6.1 | Bellows selection from 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 proof pressure (p_T):

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

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

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

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

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

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

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

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

Table 6.1.1

In the event of inside pressure loads,

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

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

$$P_{RT} \leq 2\ \frac{c_\delta}{n^2_W \cdot l_W} \qquad (6.1.3.)$$

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

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

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

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

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

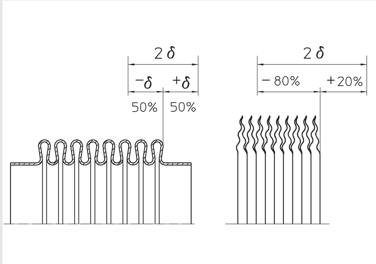

Figure 6.1.1.

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

Axial load:

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

Lateral load:

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

Angular load:

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

Influence of load cycles on impulse

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

Table 6.1.2

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

Reduction in pressure capacity

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

(4.3.2.)

increases the permissible impulse in accordance with Table 6.2.3.

Influence of pressure capacity on impulse

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

Table 6.1.3

Pressure pulsations

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

Determination of corrugation quantities

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

axial loads: (6.1.5.s)

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

lateral load: (6.1.5.b)

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

angular load: (6.1.5.c)

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

axial and angular load: (6.1.5.d)

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

axial and lateral load: (6.1.5.e)

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

Bellows spring rate

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

Axial load: (6.1.6.a)

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

Angular load: (6.1.6.b)

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

Lateral load: (6.1.6.c)

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

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

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

Table 6.1.4

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

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

(6.2.7.)