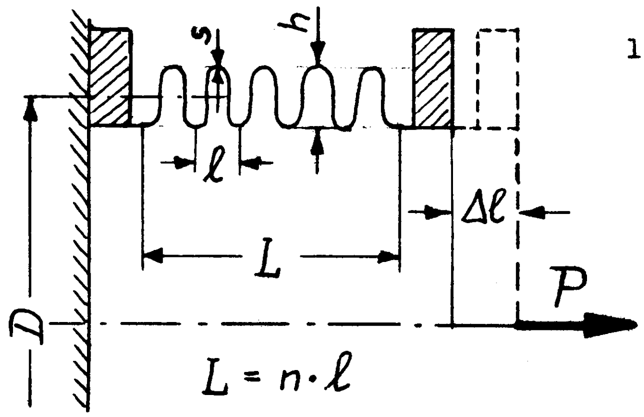
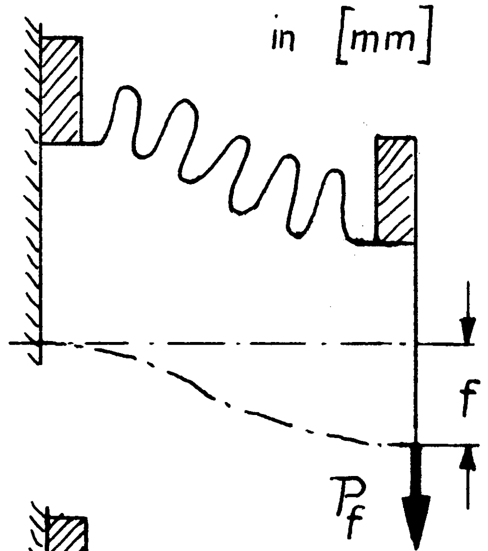
MPS/ML Note 69-21
WR/dp 26.11.1969

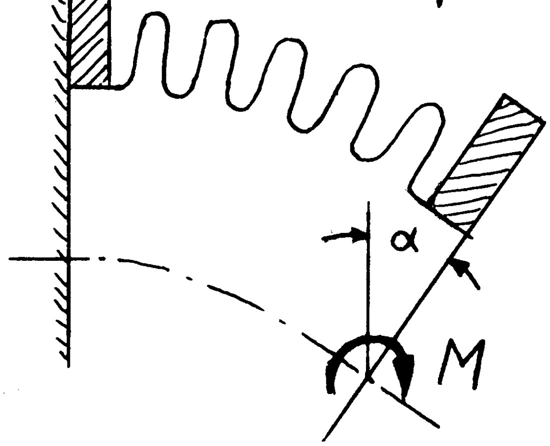
HOW TO CALCULATE BELLOWS

As first order approximations, the following formulas are recommended. They do not make a difference between hydroformed and welded types. A refined version of this note will appear later.



all dimensions in [mm]





1) Extension

$$\Delta\ell = \frac{2.n.h.\,(\ell+h)}{3.E.s.}\,\sigma \quad [mm]$$

$$P = \frac{\pi.D.s^3.E}{2.n.h^2.(\ell+h)}\,\Delta\ell \quad [kg]$$

$$\sigma = \frac{3h}{\pi.\,D.s^2}\,P \quad [kg/mm^2]$$

2) Displacement

$$f = \frac{L^2.h.(1+h/\ell)}{9.E.s.D}\,\sigma \quad [mm]$$

$$P_f = \frac{3.\pi.s^3.D^3.E.}{2.L^3.h^2.(1+h/\ell)}\,f \quad [kg]$$

$$\sigma = \frac{6.h.L}{\pi.D^2.s^2}\,P_f \quad [kg/mm^2]$$

3) Bending

$$\alpha = \frac{4.n.h.(\ell+h)}{3.E.s.D}\,\sigma \quad [rad]$$

$$M = \frac{\pi.s^3.D^3.E.}{16.n.h^2.(\ell+h)}\,\alpha \quad [mm.kg]$$

$$\sigma = \frac{12.h}{\pi.s^2.D^2.}\,M \quad [kg/mm^2]$$

4) <u>Vacuum contributions</u>

$$\Delta P = \frac{\pi . D^2 .}{4} \; p \quad [kg] \qquad \text{with } p = 0{,}01 \text{ kg/mm}^2$$

$$\Delta P_f = \frac{\pi . D^2 . f .}{4 . L} \; p \; [kg]$$

$$\Delta M = \frac{\pi . D^2 . L . (1 - \cos\alpha)}{4 \alpha} \; p \quad [mm.kg]$$

$$\Delta \sigma = \frac{3}{8} \left(\frac{h}{s}\right)^2 p \quad [kg/mm^2]$$

hence avoid bellows with $h/s > 100$ for vacuum applications

5) <u>Strain values</u>

For stainless steel (304) is $E = 20\,000$ kg/mm^2.
Recommended maximum values for σ are :

$\pm$ 12 kg/mm^2 for dynamic loads with less than 2 c/s.

$\pm$ 24 kg/mm^2 up to a maximum of 1 000 strokes.

$\pm$ 36 kg/mm^2 for no more than 10 movements.

No plastic deformation is noticable until one passes 40 kg/mm^2.

6) <u>Comparison</u>

Calorstat (Paris) uses for its hydroformed bellows 2 to 3 times bigger σ-values and gives for welded bellows a spring force which is 3 to 4 times bigger than calculated here.

Boa (Luzern) recommends for hydroformed bellows slightly lower σ- values.

Comments are welcomed

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<u>Distribution</u> :

ML-design and vacuum section

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RECOMMENDED CERN-BELLOWS FOR VACUUM APPLICATIONS

26.11.69 R.

int/ext. diameter * wall-thickness mm	n	Values for L = 100 mm and σ = 24 kg/mm² $\Delta\ell$ mm	P kg	ΔP kg	f mm	P_f kg	ΔP_f kg	α °	M mm.kg	ΔM mm.kg
7/20 × 0,08	65	34	0,33	1,43	42	0,023	0,6	288°	1,1	19,6
20/40 × 0,1	40	40	0,75	7,1	22	0,113	1,56	153°	5,6	500
30/50 × 0,1	40	40	1,0	12,6	16,7	0,2	2,1	114°	10	890
75/95 × 0,1	40	40	2,13	57	7,8	0,91	4,4	54°	45	2 500
90/115 × 0,12	40	50	2,97	82	8,1	1,52	6,6	56°	76	3 700
100/150 × 0,25	20	48	7,86	122	6,4	4,9	7,8	44°	246	4 500
160/180 × 0,1	30	32	4,28	226	3,1	3,6	7,0	22°	182	4 400
200/230 × 0,15	40	56	8,1	363	4,3	8,7	15,6	30°	435	9 400
230/270 × 0,2	20	40	12,6	490	2,7	15,8	13,2	18°	790	7 800
280/330 × 0,25	20	48	19,2	730	2,6	29,3	19	18°	1 460	11 600