosphorous pentachloride	tr																				
PCl_5		100	20	0	0	0					0					0	1				
Phthalic acid and			20	0		0	0				0	0		0	0	0	0			0	0
phthalic anhydride			200		0	3	0				0	0				0	0				0
$C_6H_4(COOH)_2$	tr		SP			0	0	0								0			0	0	

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	Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Cunifer 30 2.0882	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Picric acid	ws	3	20	3	0	0	0											0		1	0
$C_6H_2(OH)(NO_2)_3$	ws	kg		3	0	0	0	3	3		0	3	3	3	3	3	3	0		0	
	Melt		150	3	0	0	0											0		3	
Plaster																					
see Calcium sulphate																					
Potassium	Melt		604	0		0	0				1							0		0	
K			80			0	0				1							0	1	0	
Potassium acetate	Melt	100	292	1		0	0									1		0			
CH_3-COOK	ws		20	1	0	0	0		0	0	0	0			1	1	0	0			
Potassium aluminium sulphate																					
s. Alum																					
Potassium bisulphate	ws	5	20	3	3	2	0											0			
$KHSO_4$	ws	5	90	3	3	3	3											3			
Potassium bitartrate	ws	kg		3	3	0	0										0	0		0	
$KC_4H_5O_6$	ws			3	3	3	1										1	0		0	
		hs																			
Potassium bromide	ws	5	30	3	L	L	L	0	1	0	0	1	0	0		0	0	0	0	3	
KBr																					
Potassium carbonate	ws	50	20	1	0	0	0	0	0	0	0	0	1	3	1	1	0	0	0	3	0
K_2CO_3	ws	50	SP	3	3	0	0	0	0	0	0	0		3			0	0	0	3	0
Potassium chlorate	ws	5	20	3	0	0	0	0	1	0		1	3	1	1	1	1	0		0	
KClO3	ws			3	0	0	0	0	3	0	0	3	3			1	3	0	0	1	
		hs																			
Potassium chloride	ws	10	20	3	3	L	L	0	0	0	0	0	0							1	
KCl	ws	10	<SP	3	3	L	L				1		3							1	
	ws	30	SP	3	3	L	L				1	0		3	1	3		0		0	0
	ws	kg		3	L	L	L				1										
	ws			3	3	L	L				1										
		hs																			
Potassium chromate	ws	10	20	0		0	0	0	0	0	0	1	0	0	0	0	0	0		0	
K_2CrO_4	ws	10	SP	1		0	0											0		0	
Potassium cyanide	ws	10	20	3	0	0	0	0	3		0	1	3			3	3		0	3	
KCN	ws	10	SP	3	0	0	0						3	3	3	3				3	

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels			Nickel alloys					Copper alloys			Pure metals					
					Ferritic steels	Austenitic steels	Austenitic + Mo	Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Cunifer 30 2.0882	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Potassium dichromate	ws	10	40	3	0	0	0	1	1	1	1	1	0			3	1	0	0	0	
$K_2Cr_2O_7$	ws	25	40	3	3	0	0	1	1	1	1	1	3	3	3	3	1	0	0	0	0
	ws	25	SP	3	3	0	0				1		3	3	3	3		0	0	0	
Potassium ferricyanide	ws	1	20		0	0	0	1	1	0	0	0			0	0	1	0	0		
$K_3(Fe(CN)_6)$	ws	kg	20		0	0	0		0		0	0			0		0	0	0	0	3
	ws	hs	SP	3	0	0	0		0		0						0	0	0	0	3
Potassium ferrocyanide	ws	1	20		0	0	0	1	1	0	0	0	0			0	1	0	0	0	
$K_4(Fe(CN)_6)$	ws	25	20		0	0	0	0	0	0	0	0	0		0		0	0	0	0	3
	ws	25	SP		1	1	0	0	0	0	0	0	0				0	0	0	0	3
Potassium fluoride	ws	kg		0	0	0	0				0									3	
KF	ws	hs		1	0	0	0				0										
Potassium hydroxide	ws	10	20		0	S	S	1	1	1	1	0	0			3	0	0	3	3	
KOH	ws	20	SP		0	S	S	1	1	1	1	0	3				0	0	3	3	
	ws	30	SP		3	S	S	1	3		1	0				3	0	3	3	3	
	ws	50	20	S	0	S	S	1	1	1	0	0	3				0	0	3	3	
	ws	50	SP	S	3	3	3	1	3		1	0	3			3	0	3	3	3	
	ws	hs		S	3	S	S				1		0						3	3	0
	Melt	100	360	S	3	3	3		3		3						0	3	3	3	
Potassium hypochlorite	ws	All	20		L	L	L	3	3		0	3	3				3	0		3	
KClO	ws	All	SP		L	L	L	3	3		1	3	3				3	0		3	
Potassium iodide	ws		20	0	L	L	L	0	1	1	0	3	0			0	3	0	0	3	
KJ	ws		SP	0	3	L	L	0	1	1	0	3	0			0	3	0	0	3	
Potassium nitrate	ws	All	20		0	0	0	0	1	1	1	1					1	0		0	
KNO_3	ws	All	SP		0	0	0				1							0		1	
Potassium nitrite KNO_2		All	SP	1	0	0	0	1	0	0	0	0	1	1	1	1	1				
Potassium permanganate	ws	10	20	0	0	0	0				0	1	0				0	0	0	0	3
$KMnO_4$	ws	All	SP	3	1	1	1	0	1	1	1	1	0			0	0	0	0	0	
Potassium persulphate $K_2S_2O_8$	ws	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	

Medium: Designation / Chemical formula		Concentration %	Temperature °C	Non-/low- alloy steels	Stainless steels			Nickel alloys					Copper alloys			Pure metals					
					Ferritic steels	Austenitic steels	Austenitic + Mo	Incoloy 825 2.4858	Inconel 600 2.4816	Inconel 625 2.4856	Hastelloy-C 2.4610 / 2.4819	Monel 2.4360	Cunifer 30 2.0882	Tombac	Bronze	Copper	Nickel	Titanium	Tantalum	Aluminium	Silver
Potassium sulphate	ws	10	25	3	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	
K_2SO_4	ws	All	SP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
Propionic acid s. Acetic acid																					
Protein solutions			20	1	0	0	0	0	0	0	0	0	0					0	0	0	
Prussiate of potash s. Potassium ferricyanide																					
Prussic acid s. Hydrogen cyanide																					
Pyridine	tr		20		0	0	0											0		0	
C_5H_5N		All	SP		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	SP	3	0	0	0				1				0			0		0	
		100	20	0	L	L	L		0	0	0	3	3	3	3	3	0	0		1	3
Quinine bisulphate	tr		20	3	3	3	0	0		0	0	1	0			0		0	0		
Quinine sulphate	tr		20	3	0	0	0	0		0	0	1	0		0	0		0	0		
Salicylic acid	tr	100	20	1	0	0	0	0	1	0	0	1	0			0	1	0	0	0	
HOC_6H_4COOH	dc	100	20	3		0	0				1	0						0			
	ws	kg		3		0	0	0	1	0	0	0	0				0	0		1	
Saltpetre s. Potassium nitrate																					
Seawater at flow rate (v):																					
v<1.5m/s			20	1	L	L	L	0	L	0	0	L	1			1	L				
1.5<v<4.5m/s			20	1	0	0	0	0	0	0	0	0	0	0		3	1				
Silver nitrate	ws	10	20	3	0	0	0	0	1	1	1	3	3	3	3	3	3	0	0	3	
$AgNO_3$	ws	10	SP	3	0	0	0										3	0			
	ws	20	60	3	0	0	0											0			
	ws	40	20	3	0	0	0				1							0			
	Melt	100	250	3	3	0	0														
Soap	ws	1	20	0	0	0	0		0	0		0	0	1	0	0	0	0		0	
	ws	1	75	0	0	0	0					0	0	1	0	0	0			0	
	ws	10	20	0	0	0	0										0	0		0	
Sodium			200	0	0	0	0											0		1	
Na	Melt		600	3	1	0	0											0			

08

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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	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	ws	10	25	0	0	0	0		0	0	0	0				0	0	0	0	0	0
CH_3-COONa	ws	hs		3	0	0	0				0							0	0		
Sodium aluminate		100	20	0	0	0	0											0			
Na_3AlO_3	ws	10	25	0	0	0	0				1							0		3	
Sodium arsenate	ws	kg		0	0	0	0											0		0	
Na_2HAsO_4																					
Sodium bicarbonate		100	20		0	0	0											0		0	
$NaHCO_3$	ws	10	20	0	0	0	0	0	1	1	1	1	0	3	1	1	1	0		0	
	ws	kg			0	0	0	0	1	0	0	1	0			0	1	0	0	1	
	ws	hs			0	0	0				1							0			
Sodium bisulphate	ws	All	20	3	3	3	0	0	1	1	1	1	3	3	1	1	1	0	0	0	
$NaHSO_4$	ws	All	SP	3	3	3	1	0	1	1	1	1	3	3	1	3	1	0	0	1	
Sodium bisulphite	ws	10	20	3	3	0	0				1			1	0	3	0	0		0	
$NaHSO_3$	ws	50	20	3	0	0	0				1	0		1	0	3	0	0			
	ws	50	SP	3	3	3	0					0						0			
Sodium borate	ws	kg			0	0	0	0		0	0	1	0			0		0	0	1	
$Na_2B_4O_7$ 10 H_2O (Borax)	Melt			3	3	3	3				3										
Sodium bromide	ws	All	20	3	3	3	L				1							0		3	
NaBr	ws	All	SP	3	3	3	L				1							0		3	
Sodium carbonate	ws	1	20	3	0	0	0	0	1	0	0	0	0			0	0	0	0	2	
Na_2CO_3	ws	All	SP		0	0	0	0	0	0	0						0	0	0	3	
	ws		400	3	3	3	3														
	Melt		900	3	3	3	3					0					0				
Sodium chloride	ws	0.5	20		L	L	L	0	1	0	0	0	0				1	0	0		
NaCl	ws	2	20		L	L	L	0	1	0	0	0	0				1	0	0		
	ws	kg		3	L	L	L	0	1	0	0	0	0			0	1	0	0	2	0
	ws	hs		3	3	3	L	0	1	0	1	0	0			0	1	0	0	3	0
Sodium chlorite	tr	100	20	3	L	L	0		0									0			
$NaClO_2$	ws	5	20			3	L											0			
	ws	5	SP			3	3				1							0			
	ws	10	80	3		3	L		0		1							0			
Sodium chromate	ws	All	SP	0	0	0	0	0	0	0	0	0	0	0	0	0				0	
Na_2CrO_4																					

08

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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	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	Melt		600	1								3	3	3	3	3				3	3
NaCN	ws	kg		1	0	0	0					3	1	3	3	3	0	0		3	3
Sodium fluoride	ws	10	20	0		0	0								3					0	
NaF	ws	10	SP	0		0	0														
	ws	kg				S	S													0	
Sodium hydrosulphate																					
s. Sodium bisulphate																					
Sodium hydrosulphite																					
s. Sodium bisulphite																					
Sodium hydroxide	solid	100	All	0	0	0	0		0	0	0	0					0				0
NaOH	ws	<10	<60	0	0	0	0		0	0	0						0				
	ws	<10	<SP	3	3	0	0		0	0	0						0				
	ws	<20	<60	0	0	0	0		0	0	0						0				
	ws	<20	<SP	3	3	0	0		0	0	0						0				
	ws	<40	<60	0	0	0	0		0	0	0						0				
	ws	<40	<100	3	3	0	0		0	0	0						0				
	ws	<40	>100	3	3	3	3		0	0	0						0				
	ws	<50	<60	0	0	0	0		0	0	0						0				
	ws	<50	<100	3	3	0	0		0	0	0						0				
	ws	<50	>100	3	3	3	3		0	0	0						0				
	ws	<60	<90	3	3	0	0		0	0	0						0				
	ws	<60	<140	3	3	3	3		0	0	0						0				
	ws	<60	>140	3	3	3	3		3	0	3						0				
Sodium hypochlorite	ws	5	20	3	3	3	L	0	3		0	3	3			3	3	0		3	
NaOCl	ws	10	50	3		L	L		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	SP		3	0	0	0	1	1	1	1	3			3	1		0		
Sodium iodide					L	L	L	0	0	0	0					0			1		
NaJ																					
Sodium nitrate	ws	5	20	3	0	0	0	0	0	0	0	1	0			0	1	0	0	0	
$NaNO_3$	ws	10	20	1	0	0	0	0	0	0	1	1	0	3	1	1	1	0	0	0	
	ws	<10	SP	3	0	0	0				0						1	0	0	3	3
	ws	30	20	1	0	0	0	0	0	1	1	1	0				1	0	0	0	
	ws	30	SP	1	0	0	0	0	0		3	1					1	0	0	0	
	Melt		320	3	0	0	0				0						1	0	0	0	3

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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	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 nitride $NaNO_2$	ws		20			0	0	1	0	0	0	0	0			1	3	0	0	1	
Sodium perborate $NaBO_2$	ws	10	20	3	0	0	0				1							1			
	ws	10	SP	3	0	0	0				1							1			
Sodium perchlorate $NaClO_4$	ws	10	20	3	3	0	0	1			1							0			
	ws	10	SP	3		0	0	1			1							0			
Sodium peroxide Na_2O_2	ws	10	20	3	1	0	0	1	1	1	1	0	3			3	0	3	3	3	3
	ws	10	SP	3	3	0	0	1	1	1	1	0	3			3	1	3	3	3	3
	Melt		460					3	1		3	3					0				
Sodium phosphate Na_2HPO_4	ws	10	20		0	0	0	0	0	0	0	0	0	3	1	1	0	0	0	0	
	ws	10	SP		0	0	0	0	0	0	0	0				3		0	0	1	
	ws	kg			0	0	0	0	0	0	0	0					0	0	0	0	
Sodium silicate $C_6H_4(OH)COONa$	ws	All	20		0	0	0	0			0					0	0	0		0	
Sodium silicofluoride $Na_2(SiF_6)$	ws	kg		3	3	3	3	0	0	1	1	0				0				1	
Sodium sulphate Na_2SO_4	ws	10	20	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	ws	kg		3	1	0	0	0	1	0	0	1	0			0	1	0	0	0	
	ws	hs		3	3	0	0	0	0	0	0	0						0	0	1	
Sodium sulphide Na_2S	ws	1	20	3	0	0	0	0	0			1					1	0			
	ws	kg	20	3	3	3	0	0	1	0	0		3			3	1	0	0	1	
	ws	hs		3	3	3	1											0		3	
Sodium sulphite Na_2SO_3	ws	10	20	3	1	0	0					0	1	3	1	1		0		0	
	ws	50	SP	3	3	0	0											0		3	
Sodium superoxide s. Sodium peroxide																					
Sodium thiosulphate $Na_2S_2O_3$	ws	1	20	1	0	0	0					0					0	0		0	
	ws	10	20	3	0	0	0											0		0	
	ws	25	SP	3	L	L	L										0	0		1	
		kg		3	3	0	0		1			1	3			3	1	0	0	0	
Stearic acid $CH_3(CH_2)_{16}COOH$		100	20	1	0	0	0		0	0	0	0	1	3	1	1	0	0		0	0
		100	95	3	0	0	0	0	1		0	1	1			0	1	0	0	3	
		100	180								1							0		3	

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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Succinic acid $C_4H_6O_4$			SP	1	0	0	0	0	0	0	0	0	0	0	0						
Sulphur S	tr	100	60	0	0	0	0				0						0				
	Melt		130	1	0	0	0		0		0	3	3	3	3	3	3	0			3
	Melt		240	3	0	0	0				0					3		0			
	fe		20	3	2	1	0				0	3	3	3	3	3	3	0			
Sulphur dioxide SO_2	tr	100	20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	tr	100	60	3	3	1	1				0							0		0	
	tr	100	400	3	3	3	0				1			3				0		0	3
	tr	100	800	3	3	3	3				3						3	0		0	
	dc	100	20	3	3	3	0	0	0	0	0	0	3	3	1	3	0	0	0	3	
	dc	100	60	3	3	3	0				0							0		3	
	dc	100	70	3	3	3	3				0							0		3	
Sulphur trioxide SO_3	dc	100	20																	3	
	tr	100	20	0				2	3		0	3	2	0	0	0	3		3	0	
Sulphuric acid H_2SO_4		0.05	20	3	1	0	0											0	0	1	
		0.05	SP	3	1	1	0											1	0	3	
		0.1	20	3	3	0	0											0	0	1	
		0.2	SP	3	3	3	0											1	0	3	
		0.8	SP	3	3	3	3											1	0	3	
		1	20	3	3	1	0		1	0	0	1	3			1	0	0	0	1	
		3	SP	3	3	3	3				1		3					1	0	3	
		5	SP	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	SP	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	SP	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	SP	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	SP	3	3	3	3	3	3		3	3	3			3	3	3		3	
		60	20	3	3	3	3				0	1		3	3	3	0	3	0	3	
		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	3

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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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Sulphurous acid	ws	1	20	3	3	0	0		1		0	3					3		0	1	
H_2SO_3	ws	kg		3	3	0	0				0	3						1	0	3	
	ws	hs		3	3	1	0				1								0	3	
Tannic acid	ws	5	20	3	0	0	0		0			0	0	1	0	0	0	0		0	
$C_{76}H_{52}O_{46}$	ws	25	100	3	3	0	0											0			
	ws	50	SP	3	3	0	0						0					0			
Tannin s. Tannic acid																					
Tar			20	0	0	0	0						0	1	0	0		0		1	
Tartaric acid	ws	10	20	1	0	0	0	0	1	0	0	1	0	3	0		1	0	0	3	
	ws	10	SP	3	1	0	0	0	3		1	3	0	3			3	1	0	3	
	ws	25	20	3	1	0	0		0		0	0	0			0		0	0	3	
	ws	25	SP	3	3	1	0		0		1	1	0			1		1	0	3	
	ws	50	20	3	3	0	0				0		0					0	0	3	
	ws	50	SP	3	3	3	3				1		0					3	0	3	
	ws	5	20	3	L	L	L	0	1	0	0	1	3				1	0	0	3	
Tetrachloroethane s. Carbon tetrachloride																					
Tin chloride		hs		3	3	3	3														
$SnCl_2$; $SnCl_4$		All	<80	3	3	0	0		0		0										
Toluene		100	20	0	0	0	0					0	0	0	0	0		0		0	
C_5H_5-CH_3		100	SP	0	0	0	0					0	0	0	0	0		0		0	
Trichloroacetaldehyde s. Chloral																					
Trichloroacetic acid s. Chloroacetic acid																					
Trichloroethylene	pure	100	20	0	0	0	0				0		0	0	0	0	0	0		0	
$CHCl=CCl_2$	pure	100	SP			0	0				0		0	0	0	0	0	0		0	
	dc		20	3	3	L	L				0		1	3	1	1	0	0		3	
	dc		SP	3	3	L	L				0		1	3	1	1	0	0		3	
Trichloromethane s. Chloroform																					
Tricresyl phosphate				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: Incoloy 825 2.4858	Nickel alloys: Inconel 600 2.4816	Nickel alloys: Inconel 625 2.4856	Nickel alloys: Hastelloy-C 2.4610 / 2.4819	Nickel alloys: Monel 2.4360	Copper alloys: Cunifer 30 2.0882	Copper alloys: Tombac	Copper alloys: Bronze	Pure metals: Copper	Pure metals: Nickel	Pure metals: Titanium	Pure metals: Tantalum	Pure metals: Aluminium	Pure metals: Silver
Trinitrophenol s. Picric acid																					
Urea		100	20	0	0	0	0				0	0					0	0	0	0	
$CO(NH_2)_2$		100	150	3		1	0		3		1	1					1	0	0	3	1
Uric acid	ws		20	3	0	0	0	0	1	0	0	0	0			1		0		3	
$C_5H_4O_4N_3$	ws		100	3	0	0	0	0	1	0	0	0	0			1		0		3	
Varnish			20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	
Water vapour																					
O_2<1ppm;Cl<10ppm			<560	1	1	1	0				0							0			
O_2>1ppm;Cl<10ppm			<315	S	S	S	S				0						0	0			
O_2>15ppm;Cl<3ppm			>450	S	S	S	S				0							0			
Wine			20	3	0	0	0		0					3	3		3		0	3	
			SP	3	0	0	0		0					3	3		3		0	3	
Yeast			20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zinc chloride	ws	5	SP	3	3	3	3	0	3		1	3	3				1	0	0	3	
$ZnCl_2$	ws	10	20	3	L	L	L					3					0	0	0	0	
	ws	20	20	3	L	L	L						3	3	3			0	0		
	ws	75	20	3	3	L	L											0	0		
	ws	2	20	3	0	0	0				0		0					0	0	0	
Zinc sulphate	ws	20	SP	3	0	0	0				1							0	0	3	
$ZnSO_4$	ws	30	SP	3	3	0	0				1							0	0	3	
	ws	kg		3	0	0	0	0	1	0	1	1	0				1	0	0	1	
	ws	hs		3	3	0	0				1							0	0	3	
	ws	5	20	3	3	3	3	3	3		0	1	3				1	0	0	3	

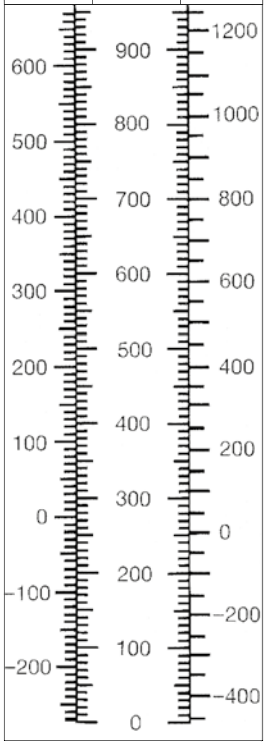
CONVERSION TABLES AND FORMULA SYMBOLS

09

TEMPERATURE, SATURATED STEAM, PRESSURE

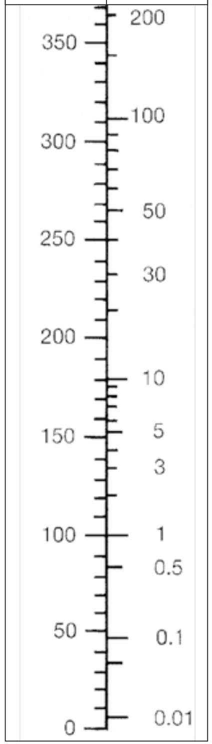
Temperatures

°C	K	deg F



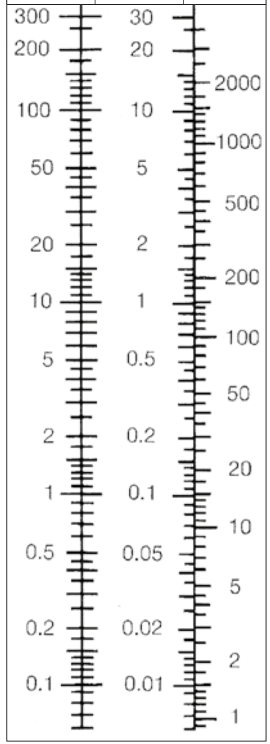
Saturated steam

°C	bar



Pressure

bar	MPa	psi



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STEAM TABLE

Pressure (absolute)	Saturation temperature	Kinematic viscosity of steam	Density of steam
bar	°C	10^{-6} m^2/s	kg/m^3
P	t	ν^n	ρ^n
0.02	17.513	650.24	0.01492
0.04	28.983	345.295	0.02873
0.06	36.183	240.676	0.04212
0.08	41.534	186.72	0.05523
0.1	45.833	153.456	0.06814
0.14	52.574	114.244	0.09351
0.2	60.086	83.612	0.1307
0.25	64.992	68.802	0.1612
0.3	69.124	58.69	0.1912
0.4	75.886	45.699	0.2504
0.45	78.743	41.262	0.2796
0.5	81.345	37.665	0.3086
0.6	85.954	32.177	0.3661
0.7	89.959	28.178	0.4229
0.8	93.512	25.126	0.4792
0.9	96.713	22.716	0.535
1	99.632	20.76	0.5904
1.5	111.37	14.683	0.8628
2	120.23	11.483	1.129
2.5	127.43	9.494	1.392
3	133.54	8.13	1.651
3.5	138.87	7.132	1.908
4	143.62	6.367	2.163
4.5	147.92	5.76	2.417

Pressure (absolute)	Saturation temperature	Kinematic viscosity of steam	Density of steam
bar	°C	10^{-6} m^2/s	kg/m^3
P	t	ν^n	ρ^n
5	151.84	5.268	2.669
6	158.84	4.511	3.17
7	164.96	3.956	3.667
8	170.41	3.531	4.162
9	175.36	3.193	4.655
10	179.88	2.918	5.147
11	184.07	2.689	5.637
12	187.96	2.496	6.127
13	191.61	2.33	6.617
14	195.04	2.187	7.106
15	198.29	2.061	7.596
20	212.37	1.609	10.03
25	223.94	1.323	12.51
30	233.84	1.126	15.01
34	240.88	1.008	17.03
38	247.31	0.913	19.07
40	250.33	0.872	20.1
45	257.41	0.784	22.68
50	263.91	0.712	25.33
55	269.93	0.652	28.03
60	275.55	0.601	30.79
65	280.82	0.558	33.62
70	285.79	0.519	36.51
75	290.5	0.486	39.48

PHYSICAL UNITS (D, GB, US)

DIN 1301-1, edition 10.2010 among others

SI-Basic Units

Size	SI-Basic Unit	
	Name	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Current intensity	Ampere	A
Thermodynamic temperature	Kelvin	K
Quantity of material	Mol	mol
Light intensity	Candela	cd

Prefix symbol

Prefix	Prefix symbol	Multiplication factor
Piko	p	10^{-12}
Nano	n	10^{-9}
Micro	µ	10^{-6}
Milli	m	10^{-3}
Centi	c	10^{-2}
Deci	d	10^{-1}
Deca	da	10^{1}
Hecto	h	10^{2}
Kilo	k	10^{3}
Mega	M	10^{6}
Giga	G	10^{9}

Length - SI-Unit metre, m

Symbol	Name	in m
mm	millimetre	0.0010
km	kilometre	1000
in	Inch	0.0254
ft	foot (=12 in)	0.3048
yd	yard (=3ft / = 36 in)	0.9144

PHYSICAL UNITS (D, GB, US)

DIN 1301-1, edition 10.2010 among others

Mass – SI-Unit kilogram, kg

Symbol	Name	in kg
g	gram	0.00100
t	to	1000
oz	ounce	0.02835
lb	pound	0.45360
sh tn	short ton (US)	907.2
tn	ton (UK)	1016

Time – SI-Unit second, 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

Symbol	Name	in K	in °C
°C	degree centigrade	ϑ/°C + 273.16	1
deg F	degree 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 (new deg.)	$\pi/200$
°	degree (deg.)	$\pi/180$
'	minute	$\pi/1.08 \cdot 10^{4}$
"	second	$\pi/6.48 \cdot 10^{5}$

PHYSICAL UNITS (D, GB, US)

DIN 1301-1, edition 10.2010 among others

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

Symbol	Name	in Pa	in bar
Pa = N/m^2	Pascal	1	0.00001
hPa = mbar	Hectopascal = millibar	100	0.001
kPA	Kilopascal	1000	0.01
bar	Bar	100000	1
MPa = N/mm^2	Megapascal	1000000	10
mm WS	millimetre water column	9.807	0.0001
lbf/in^2 = psi	pound-force per square inch	6895	0.0689
lbf/ft^2	pound-force per square foot	47.88	0.00048

Energy (also called work, amount of heat) SI-unit joule, J = Nm = Ws

Symbol	Name	in J
kWs	kilowatt second	1000
kWh	kilowatt hours	$3.6 \cdot 10^6$
kcal	kilocalorie	4186
lbf x ft	pound-force foot	1.356
Btu	British thermal unit	1055

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

Symbol	Name	in W
kW	kilowatt	1000
PS	horsepower	735.5
hp	horsepower	745.7

Volume – SI-unit, m³

Symbol	Name	in m^3
l	litre	0.001
in^3	cubic inch	$1.6387 \cdot 10^{-5}$
ft^3	cubic foot	0.02832
gal	gallon (UK)	0.004546
gal	gallon (US)	0.003785

FORMULA SYMBOLS USED

Formula symbol	Meaning
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 connector
D_i	Bellows inside diameter
D_m	Average bellows diameter
E(T)	Temperature-dependent value of E-module
F	Force, pressure reaction force
$K_{P\delta}$	Reduction factor for pressure at high temperatures
$K_{\Delta N}$	Correction factor for the effect of load cycles endured on the momentum
$K_{\Delta P}$	Correction factor for the effect of pressure on the momentum
M_B	Bending moment
M_T	Torque
$M_{T,c}$	Critical torque
N	Load cycles endured
$N_{xx\%}$	Number of load cycles endured 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	Temperatures
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 SYMBOLS USED

Formula symbol	Meaning
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 (perpendicularly to the 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 load
$\sigma_{B, meridional}$	Bending stress parallel to bellows surface
σ_{um}	Average circumferential stress
$\sigma_{max, meridional}$	Maximum permissible meridional stress under pressure
τ	Shear stress

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GREEK ALPHABET

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

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