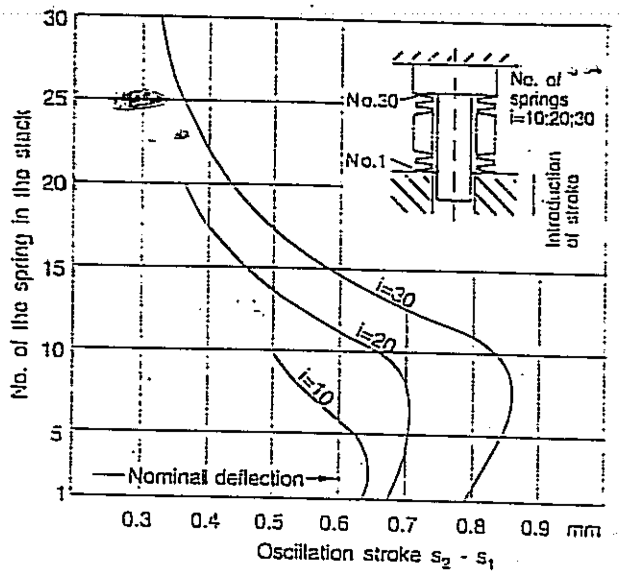


Figure 26:

Example of the uneven deflection within a spri stack

8.3 Guide Clearance

Disc springs always need a guide element to prevent lateral movement. The guide can be on the outside D_a or the inside D_i of the springs, but inside guidance on a bolt or shaft is preferred the outside guidance in a sleeve, because offers design and economic advantages.

For the clearance between the guide and the spring DIN 2093 recommends the following values.:

Table 8.3

D_i or D_a mm	Clearance mm
to 16	0.2
over 16 to 20	0.3
over 20 to 26	0.4
over 26 to 31.5	0.5
over 31.5 to 50	0.6
over 50 to 80	0.8
over 80 to 140	1.0
over 140 to 250	1.6

These values represent the difference in the diameters. Under certain conditions this guide clearance can be reduced, e.g. with high-speed spindles. In order to avoid jamming of th individual disc springs on the guide bolt or in th guide sleeve, the spring cross-sections must b designed to be rectangular (Fig. 27). All fo corners are slightly rounded with a radius approximately t/8.

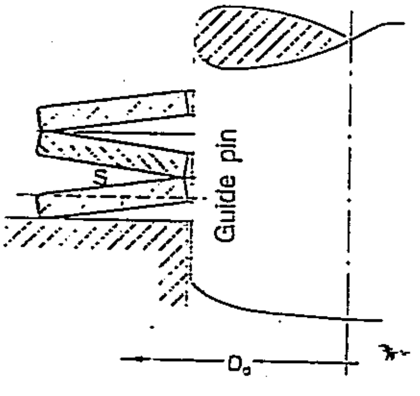


Figure 27:

With the rectangular spring cross section jamming at th guide pin during deflection is prevented

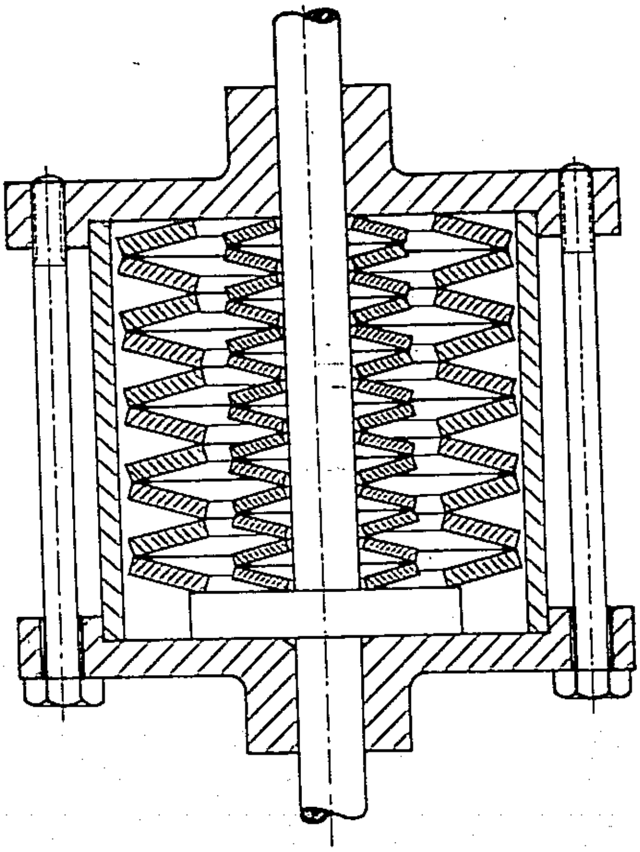


fig. 83

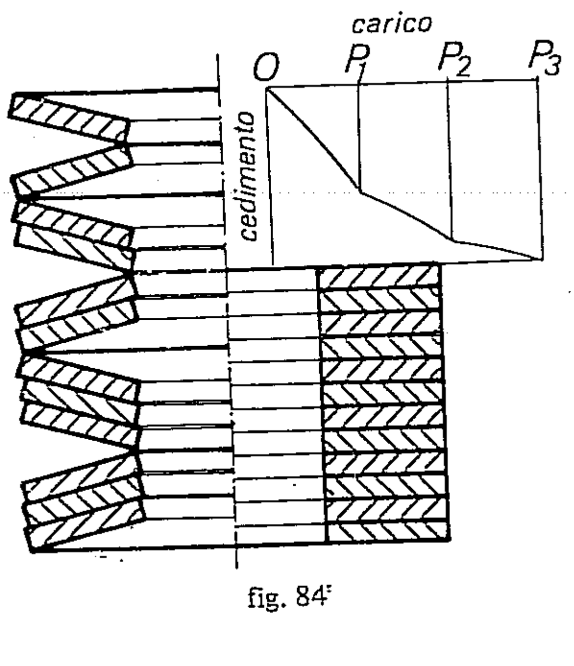


fig. 84

On the other hand, the force of the flattened disc spring increases linearly. If, for example, a spring calculation cannot predict this in a satisfactory manner, then a first step in the form of a change in the free height may already produce the desired load/deflection diagram. Here, however, the permissible stress must be observed, as these increase with increasing cone height h_0.

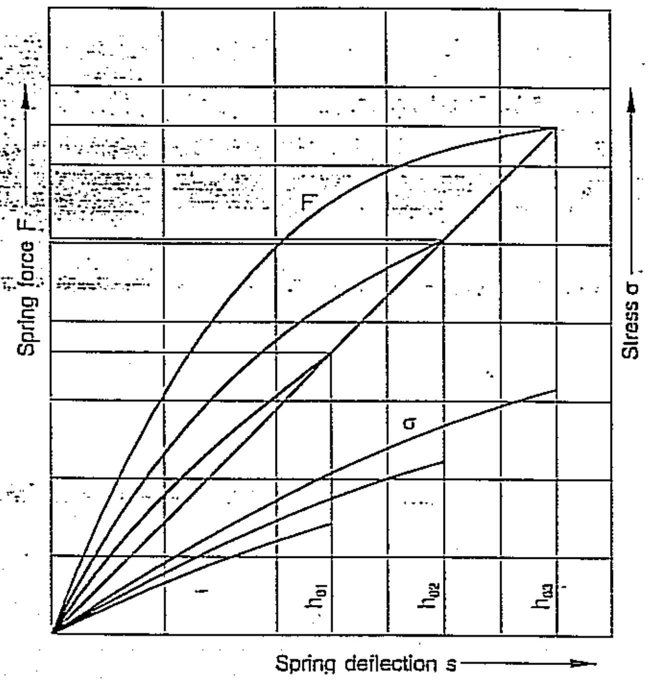


Figure 8:
Characteristic of a single disc with different height h_0

At $h_0/t > \sqrt{2}$, the spring force reaches a maximum and then decreases again. In some cases the decreasing segment of the curve is utilised. Under certain conditions te spring must be loaded beyond the flat position, for which certain design conditions must be given (Fig. 9).

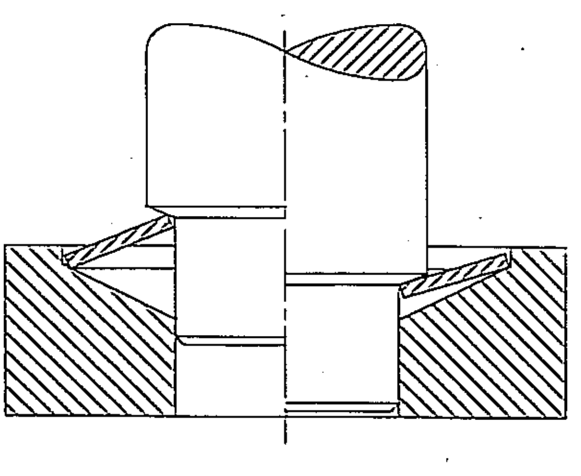


Figure 9:
Spring loaded beyond the flat position

8 The Application of Disc Springs

8.1 Spring Stacks and their Features

The best spring arrangement is the one which uses the least number of individual springs. In order to achieve this the goal, the outside diameter should always be as large as possible.

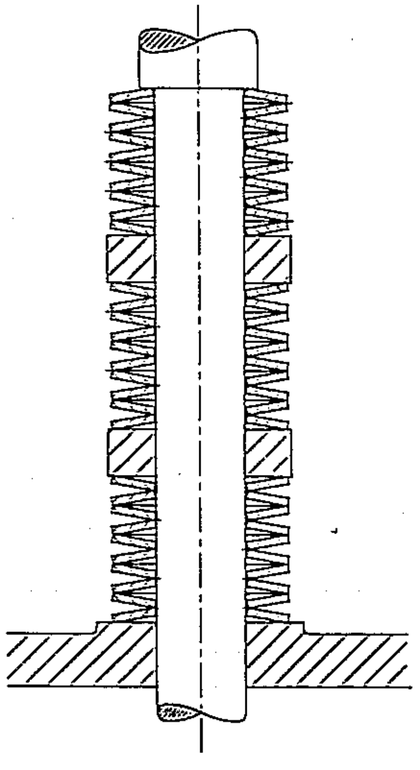


Figure 25: Division of a long spring stack

This automatically keeps the stack length short. With an increasing number of disc springs, the friction and the uneven deflection of individual discs within the stack increases. We recommend

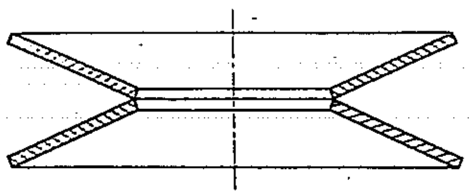
$L_0 \leq 3 \cdot D_e$

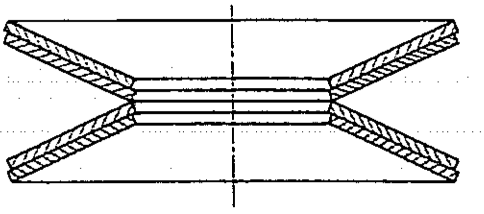
as the approximate stack length. If it is not possible to avoid a longer stack, then it should be divided into 2 or possibly 3 partial stacks with suitable washers. These washers should be guided as exactly as possible (Fig. 25).
In order to keep the friction within reasonable limits, no more than 2 or 3 springs should be stacked in parallel unless a large friction loss is expressly desired. Particularly in the case of dynamic loading, considerable warming must be expected with 2 or more springs in parallel. Whenever possible, the abutments of a disc spring stack should contact the outside diameter, however this is only possible at both abutments with an even number of individual springs or spring sets.

8.2 Alignment of Spring Stacks

Within a spring stack the disc springs do not always move evenly (Fig. 26).
This naturally leads to overloading at one end of the stack with consequential reduction in fatigue life. This is also the reason why, with dynamic loads, the first breaks occur at an end of the spring stack in most cases. Therefore, we recommend that the spring stack be aligned on the guide rod with a "vee bar" and then maintained in position with a light preload. After alignment the spring stack should not be completely relaxed. This procedure has been found most satisfactory in practice for minimizing friction in spring stacks. If it is not possible to align the stack for design reasons, the stack should be compressed flat once or twice. This also has the effect of centralising the springs and reducing friction.

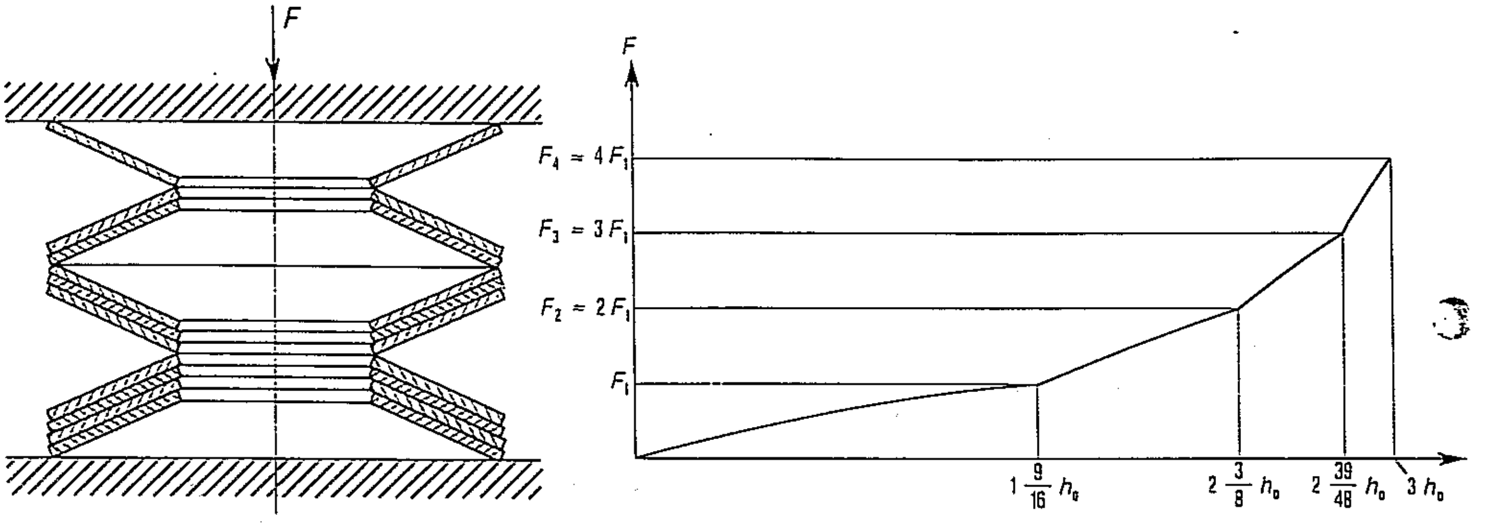
The friction is usually somewhat less in a vertically arranged stack than in the horizontal installation position. It is therefore better to have long stacks arranged vertically rather than horizontally.
With a dynamically loaded stack there is a running in period during which the friction is reduced, especially with multiple layering. The reason for this is a certain smoothing effect at both the contact edges and the touching spring flanks.





a) colonna costituita da due molle ordinate in senso alternato (in serie)

b) colonna costituita da due pacchi di due molle ciascuno (in serie-parallelo)



c) colonna costituita da una molla singola e da tre pacchi rispettivamente di due, tre e quattro molle (in serie-parallelo). Di questa colonna è riportato il diagramma di carico in funzione della freccia, nell'ipotesi che opportuni anelli o spallamenti impediscano che la freccia di ogni molla o pacco superi 0,75 h_0.

Fig. 7 — Colonne di molle a tazza ordinate in senso alterno

1.6. Caratteristiche d'impiego

Tutti i tipi di molle a tazza indicati in 1.2 presentano le seguenti caratteristiche che possono suggerire la convenienza dell'impiego:

- possibilità di ottenere elevati valori del carico e della rigidità con un ingombro relativamente limitato;
- possibilità di realizzare curve caratteristiche (rappresentanti il carico in funzione della freccia) con andamento non lineare, ossia con rigidità variabile in funzione della freccia fino ad annullarsi e in determinati intervalli assumere valori negativi;
- possibilità di ottenere una vasta gamma di valori del carico della rigidità raggruppando due o più molle in pacchi e/o colonne (vedere 1.5) con l'impiego di un limitato numero di molle unificate (vedere UNI 8737).

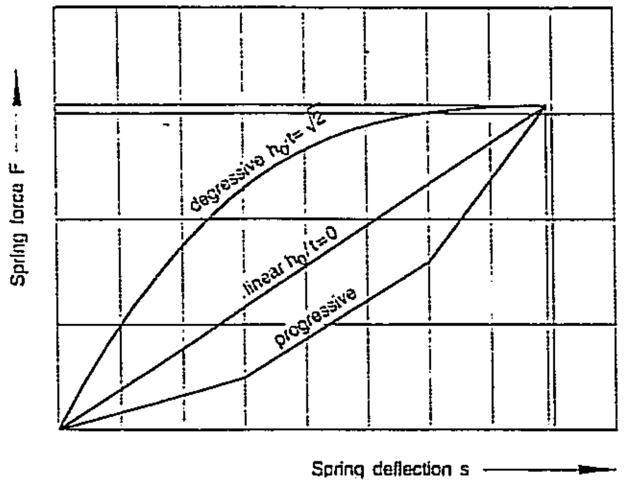


Figure 16:
Various types of spring characteristics

With a spring stack as shown in (Fig. 17-Chart a), the discs of the 1, 2 and 3-fold layering will be flattened in sequence when a load is applied. The characteristic of such a spring stack results when the individual characteristics are added together, as shown schematically in Fig. 17. The same results can be achieved if disc springs of differing thicknesses are combined to form a stack (Fig. 17-Chart b). In this case it must be considered that the spring sets stacked 1 or 2-fold or the thinner single discs are subjected to very high stresses if disc springs as per DIN 2093 or the SCHNORR factory standard have been selected. However, this overloading can be prevented with a smaller cone height or with spacer sleeves or rings to limit the deflection.

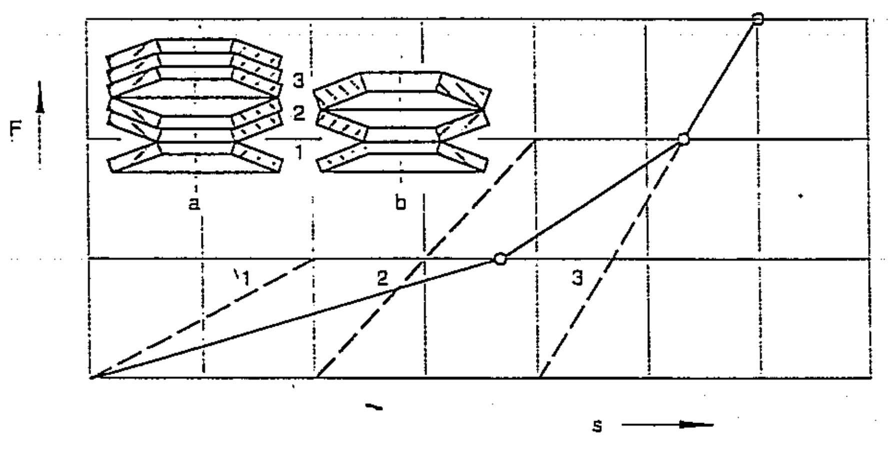


Figure 17:
Progressive characteristic with disc springs

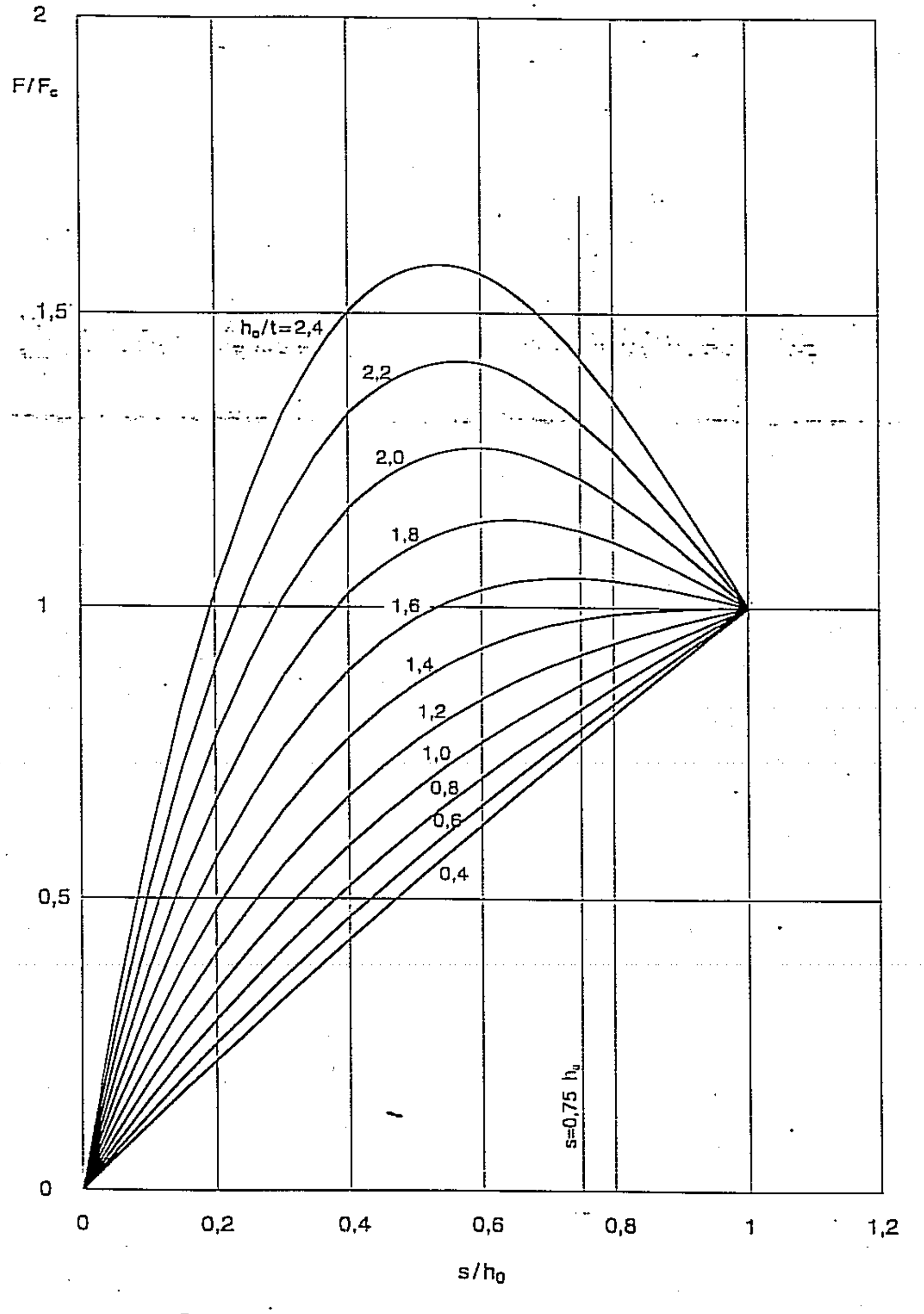


Figure 3: Spring characteristic curve with respect to h_0/t and s/h_0

Scegliere le molle di un sistema elastico di un freno di emergenza, riportato nella figura 1, per la vettura di un impianto funiviario. Si tratta di un freno detto in "negativo" in quanto:

- A ganasce aperte il sistema elastico è tenuto compresso da olio in pressione.
- L'intervento del freno è provocato dallo scarico del circuito idraulico contenente il succitato olio in pressione.
- Mancando la pressione dell'olio, le molle si rilasciano e spingono le ganasce che vanno a premere sulla fune.

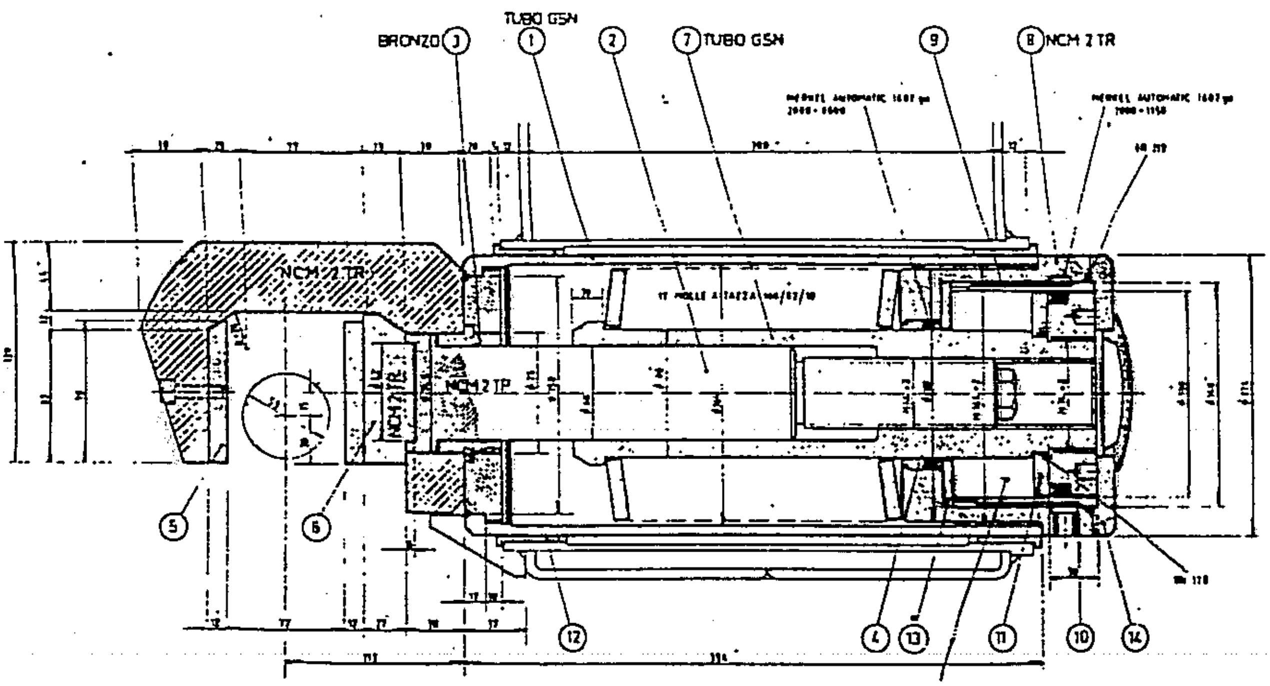


Figura 1

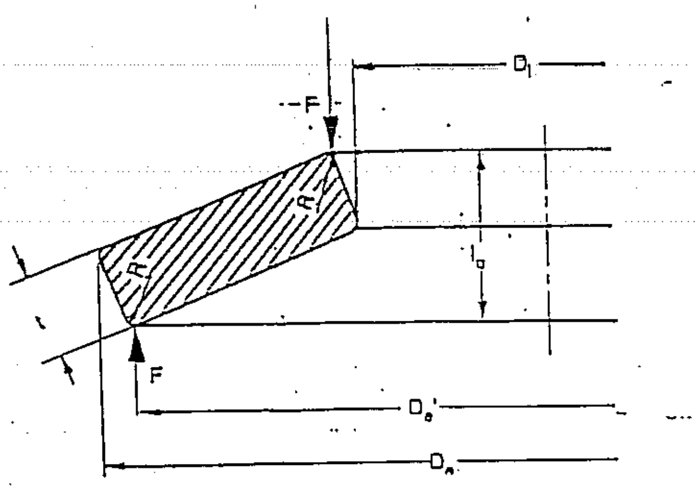


Figura 1: Molla a tazza di gruppo 2 secondo DIN 2093

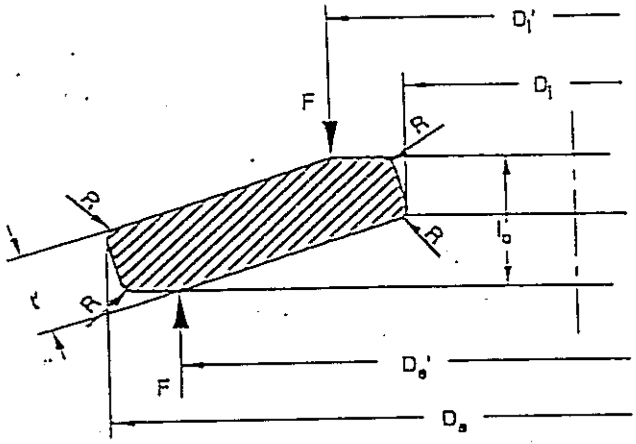


Figura 2: Molla a tazza di gruppo 3 secondo DIN 2093

gruppo	spessore	spianatura
1	$t < 1,25$	no
2	$1,25 \leq t \leq 6$	no
3	$t > 6$	si

serie	D_e/t	h_0/t
A	≈ 18	$\approx 0,4$
B	≈ 28	$\approx 0,75$
C	≈ 40	$\approx 1,3$

Tabella 1: Classificazione delle molle a tazza in gruppi e serie, secondo DIN 2093

serie	w_m	w_r
A	$0,005 \ldots 0,030$	$0,03 \ldots 0,05$
B	$0,003 \ldots 0,020$	$0,02 \ldots 0,04$
C	$0,002 \ldots 0,015$	$0,01 \ldots 0,03$

Tabella 2: Valori dei coefficienti di attrito secondo DIN 2092

denominazione DIN 2093 ...	gruppo	D_e mm	D_i mm	t, (t') mm	h_0 mm	l_0 mm	F N	s mm	σ_{MAX} N/mm²	σ_{OM} N/mm²
- A 40	2	40	20,4	2,25	0,9	3,15	6540	0,68	$\sigma_{II} = 1340$	−1210
- B 40	2	40	20,4	1,5	1,15	2,65	2620	0,86	$\sigma_{III} = 1130$	−1020
- C 40	1	40	20,4	1	1,3	2,3	1020	0,98	$\sigma_{II} = 1070$	−772
- A 200	3	200	102	12 (11,25)	4,2	16,2	183 000	3,15	$\sigma_{II} = 1230$	−1210
- B 200	3	200	102	8 (7,5)	5,6	13,6	76 400	4,2	$\sigma_{III} = 1250$	−1060
- C 200	2	200	102	5,5	7	12,5	36 100	5,25	$\sigma_{III} = 1250$	−910

Tabella 3: Differenti dimensionamenti tratti da DIN 2093, $E = 206\,000$ N/mm², $\nu = 0,3$

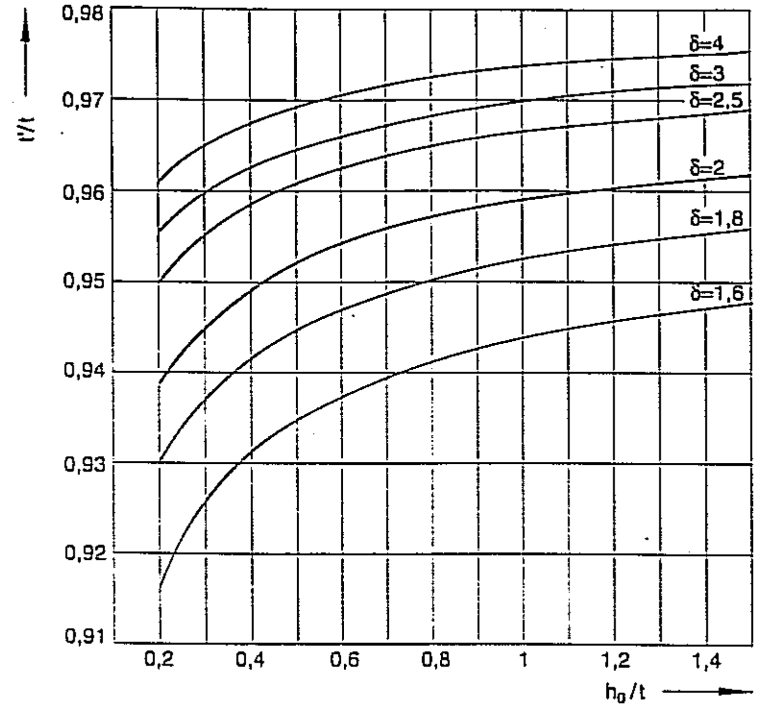


Figure 6:
Factor t'/t for disc springs with σ_{CM} = -1600 N/mm²

As the overall height is not reduced, springs with reduced thickness inevitably have an increased flank angle and a greater cone height h_0' than springs of the same nominal dimension without reduced thickness. Therefore, the characteristic curve is altered and becomes more curved. Figure 7 shows the characteristic curves for springs of the series A, B and C as per DIN 2093 with and without contact flats and reduced thickness.

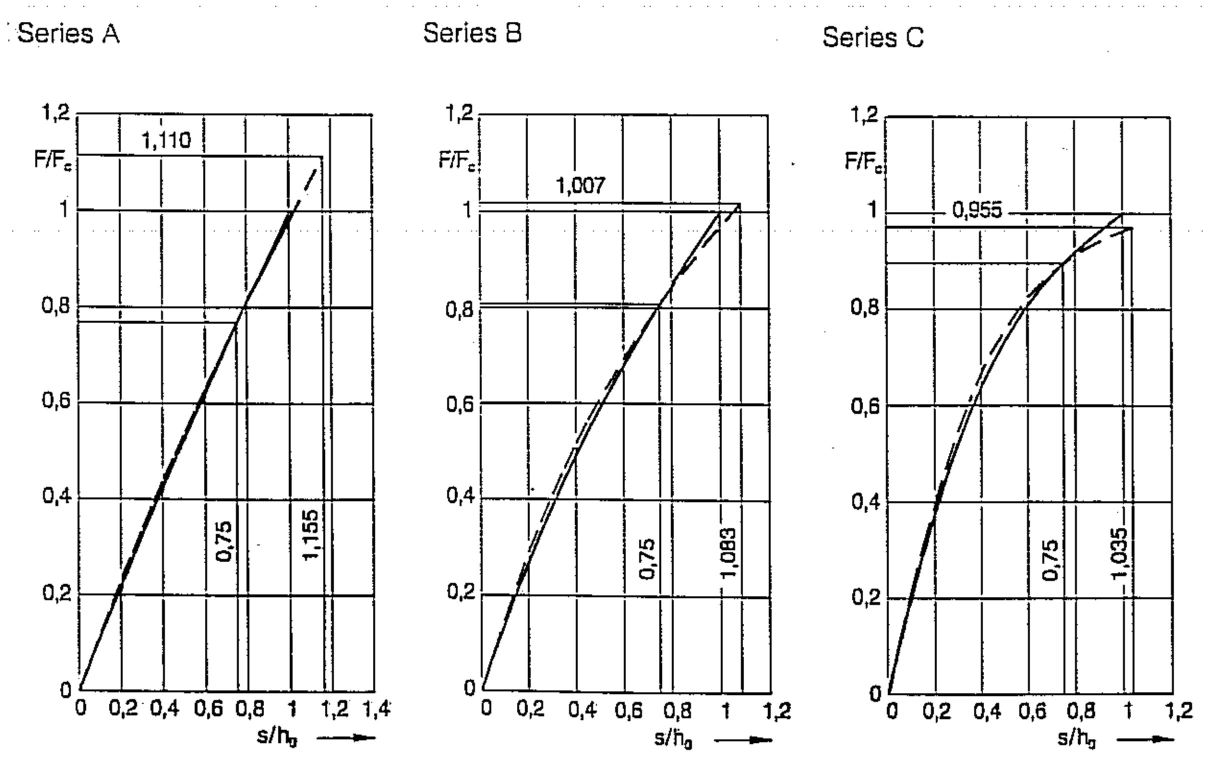
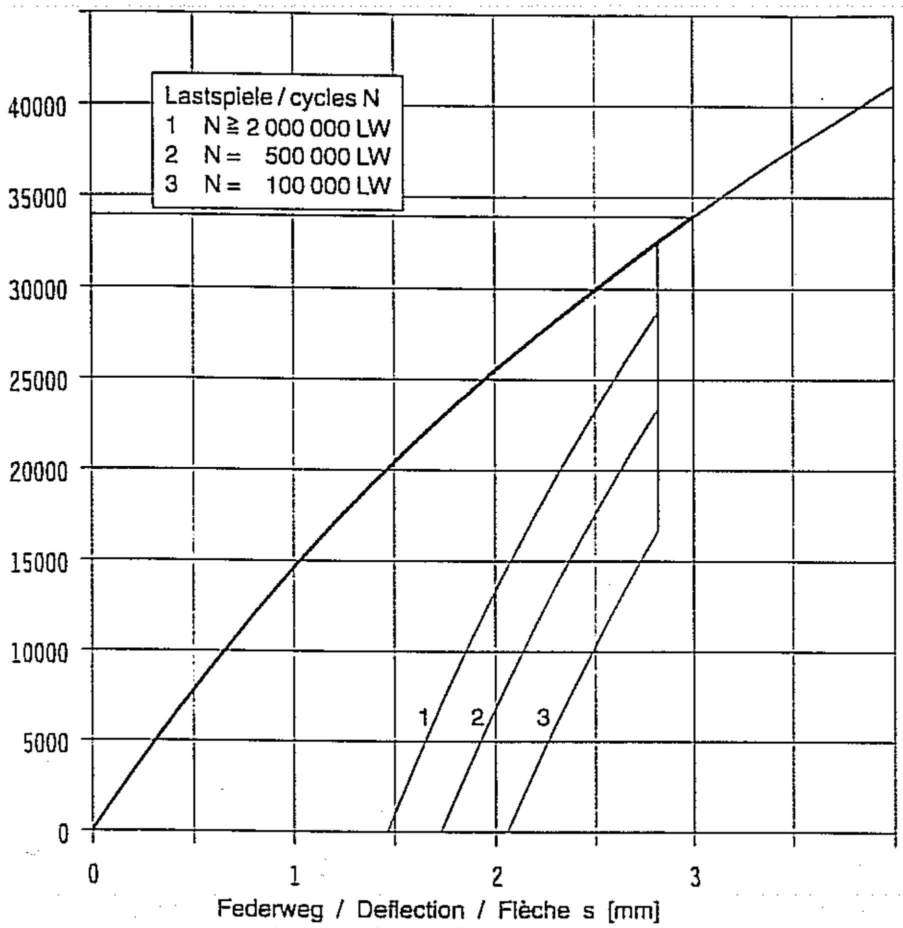


Figure 7:
Calculated characteristics for disc springs with and without contact flats. F_c is valid for springs without contact flats (continuos line).

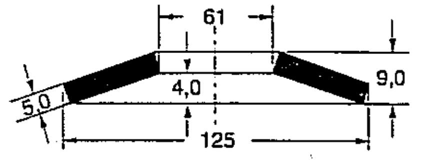
Short Name	W.-Nr.	Standard	Physical and Mechanical Properties										Thickness range	Avail- ability
			Density Kg/dm³	E-modulus in kN/mm² at RT	100 °C	200 °C	300 °C	400 °C	500 °C	600 °C	Working Temperature °C	Tensile Strength N/mm²	mm	
Steel for Normal Applications														
Quality Steel														
C 60	1.0601	DIN 17222	7.85	206	202	-	-	-	-	-	-20...+100	1180-1680	0.2...7.0	easy
C 75	1.0605	DIN 17222	7.85	206	202	-	-	-	-	-	-20...+100	1320-1870	0.2...7.0	easy
Refined Steel														
Ck 67	1.1231	DIN 17222	7.85	206	202	-	-	-	-	-	-20...+100	1230-1770	0.1...2.5	easy
Ck 75	1.1248	DIN 17222	7.85	206	202	-	-	-	-	-	-20...+100	1320-1870	0.1...1.5	easy
Ck 85	1.1269	DIN 17222	7.85	206	202	-	-	-	-	-	-20...+100	1400-1950	0.1...1.5	easy
50 CrV 4	1.8159	DIN 17222	7.85	206	202	196	-	-	-	-	-50...+200	1400-2000	0.3...80	easy
		DIN 17221												
Corrosion Resistant Steel														
X 12 CrNi 17 7	1.4310	DIN 17224	7.90	190	186	180	-	-	-	-	-200...+200	1350-1900	0.2...2.5	easy
X 7 CrNiAl 17 7	1.4568	DIN 17224	7.90	195	190	180	171	-	-	-	-200...+300	950-1500	0.2...4.0	less easy
X 5 CrNiMo 18 10	1.4401	DIN 17224	7.95	185	181	176	-	-	-	-	-200...+200	1100-1800	0.2...1.6	difficult
Heat Resistant Steel														
21 CrMoV 5 7	1.7709	DIN 17240	7.85	206	199	191	182	-	-	-	-50...+350		2.0...8.0	less easy
X 22 CrMoV 12 1	1.4923	DIN 17240	7.7	209	202	194	184	173	162	-	-50...+500	1200-1400	1.5...20	easy
X 35 CrMo 17	1.4122	SEW 400	7.7	209	205	199	192	181	-	-	-50...+400	1200-1400	0.3...6.0	easy
X 30 WCrV 5 3	1.2567		8.2	206	202	196	189	178	-	-	-50...+450	1200-1400	8.0...20	less easy
	1.8242													
Copper Alloys														
CuSn 8	2.1030	DIN 17670	8.8	115	110	-	-	-	-	-	-50...+100	590-690	0.1...6.0	easy
		DIN 17662												
CuBe 2	2.1247	DIN 17670	8.8	135	131	125	-	-	-	-	-260...+200	1270-1450	0.1...2.5	easy
		DIN 17666												
Nickel and Cobalt Alloys														
Nimonic 90	2.4632 (LW)		8.18	220	216	208	202	193	187	178	-200...+700	≥ 1100	bis 6.35	difficult
	2.4969													
Inconel X 750	2.4669		8.28	214	207	198	190	179	170	158	-200...+600	≥ 1170	bis 6.35	difficult
Inconel 718	2.4668		8.19	199	195	190	185	179	174	167	-200...+600	≥ 1240	bis 6.35	difficult
Duratherm 600	-		8.50	220	215	208	202	195	188	-	-200...+550	1150-1550	0.1...3.0	difficult

The values quoted for E-modulus and tensile strength are for reference only.
The range of working temperature and thickness only serve as an indication.
The heat treatment and the hardness of disc springs made from heat resistant steels is deviating from the standards mentioned above.



125 x 61 x 5

Schnorr Werksnorm Gruppe 2



Abmessungen / Dimensions

D_e x D_i x t
125 x 61 x 5,0

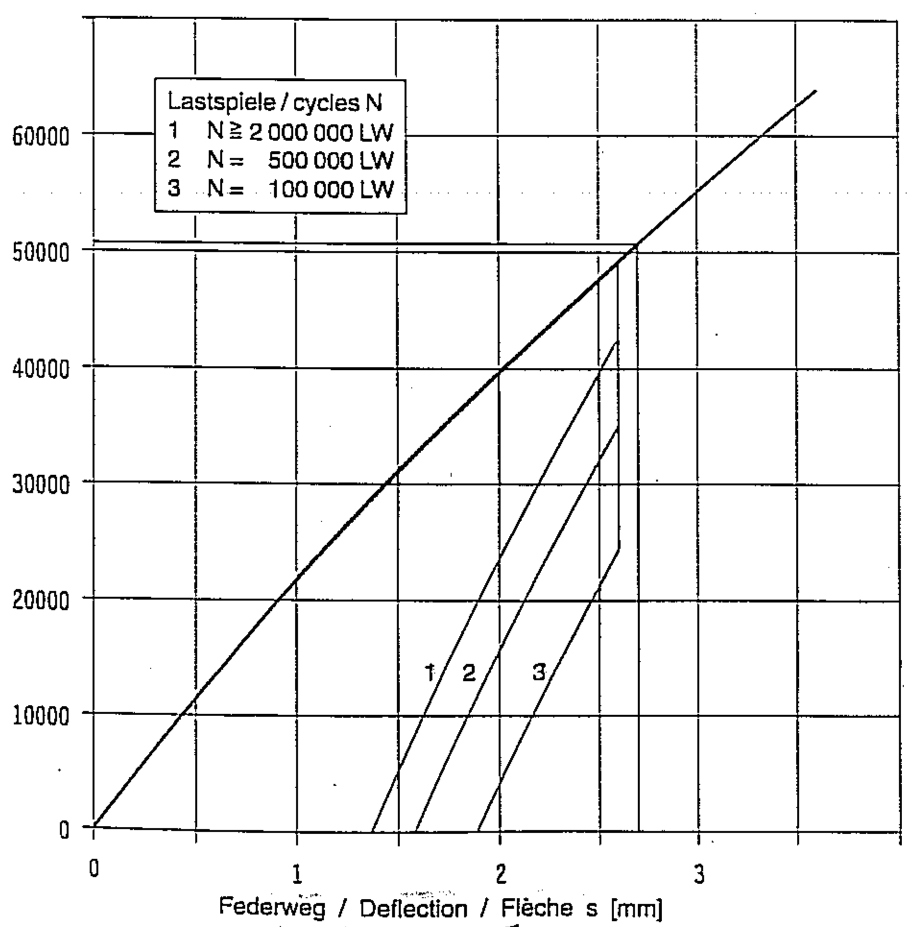
l_0 = 9,0 mm
h_0 = 4,0 mm

Schnorr-Art.Nr. 019 900

TF-Kennwerte / parameters / rapports

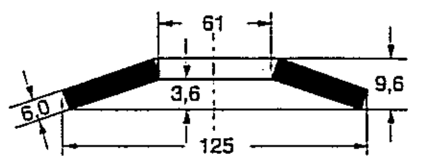
D_e/D_i	2,049
D_e/t	25
h_0/t	0,800

Gewicht / weight / poids / 1000 Stück / pcs 357,6 kg



125 x 61 x 6

Schnorr Werksnorm Gruppe 2



Abmessungen / Dimensions

D_e x D_i x t
125 x 61 x 6,0

l_0 = 9,6 mm
h_0 = 3,6 mm

Schnorr-Art.Nr. 020 050

TF-Kennwerte / parameters / rapports

D_e/D_i	2,049
D_e/t	20,83
h_0/t	0,600

Gewicht / weight / poids / 1000 Stück / pcs 425,4 kg