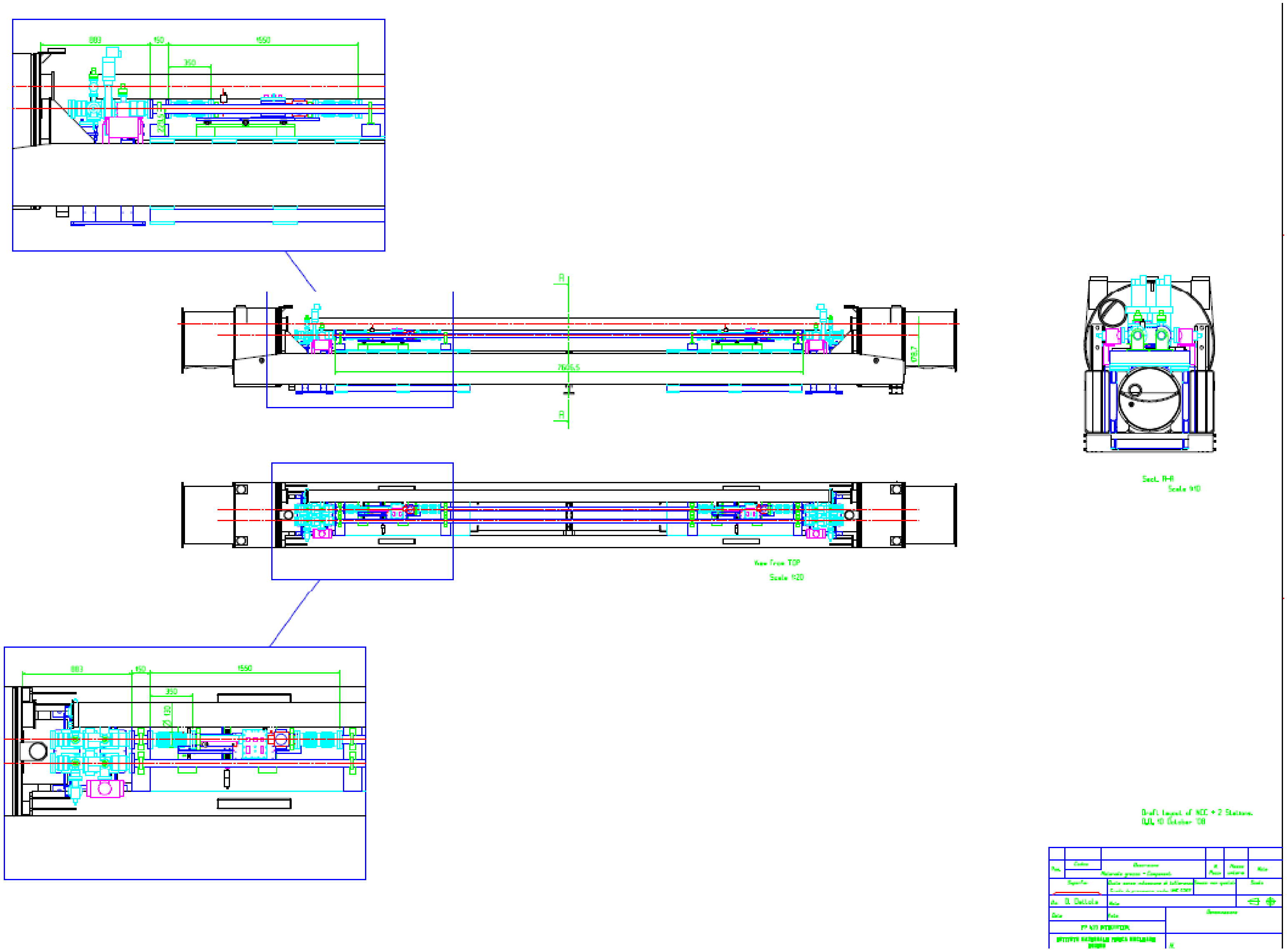
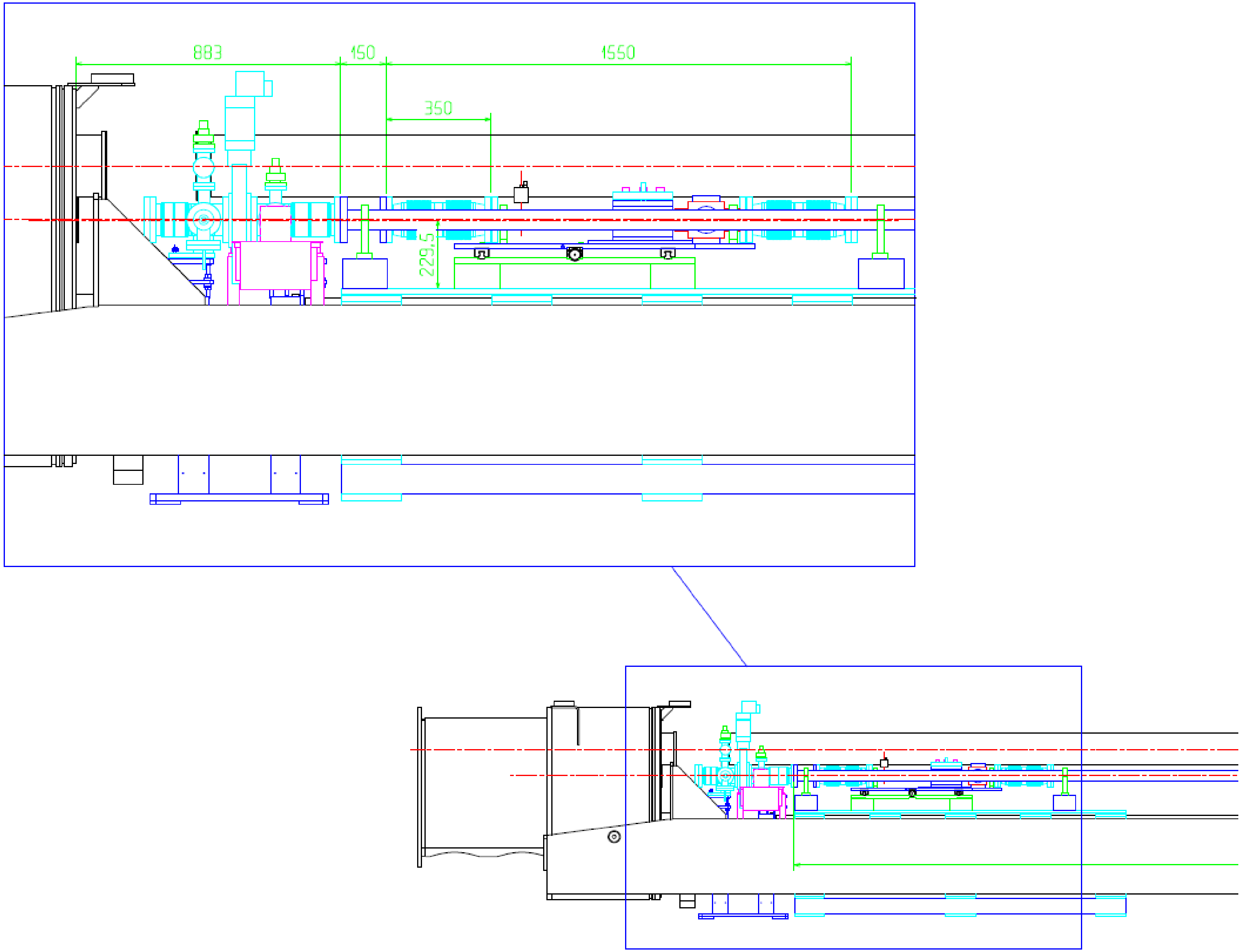
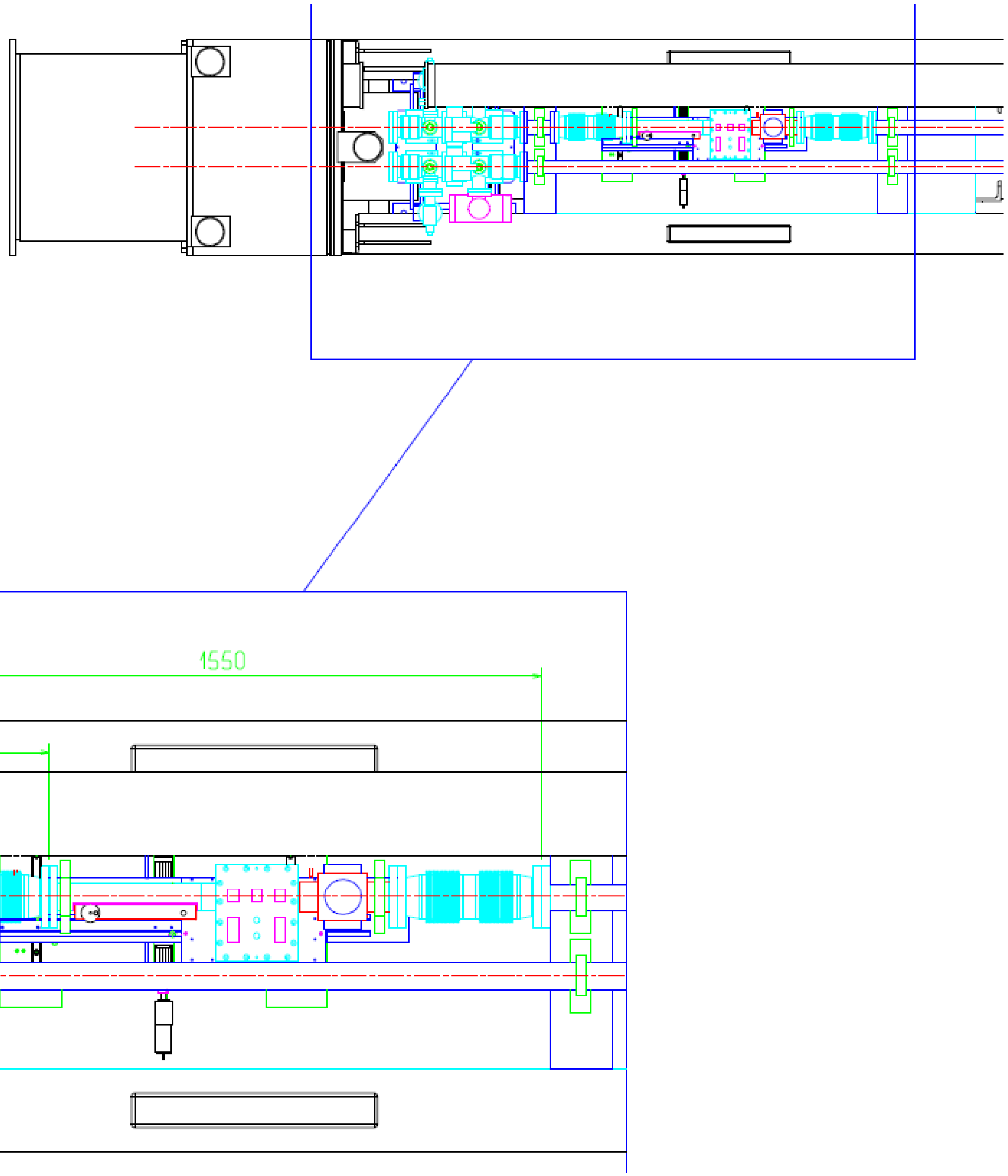
FP420 Integration



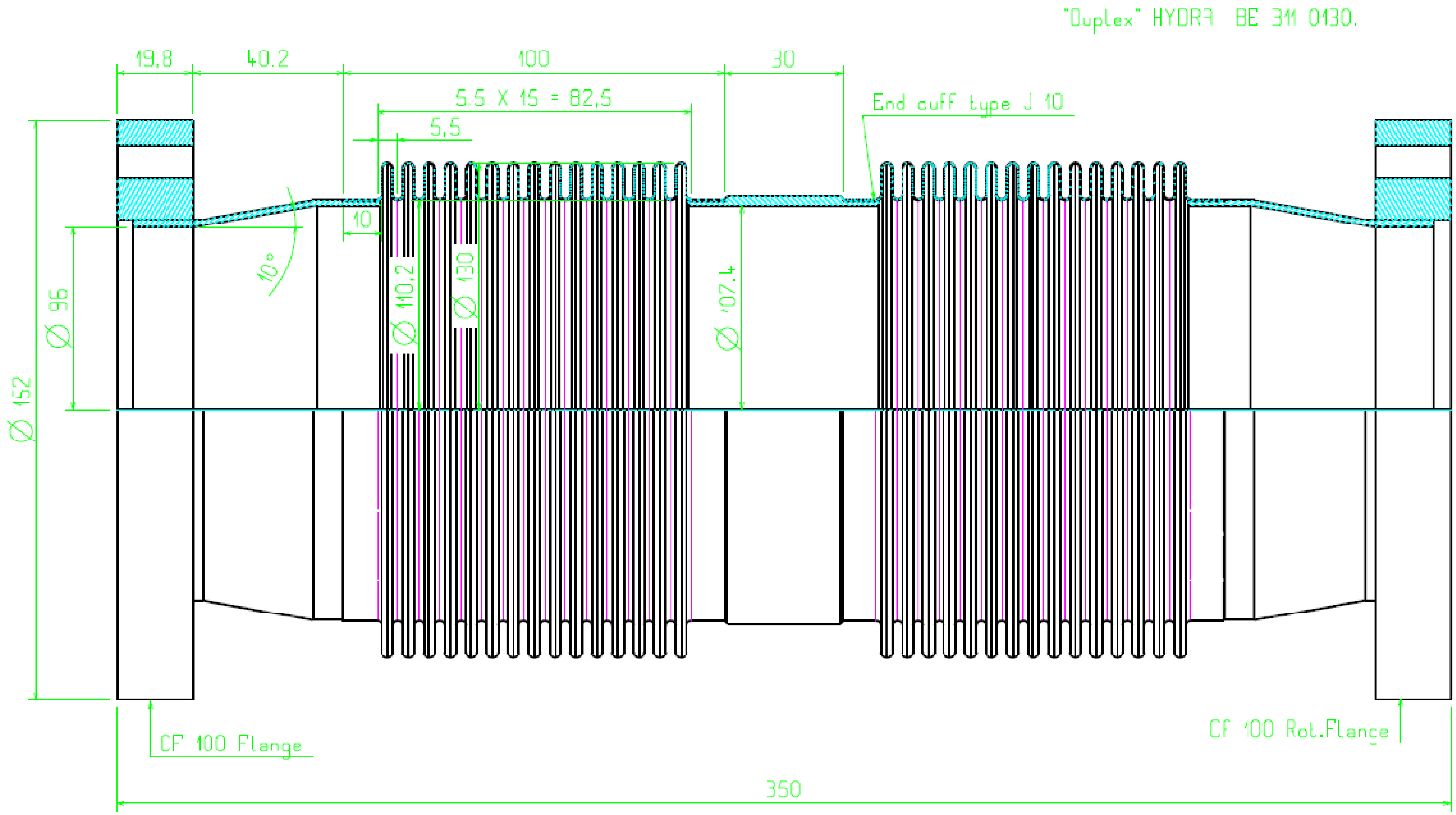
Detail Lateral view



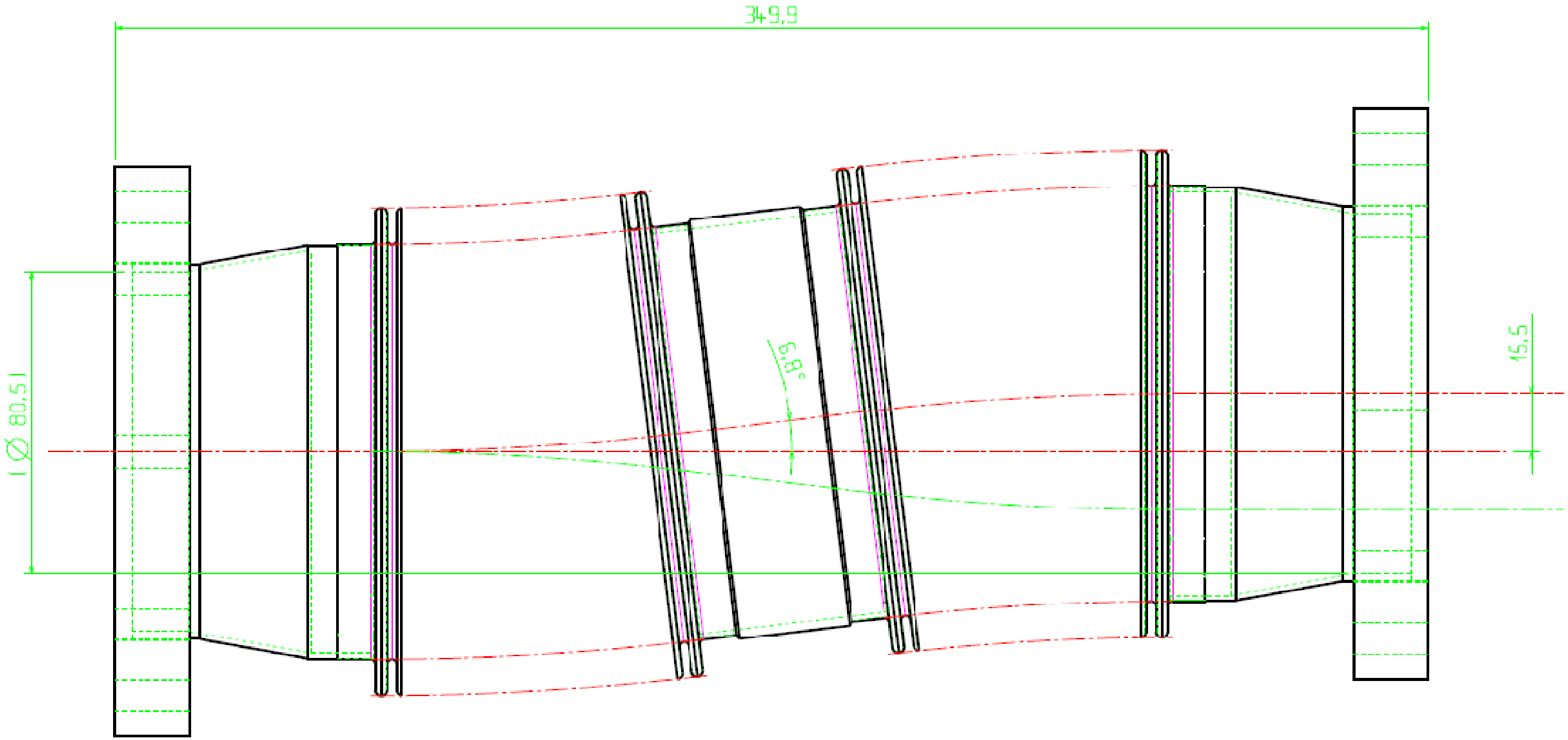
Detail Top view



Bellows Studio



Bellows studio Lateral movement



Stainless Steel Bellows

HYDRA

standard material: 1.4571 longitudinally welded
* material: 1.4541 seamless

type		bellows diameter internal d1	internal Tol.	external d2	external Tol.	number of plies	lw	length max.	bb-end Ø d4	S-end Ø d3 internal	S-end length l2	J-end Ø d3 internal	J-end length l2
		[mm]	[mm]	[mm]	[mm]	[-]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
columns: 1		2	3	4	5	6	7	8	9	12	13	14	15
BE	370230	70,5	-0,6/+0,2	95,0	±1,0	2	5,90	400	85,0	84,3	5,0	70,5	10
BE	370330	70,5	-0,5/+0,3	92,0	±1,0	3	6,10	400	85,0	-	-	70,5	10
BE	370430	70,5	-0,5/+0,3	92,0	±1,0	4	6,90	400	85,0	-	-	70,5	10
BE	370450	70,5	-0,7/+0,3	98,0	±1,0	4	9,00	300	85,0	-	-	70,5	10
BE	370550	70,5	-0,7/+0,3	99,0	±1,0	5	8,90	300	85,0	-	-	70,5	10
BE	370650	70,5	-0,7/+0,3	100,5	±1,0	6	11,4	300	85,0	-	-	70,5	10
BE	377125	77,5	-0,6/+0,2	101,0	±1,0	1	5,50	350	95,0	95,3	5,0	77,5	10
BE	377225	77,5	-0,6/+0,2	101,0	±1,0	2	6,30	350	95,0	95,3	5,0	77,5	10
BE	377230	77,4	-0,6/+0,2	101,0	±1,0	2	6,40	350	95,0	95,3	5,0	77,4	10
BE	376330	76,5	-0,5/+0,3	101,0	±1,0	3	7,20	350	95,0	-	-	76,5	10
BE	385120	85,1	-0,6/+0,2	114,5	±1,0	1	7,00	400	104,0	-	-	85,1	10
BE	385130	85,0	-0,6/+0,2	110,0	±1,0	1	6,50	400	104,0	103,5	5,0	85,0	10
BE	385230	85,0	-0,6/+0,2	106,0	±1,0	2	6,00	400	101,0	99,0	5,0	85,0	10
BE	385330	85,0	-0,7/+0,3	106,0	±1,0	3	6,50	400	101,0	-	-	85,0	10
BE	385430	85,0	-0,7/+0,3	106,0	±1,0	4	6,90	400	101,0	-	-	85,0	10
BE	385530	85,0	-0,7/+0,3	108,0	±1,0	5	7,60	400	101,0	-	-	85,0	10
BE	393230	93,0	-0,8/+0,2	120,0	±1,0	2	9,00	400	110,0	113,0	5,0	93,0	10
BE	396225	96,0	-0,8/+0,2	122,0	±1,0	2	6,50	400	113,0	115,4	5,0	96,0	10
BE	396130	96,0	-0,8/+0,2	122,0	±1,0	1	7,10	400	113,0	115,4	5,0	96,0	10
BE	396230	96,0	-0,8/+0,2	122,0	±1,0	2	6,70	400	113,0	115,4	5,0	96,0	10
BE	396330	96,0	-0,7/+0,3	122,0	±1,0	3	7,40	400	113,0	115,4	5,0	96,0	10
BE	396250	96,0	-0,7/+0,3	122,0	±1,0	2	7,40	400	113,0	-	-	96,0	10
BE	396350	96,0	-0,7/+0,3	122,0	±1,0	3	7,80	300	113,0	-	-	96,0	10
BE	396450	96,0	-0,7/+0,3	124,0	±1,0	4	8,60	300	113,0	-	-	96,0	10
BE	3102230	102,2	-0,8/+0,2	128,0	±1,0	2	6,80	400	122,0	120,0	5,0	102,2	10
BE	3110130	110,2	-0,8/+0,2	130,0	±1,5	1	5,50	400	125,0	124,4	8,0	110,2	10
BE	3110230	110,2	-0,8/+0,2	130,0	±1,5	2	6,20	400	125,0	124,4	8,0	110,2	10
BE	3110330	110,2	-0,7/+0,3	130,0	±1,5	3	7,00	200	125,0	-	-	110,2	10
BE	3110430	110,2	-0,7/+0,3	132,0	±1,5	4	7,50	200	125,0	-	-	110,2	10
BE	3110530	110,2	-0,7/+0,3	134,0	±1,5	5	8,00	200	125,0	-	-	110,2	10

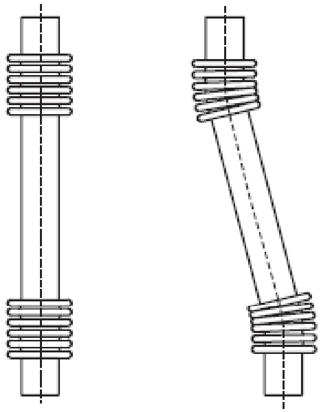
type		pressure PN	movement per corrugation axial δ_n	movement per corrugation angular α_s	movement per corrugation lateral λ_n	spring rate per corrugation axial c_δ	spring rate per corrugation angular c_α	spring rate per corrugation lateral c_λ	cross-sectional area A	weight per corrugation
		(bar)	[mm]	[degree]	[mm]	[N/mm]	[Nm/degree]	[N/mm]	[cm^2]	[g]
columns: 1		16	17	18	19	20	21	22	23	24
BE	370230	18	±1,00	±1,35	±0,024	360	5,400	93200	54,90	28,00
BE	370330	42	±0,70	±0,90	±0,018	900	12,800	239500	52,50	37,00
BE	370430	60	±0,67	±0,80	±0,012	1800	19,000	250000	53,00	50,00
BE	370450	105	±0,60	±0,80	±0,011	3800	58,000	470000	56,30	88,00
BE	370550	135	±0,57	±0,70	±0,010	4700	75,000	510000	57,00	110,00
BE	370650	175	±0,54	±0,60	±0,009	5200	83,000	450000	58,70	136,00
BE	377125	7	±1,20	±1,30	±0,027	120	2,100	47400	63,50	13,00
BE	377225	16	±1,10	±1,20	±0,025	250	4,600	75300	63,60	26,00
BE	377230	20	±0,95	±1,10	±0,024	425	7,400	123800	63,40	31,00
BE	376330	30	±0,90	±0,95	±0,018	610	11,000	139000	63,30	46,00
BE	385120	3	±1,90	±1,40	±0,028	45	1,000	15400	79,10	10,00
BE	385130	8	±1,20	±1,20	±0,020	200	4,000	65500	75,40	10,00
BE	385230	25	±0,90	±1,00	±0,020	710	14,000	269800	72,80	34,00
BE	385330	42	±0,70	±0,80	±0,018	1150	22,000	372400	73,20	51,00
BE	385430	63	±0,60	±0,70	±0,016	1600	30,000	460000	73,60	68,00
BE	385530	80	±0,55	±0,60	±0,014	1700	34,000	411000	74,80	85,00
BE	393230	16	±1,30	±1,00	±0,020	360	9,000	75600	90,10	50,00
BE	396225	12	±1,25	±1,05	±0,025	220	6,000	92800	94,60	37,00
BE	396130	8	±1,20	±1,10	±0,025	180	4,700	63600	94,20	23,00
BE	396230	18	±1,00	±0,90	±0,021	385	10,000	152800	94,70	45,00
BE	396330	28	±0,85	±0,80	±0,020	620	16,000	202000	95,20	66,00
BE	396250	40	±0,65	±0,65	±0,016	2100	57,000	600000	93,70	73,00
BE	396350	62	±0,60	±0,50	±0,014	3600	94,000	900000	94,70	110,00
BE	396450	88	±0,58	±0,45	±0,012	4200	113,000	890000	95,50	146,00
BE	3102230	17	±1,00	±0,90	±0,020	380	11,000	163300	105,50	51,00
BE	3110130	12	±0,85	±0,90	±0,015	425	13,000	305000	114,00	18,00
BE	3110230	25	±0,80	±0,80	±0,013	900	28,000	506600	115,00	37,00
BE	3110330	40	±0,70	±0,70	±0,012	1475	46,000	651300	115,00	55,00
BE	3110430	60	±0,65	±0,60	±0,010	1620	57,000	633500	117,00	72,00
BE	3110530	75	±0,60	±0,50	±0,008	1700	55,000	594000	119,20	90,00

98 99

Bellows with intermediate tube

Metal Bellows with Intermediate Tube for Extensive Lateral Movement

With long metal bellows, as they are required for compensation of extensive lateral movements, the corrugations in the bellows center are not subject to deflection but to squirming stress. For this reason, it is appropriate to substitute this part of the bellows by a rigid piping element. The two resulting bellows elements are only subject to bending, i.e. to angular stress and are to be designed according to the formulae on pages 70 and 71.



Besides economical advantages, the use of an intermediate tube increases the resistance to internal pressure and the total number of corrugations is lower than in a "continuous" bellows and the corresponding reduction factor k_i (see page 63) will increase (come closer to 1).

The use of bellows with intermediate pipe is not possible if

a) the space required for installation is not available and

b) the net weight of the intermediate pipe causes an excessive additional stress to the two bellows elements, thus reducing their service life.
At adequate pressure and squirming factor values thin-walled piping element (perhaps reinforced by beads) can be manufactured as one unit without any weldings.

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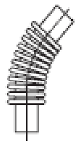
Number of convolution – cycle life expectancy

Explanations

Column 18 angular deflection


angular

The values of the elastic deformation for the bending angles quoted in the dimensional tables apply to one corrugation. Due to their selection, 10000 stress cycles at ambient temperature (20-30 °C) and under the reference pressure quoted can be expected. Under thermal stress, the permissible elastic deformation will decrease. Furthermore, it is to be reduced if cycle life expectancy is raised, and vice versa.
The permissible bending angles are calculated from the following table; according to the service conditions, only one formula is to be selected for each individual case.

Nw= 6.75/(0.9x0.5)=15Convolution

cycle life expectancy	thermal stress	At total or almost total permissible service pressure rate according to column 16 $\frac{p_b}{p_{az}}$ or $\frac{p_b}{p_{iz}} \sim 1$ — bending angle α: 1 corrugation	bending angle α: n_w corrugations	number of corrugations for the total angle (round off to higher number)	With only partial application without excess of the permissible pressure according to calculation in column 16 $\frac{p_b}{p_{az}}$ or $\frac{p_b}{p_{iz}} \lesssim 1$ — bending angle α: 1 corrugation	bending angle α: n_w corrugations	number of corrugations for the total angle (round off to higher number)
10 000	20 °C	$\alpha_z = \alpha_n$	$\alpha_g = \alpha_n \cdot n_w$	$n_w = \frac{\alpha_b}{\alpha_n}$	$\alpha_z = \alpha_n \cdot k_l$	$\alpha_g = \alpha_n \cdot k_l \cdot n_w$	$n_w = \frac{\alpha_b}{\alpha_n \cdot k_l}$
	> 20 °C	$\alpha_z = \alpha_n \cdot k_\vartheta$	$\alpha_g = \alpha_n \cdot k_\vartheta \cdot n_w$	$n_w = \frac{\alpha_b}{\alpha_n \cdot k_\vartheta}$	$\alpha_z = \alpha_n \cdot k_\vartheta \cdot k_l$	$\alpha_g = \alpha_n \cdot k_\vartheta \cdot k_l \cdot n_w$	$n_w = \frac{\alpha_b}{\alpha_n \cdot k_\vartheta \cdot k_l}$
other load cycle numbers	20 °C	$\alpha_z = \alpha_n \cdot k_f$	$\alpha_g = \alpha_n \cdot k_f \cdot n_w$	$n_w = \frac{\alpha_b}{\alpha_n \cdot k_f}$	$\alpha_z = \alpha_n \cdot k_n$	$\alpha_g = \alpha_n \cdot k_n \cdot n_w$	$n_w = \frac{\alpha_b}{\alpha_n \cdot k_n}$
	> 20 °C	$\alpha_z = \alpha_n \cdot k_\vartheta \cdot k_f$	$\alpha_g = \alpha_n \cdot k_\vartheta \cdot k_f \cdot n_w$	$n_w = \frac{\alpha_b}{\alpha_n \cdot k_\vartheta \cdot k_f}$	$\alpha_z = \alpha_n \cdot k_\vartheta \cdot k_n$	$\alpha_g = \alpha_n \cdot k_\vartheta \cdot k_n \cdot n_w$	$n_w = \frac{\alpha_b}{\alpha_n \cdot k_\vartheta \cdot k_f}$

- α_b = required bending angle for the whole bellows — the value for one direction of movement is to be inserted (°)
- α_g = permissible bending angle for the complete bellows (°)
- α_n = nominal bending angle per corrugation according to dimensional tables (°/corr.)
- α_z = permissible bending angle per corrugation (°/corr.)
- n_w = number of corrugations
- k_ϑ = reduction factor for the bellows movement (elastic deflection) at temperatures > 20 °C according to tables on pages 74 to 77
- k_f = reduction factor (elastic deflection) for stress cycles under maximum service pressure conditions
- p_{az} = permissible external pressure — calculated values according to column 16 (bar)
- p_{iz} = permissible internal pressure — calculated values according to column 16 (bar)
- p_b = service pressure (bar)
- k_l = reduction factor (elastic deflection) for service pressure at 10000 stress cycles
- k_n = corrective factor (elastic deflection) at higher design than service pressure conditions, see table page 83

number of stress cycles	corrective factor k_f
10^7	0,05
$5 \cdot 10^6$	0,1
$2 \cdot 10^6$	0,2
$8 \cdot 10^5$	0,3
$4 \cdot 10^5$	0,4
$2 \cdot 10^5$	0,5
10^5	0,6
50 000	0,7
25 000	0,8
14 000	0,9
10 000	**1,0**
4 000	1,2
1 700	1,4
1 000	1,6

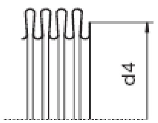
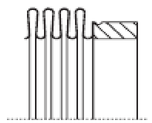
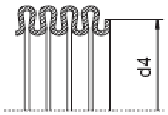
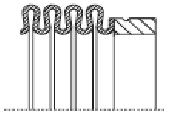
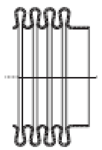
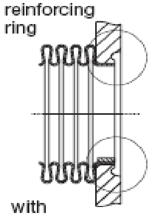
$k_f = k_n$ (also see page 83)

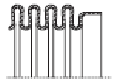
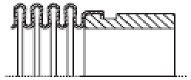
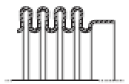
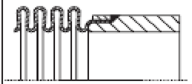
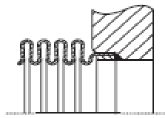
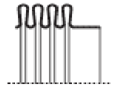
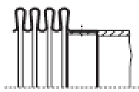
$\frac{p_b}{p_{az}}$ or $\frac{p_b}{p_{iz}}$	k_l
1	1
0,8	1,05
0,6	1,08
0,4	1,1
0,2	1,13
0	1,15

$k_l = k_n$ (also see page 83)

If the length of the corrugated section has been increased in these calculations, the pressure resistance will have to be verified again acc. to column 16 (squirm reduction factor). The calculation of the angular movement is to be repeated, if necessary. This will also apply in calculations where mandatory spring rates influence the corrugated length.

Standard end fittings and connection methods

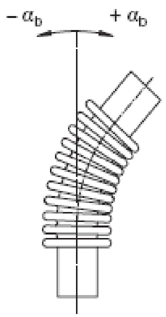
bellows end	connection type	weld method	preferred application
end type bb 		fusion welding (inert gas welding) DIN ISO 4063 **without** filler material micro-plasma and laser welding	for metal bellows monoply to 4 plies
end type bb 		TIG welding (inert gas welding) DIN ISO 4043 **with** filler material.	for metal bellows 5 to 8 plies
end type J  without reinforcing ring	without reinforcing ring  with reinforcing ring	fusion welding (inert gas welding) DIN ISO 4063 **without** filler material.	for metal bellows monoply to 4 plies with flange-type end fittings

bellows end	connection type	weld method	preferred application
end type S 		fusion welding (inert gas welding) DIN ISO 4043 **without** filler material.	only for special applications
Special end type Ja 	 	TIG welding (inert gas welding) DIN ISO 4063 **with** filler material.	for high-pressure bellows with more than 3 plies
end type J 		resistance welding	for metal bellows with 1 or 2 plies
We have procedures qualified by TÜV for arc fusion welding (in accordance with AD sheet H1) for **standard** material combinations. (Please inquire, if necessary).			

Angular spring rate

Column 21 angular spring rate

Explanations



The angular spring rate is quoted for one single corrugation in Nm per angular degree. It decreases linear to the number of corrugations. The bending force increases proportionally to the bending angle.

$$c_{\alpha g} = \frac{c_\alpha}{n_w}$$

$$f_{\alpha g} = c_{\alpha g} \cdot \alpha_b = \frac{c_\alpha \cdot \alpha_b}{n_w}$$

$$n_w = \frac{c_\alpha}{c_{\alpha g}} = \frac{c_\alpha \cdot \alpha_b}{f_{\alpha g}}$$

C_α = 13Nm

Nw =15

$C_{\alpha g}$=0.867

F = ~5.85 N

c_α =	angular spring rate of a single corrugation according to dimensional table	$\left(\frac{Nm}{°}\right)$
$c_{\alpha g}$ =	angular spring rate of the bellows	$\left(\frac{Nm}{°}\right)$
$f_{\alpha g}$ =	angular force of the bellows	(Nm)
α_b =	required bending angle	(°)
n_w =	number of corrugations	

If the length of the bellows has been changed due to this calculation, the pressure resistance is to be verified again according to column 16 (squirm reduction factor) and the permissible bending angle is also to be verified again according to column 18, if necessary.

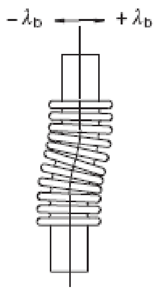
The spring rate tolerances of bellows are

in "standard version" ±30%
in "high-precision version" +15%.

The spring rate depends on temperature and decreases at a rise in temperature according to the table on page 82.

Column 22 lateral spring rate

Explanations



The rate of lateral movement is quoted for one single corrugation in Nm per lateral deflection. It decreases reciprocally to the third power of the number of corrugations. The lateral force increases proportionally to the lateral movement.

$$c_{\lambda g} = \frac{c_\lambda}{n_w^3}$$

$$f_{\lambda g} = c_{\lambda g} \cdot \lambda_b = \frac{c_\lambda \cdot \lambda_b}{n_w^3}$$

$$n_w = \sqrt[3]{\frac{c_\lambda}{c_{\lambda g}}} = \sqrt[3]{\frac{c_\lambda \cdot \lambda_b}{f_{\lambda g}}}$$

c_λ =	lateral spring rate of a single corrugation according to dimensional table	$\left(\frac{N}{mm}\right)$
$c_{\lambda g}$ =	lateral spring rate of the bellows	$\left(\frac{N}{mm}\right)$
$f_{\lambda g}$ =	lateral force of the bellows	(N)
λ_b =	required lateral movement for the whole bellows	(mm)
n_w =	number of corrugations	

If the length of the bellows has been changed due to this calculation, the pressure resistance is to be verified again according to column 16 (squirm reduction factor) and the permissible lateral movement is also to be verified again according to column 19, if necessary.

The spring rate tolerances of bellows are

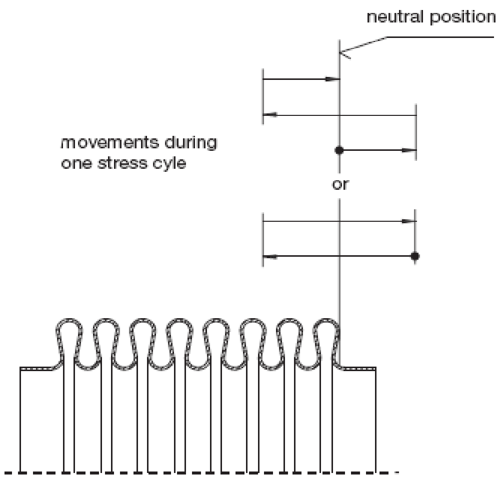
in "standard version" ±30%
in "high-precision version" ±15%.

The spring rate depends on temperature and decreases at a rise in temperature according to the table on page 82.

Service life

Service Life

The service life of a corrugated metal bellows or a diaphragm bellows is the number of stress cycles endured until first leakage, with a total forward and return movement, i.e. return to the initial position, being one stress cycle.



The pressures and movements quoted in the data sheets have thus been specified that in the case of cold stress (room temperature 20–30 °C) and expert installation at least

10 000 stress cycles

will be endured. The number of cycles to fracture is, considerably higher in general.

The following survey gives a detailled presentation of the number of stress cycles to be expected. They show that one load cycle per minute (with an operating period of 8 hours per day) will make 10^5 stress cycles per year.

1 year has	days ≈	hours ≈	minutes ≈	seconds ≈
with an operating period of 24 hours per day	365	9000	$5 \cdot 10^5$	$3 \cdot 10^7$
with an operating period of 8 hours per day	240	2000	10^5	$7 \cdot 10^6$

The figure 10 000 is a nominal stress cycle number which may change under the influence of the operating conditions in practice or of stress factors to be fixed accordingly. The main affecting factors are

1. Temperature
2. Elastic Deflection (Maximum Movement)
3. Service Pressure Load
4. Pre-Setting of Stroke
5. Stroke Frequency

Factors of incalculable negative influence such as

6. Pressure Shocks, Pulsations
7. Thermal Shocks
8. Corrosion
9. Inadequate Installation etc.

are to be taken into consideration.

When selecting the bellows type and dimension, the design engineer should at least have an approximate idea of the number of stress cycles required. The more precise the information about the requirements of an application is, the better the possibility of selecting the appropriate bellows.