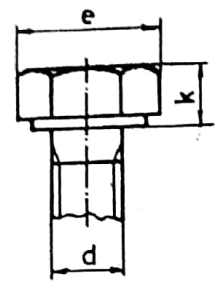
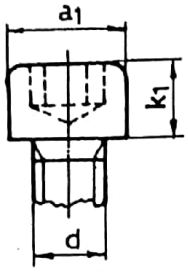
4 Machine Elements

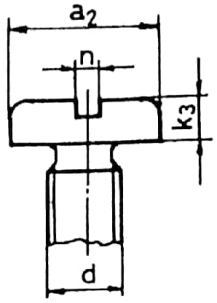
4.1 Screws

4.1,1 Types of Heads, Dimensions

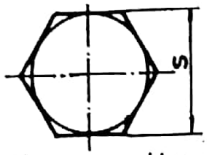
Table 120/1 Head Dimensions



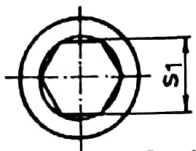




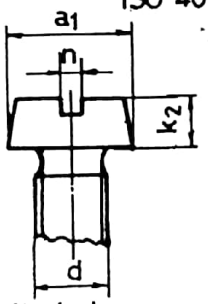
Fillister Head
ISO R 1580



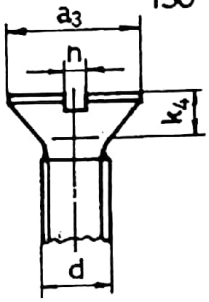
Hexagon Head
ISO 4017



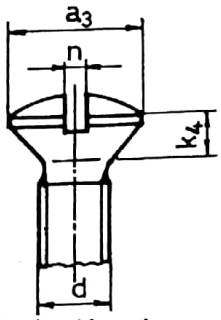
Hexagon Socket Head
ISO 4762



Slotted cheese
(fillister) head
ISO 1207



Flat Head
ISO 2009



Oval Head
ISO 2010

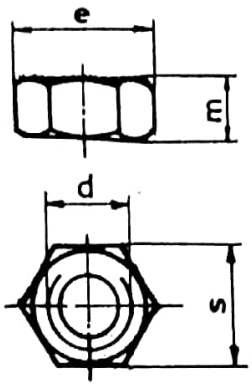
dimensions in mm

Thread diameter d	Hexagon Head s	e	k	Dimensions of the Heads a_1	s_1	k_1	k_2	a_2	k_3	a_3	k_4	f	n.nom
M 1	2,9	2,9	—	2	—	—	0,7	—	—	1.9	0,6	0,25	0.25
M 1,2	3	3,5	—	2,3	—	—	0,8	—	—	2,3	0,7	0,3	0.3
M 1,6	3,2	3,7	1,1	3	1,5	1,6	1	—	—	3	0.96	0,4	0.4
M 2	4	4,6	1,4	3,8	1.5	2	1,3	—	—	3,8	1,2	0,5	0.5
M 2,5	5	5,8	1,7	4,5	2	2,5	1,6	5	1,5	4.7	1,5	0,6	0.6
M 3	5,5	6.0	2	5,5	2,5	3	2	6	1,8	5,6	1,05	0,75	0.8
M 4	7	7.7	2.8	7	3	4	2.6	8	2.4	7.4	2.2	1	1
M 5	8	8,6	3.5	8,5	4	5	3,8	10	3	9,2	2,5	1,25	1.2
M 6	10	10,9	4	10	5	6	3,9	12	3,6	11	3	1.5	1.6
M 8	13	14,2	5,3	13	6	8	5	16	4,8	14,5	4	2	2
M 10	16	17,6	6,4	16	8	10	6	20	6	18	5	2,5	2.5
M 12	18	19,9	7,5	18	10	12	7	—	—	21,5	6	3	3
M 16	24	26,2	10	24	14	16	9	—	—	28,5	8	4	4
M 20	30	33.0	12,5	30	17	20	11	—	—	36	10	5	5
M 24	36	39,6	15	36	19	24	—	—	—	—	—	—	—
M 30	46	50,9	18,7	45	22	30	—	—	—	—	—	—	—
M 36	55	60,8	22,5	54	27	36	—	—	—	—	—	—	—

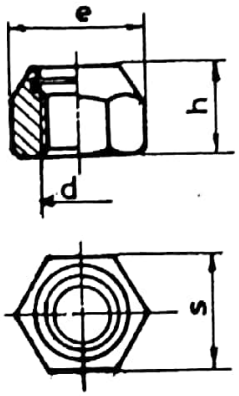
4.2 Nuts, Washers and Spring Washers

4.2.1 Nuts, Washers and Spring Washers, Dimensions

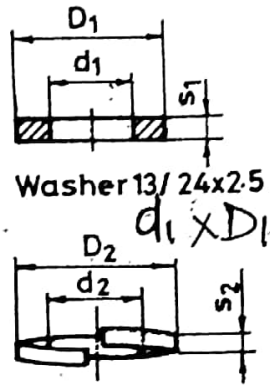
Examples for specification



Hexagon Nut M24
ISO 4032



Stop Nut M12

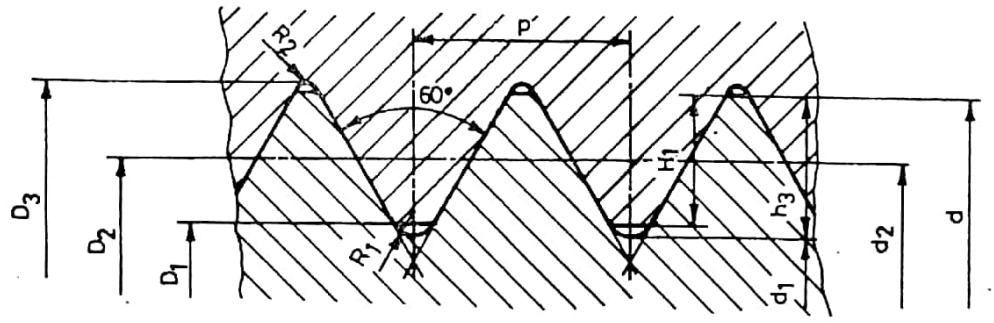


Lock Washer.

Table 122/1 Dimensions in mm

Thread diameter	Hexagon Nut Stop Nut				Washers			Lock Washer		
d	s	e	m	h	d_1	D_1	s_1	d_3	D_2	s_2
M 1	2.5	2.9	0.8	—	1.1	3.2	0.3	—	—	—
M 1.2	3	3.5	1	—	1.3	3.8	0.3	—	—	—
M 1.6	3.2	3.7	1.3	—	1.7	4	0.3	—	—	—
M 2	4	4.6	1.6	—	2.2	5	0.3	2.1	4.4	0.5
M 2.5	5	5.8	2	—	2.7	6.5	0.5	2.6	5.1	0.5
M 3	5.5	6.4	2.4	3.6	3.2	7	0.5	3.1	6.2	0.8
M 4	7	8.1	3.2	4.8	4.3	9	0.8	4.1	7.6	0.9
M 5	8	9.2	4	6	5.3	10	1	5.1	9.2	1.2
M 6	10	11.5	5	6.6	6.4	12.5	1.6	6.1	11.8	1.6
M 8	13	15	6.5	8.8	8.4	17	1.6	8.1	14.8	2
M 10	17	19.6	8	11	10.5	21	2	10.2	18.1	2.2
M 12	19	21.9	10	13.2	13	24	2.5	12.2	21.1	2.5
M 16	24	27.7	13	17.6	17	30	3	16.2	27.4	3.5
M 20	30	34.6	16	22	21	37	3	20.2	33.6	4
M 24	36	41.6	19	26.4	25	44	4	24.5	40	5
M 30	46	53.1	24	30	31	56	4	30.5	48.2	6
M 36	55	63.5	29	36	37	66	5	36.5	58.2	6

Table 102/1: ISO Metric Screw thread, dimensions ISO 724



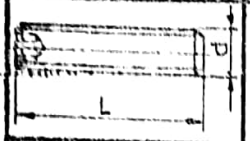
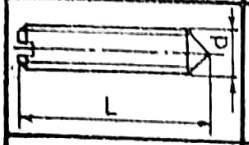
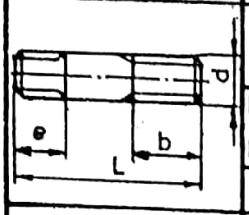
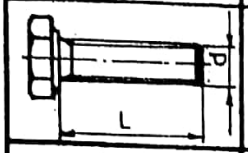
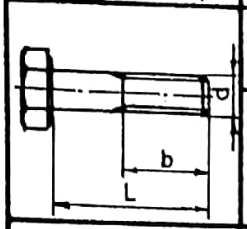
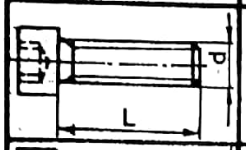
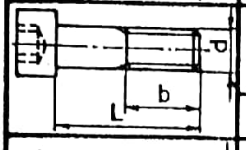
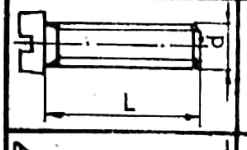
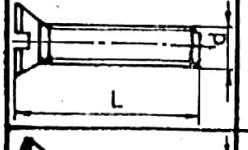
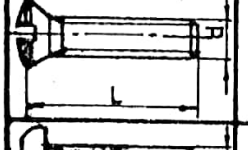
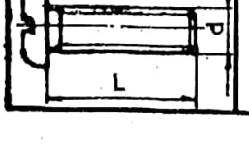
Dimensions in millimetres

Nominal diameter d = D 1st Choice	Nominal diameter d = D 2nd Choice	Pitch p	Pitch diameter $d_2=D_2$	Minor diameter d_1	Minor diameter D_1	Major diameter (min) D_3	Radius R_1	Radius R_2	Tensile Stress area A_s 1)
1		0,25	0,838	0,623	0,729	1,018	0,036	0,018	0,460
1,2		0,25	1,038	0,893	0,929	1,218	0,036	0,018	0,732
	1,4	0,30	1,205	1,032	1,075	1,422	0,043	0,022	0,983
1,6		0,35	1,373	1,171	1,221	1,625	0,051	0,025	1,27
	1,8	0,35	1,573	1,371	1,421	1,825	0,051	0,025	1,70
2		0,40	1,740	1,509	1,567	2,029	0,058	0,029	2,07
	2,2	0,45	1,908	1,648	1,713	2,232	0,065	0,032	2,48
2,5		0,45	2,208	1,948	2,013	2,532	0,065	0,032	3,39
3		0,50	2,675	2,387	2,459	3,036	0,072	0,036	5,03
	3,5	0,60	3,110	2,764	2,850	3,543	0,087	0,043	6,78
4		0,70	3,545	3,141	3,242	4,051	0,101	0,051	8,78
5		0,80	4,480	4,019	4,134	5,058	0,115	0,058	14,20
6		1,0	5,350	4,773	4,917	6,072	0,144	0,072	20,10
8		1,25	7,188	6,466	6,647	8,090	0,180	0,090	36,60
10		1,5	9,026	8,160	8,376	10,108	0,217	0,108	58
12		1,75	10,863	9,853	10,106	12,126	0,253	0,126	84,3
	14	2	12,701	11,546	11,835	14,144	0,289	0,144	115
16		2	14,701	13,546	13,835	16,144	0,289	0,144	157
	18	2,5	16,376	14,933	15,294	18,180	0,361	0,180	192
20		2,5	18,376	16,933	17,294	20,180	0,361	0,180	245
	22	2,5	20,376	18,933	19,294	22,180	0,361	0,180	303
24		3	22,051	20,319	20,752	24,217	0,433	0,217	353
	27	3	25,051	23,319	23,752	27,217	0,433	0,217	459
30		3,5	27,727	25,706	26,211	30,253	0,505	0,253	561
	33	3,5	30,727	28,706	29,211	33,253	0,505	0,253	694

4.1.2 Length of Screws and Threads

Table 121/1

Dimensions in mm

FIGURE	Nominal length length of thread resp	Thread diameter M																
		1	1,2	1,6	2	2,5	3	4	5	6	8	10	12	16	20	24	30	36
	l_{min}	–	–	2	2	2	2	2,5	3	4	5	6	8	10	12	16	–	–
	l_{max}	–	–	8	10	12	16	20	25	30	40	50	60	60	60	60	–	–
	l_{min}	2	2	3	3	4	4	6	6	8	8	10	12	16	20	–	–	–
	l_{max}	10	12	18	20	25	25	25	25	30	40	50	60	60	60	–	–	–
	l_{min}	–	–	–	–	–	–	20	25	25	30	35	40	50	60	70	–	–
	l_{max}	–	–	–	–	–	–	40	50	60	80	100	120	160	200	200	–	–
	b for $l \leq 125$	–	–	–	–	–	–	14	16	18	22	26	30	38	46	54	–	–
	b for $l > 125$	–	–	–	–	–	–	–	–	–	–	–	–	44	52	60	–	–
	e	–	–	–	–	–	–	5	6,5	7,5	10	12	15	20	25	30	–	–
	l_{min}	–	–	3	3	3	3	4	5	6	8	10	12	16	20	25	30	35
	l_{max}	–	–	12	16	25	30	40	50	60	80	100	100	100	100	100	100	100
	l_{min}	–	–	10	12	14	14	16	20	25	30	35	40	45	55	65	80	90
	l_{max}			16	20	25	30	40	50	60	80	100	120	160	200	240	300	300
	b for $l \leq 125$	–	–	9	10	11	12	14	16	18	22	26	30	38	46	54	66	78
	b for $l > 125 \cdots 200$	–	–	–	–	–	–	–	–	24	28	32	36	44	52	60	72	84
	b for $l > 200$	–	–	–	–	–	–	–	–	–	–	–	49	57	65	73	85	97
	l_{min}	–	–	25	3	4	5	6	8	10	12	16	20	25	30	40	45	55
	l_{max}	–	–	16	16	20	20	25	25	30	35	40	45	55	65	80	90	100
	l_{min}	–	–	–	20	25	25	30	30	35	40	45	50	60	70	90	100	110
	l_{max}	–	–	–	20	25	30	40	45	60	80	100	120	160	200	200	200	200
	b	–	–	–	16	17	18	20	22	24	28	32	36	44	52	60	72	84
	l_{min}	1	1,2	1,6	2	2,5	3	4	5	6	8	10	12	16	20	–	–	–
	l_{max}	10	12	16	16	20	20	25	25	30	35	45	50	65	75	–	–	–
	l_{min}	2	2	2,5	3	4	5	6	8	8	10	12	16	25	30	–	–	–
	l_{max}	10	12	16	20	25	30	40	50	60	80	80	80	80	80	–	–	–
	l_{min}	2	2	2,5	3	4	5	6	8	8	10	12	–	–	–	–	–	–
	l_{max}	10	12	16	20	25	30	40	50	50	50	50	–	–	–	–	–	–
	l_{min}	–	–	–	–	2,5	3	4	5	6	8	10	–	–	–	–	–	–
	l_{max}	–	–	–	–	20	20	25	25	30	35	45	–	–	–	–	–	–

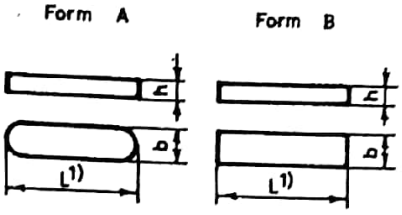
3) For cylindrical heads with washers, [illegible]

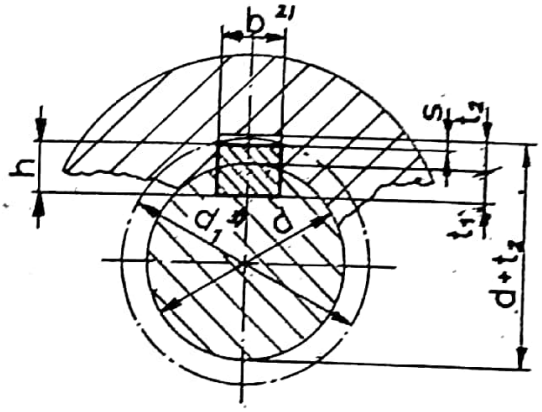
4.8 Keys and Keyways

Parallel Keys Deep Pattern (DIN 6885, ISO 1084)

Material St 50-1K $h \leq 25$ DIN 1652
St 60-2K $h > 25$ DIN 1652

Designation of a parallel key of form A of height h = 12, width b = 20 and length l = 50
- Parallel key A 20 x 12 x 50





ROUNDING OF THE GROOVE CORNERS

SHAFT DIAMETER d		KEY		LENGTH	ALLOWANCE		GROOVE DEPTH					
					s		SHAFT			HUB		
from	to	b tol. h 9	h	L 1) 4)	min	max	t_1	tol	r	t_2	tol	d_1 3)
6	8	2	2	6... 20	0,2	0,42	1,2			1		d + 25
8	10	3	3	6... 32	0,2	0,42	1,8	+0,1 0	0,08...0,16	1,4	+0,1 0	d + 3,5
10	12	4	4	8... 40	0,3	0,53	2,5			1,8		d + 4
12	17	5	5	10... 50	0,3	0,53	3			2,3		d + 5
17	22	6	6	16... 63	0,3	0,53	3,5		0,16...0,25	2,8		d + 6
22	30	8	7	20... 80	0,3	0,79	4			3,3		d + 8
30	38	10	8	25...100	0,3	0,79	5			3,3		d + 8
38	44	12	8	32...125	0,3	0,79	5,5			3,3		d + 8
44	50	14	9	40...160	0,3	0,79	5,5		,25...0,4	3,3		d + 8
50	58	16	10	50...180	0,3	0,79	6			3,8		d + 9
58	65	18	11	50...200	0,4	0,91	7	+0,2 0		4,3	+0,2 0	d + 11
65	75	20	12	63...220	0,4	0,91	7,5		,4...0,6	4,4		d + 11
75	85	22	14	63...250	0,4	0,91	9			4,9		d + 12
85	95	25	14	80...280	0,4	0,91	9			5,4		d + 14
95	110	28	16	80...320	0,4	0,91	10			5,4		d + 14
										6,4		d + 16

1) Nominal lengths : 6, 8, 10, 12, 16, 20, 25, 32, 40, 50, 63, 80, 100, 125, 160, 180, 200, 220, 250, 280, 300

2) Tolerances of groove width in shaft/hub
~~H9/H9 loose key connection, N9/JS9 push key connection,~~
P9/P9 force key connection

3) Smallest bore, which can be added over the shaft with fitted key

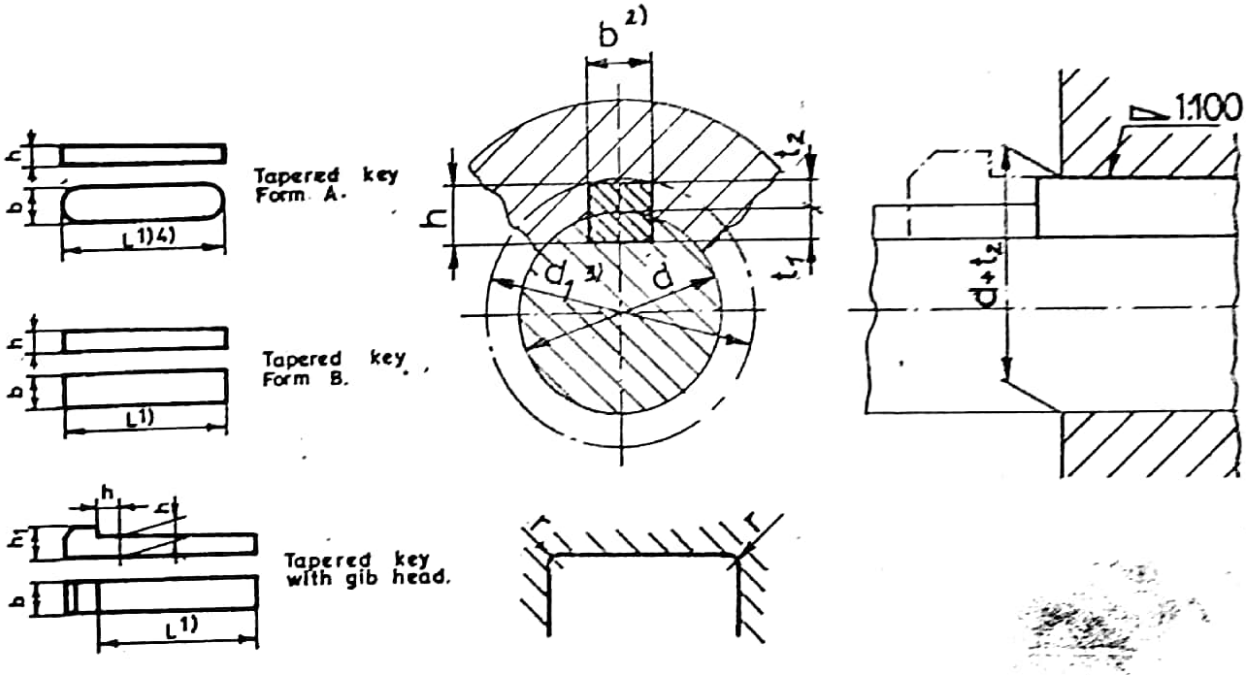
4) Tolerances of the lengths l for Form A

LENGTH L	6...25	32...80	100...320
GROOVE	$^{+0,3}_{+0,1}$	$^{+0,4}_{+0,1}$	$^{+0,7}_{+0,2}$
KEY	$^{0}_{-0,2}$	$^{0}_{-0,3}$	$^{0}_{-0,5}$

Taper Keys With or Without Gib Head (DIN 6886, 6887 ISO 1035)

Material : St 50-1K for h ≤ 25mm
St 60-2K for h > 25mm

Designation of a tapered key of width b = 18mm, height h = 11mm and length l = 100 mm
- Tapered key A 18 x 11 x 100 DIN 6886
- Tapared key with gip head 18 x 11 x 100 DIN 6887



4.9 Retaining and Guardrings, Circlips

4.9.1 Radial Retaining Rings for Shafts DIN 6799

Material Spring steel 470 .... 560 HV 30

Designation of a radial retaining ring for shaft of diameter d_1 = 4 mm

- Radial Retaining Ring for Shaft 4 DIN 6799

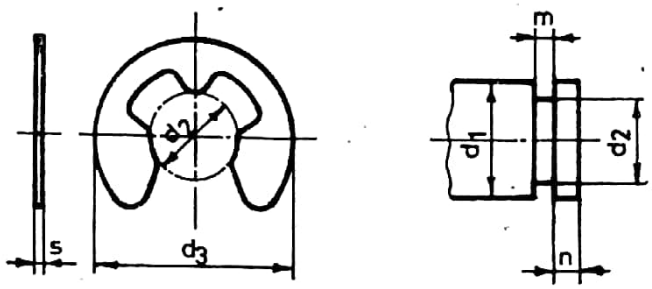


Table 140/1 : Radial Retaining Rings

Shaft diameter d_1		Ring dimension			Groove dimension				Allowable axial load in N	
		d_2	d_3	s	d_2	m 1)		n		
from	to	nominal size			tol. h11		tolerance	min	d_1 min.	d_2 max
1	1,4	0,8	2	0,2	0,8	0,24	$+\frac{0,02}{0}$	0,4	20	30
1,4	2	1,2	3	0,3	1,2	0,34		0,6	40	80
2	2,5	1,5	4	0,4	1,5	0,44		0,8	70	120
2,5	3	1,9	4,5	0,5	1,9	0,54	$+\frac{0,03}{0}$	1	100	200
3	4	2,3	6	0,6	2,3	0,64		1	140	320
4	5	3,2	7	0,6	3,2	0,64		1	200	450
5	7	4	9	0,7	4	0,74		1,2	300	650
6	8	5	11	0,7	5	0,74		1,2	400	750
7	9	6	12	0,7	6	0,74		1,2	500	1000
8	11	7	14	0,9	7	0,94		1,5	600	1200
9	12	8	16	1	8	1,05	$+\frac{0,06}{0}$	1,8	700	1700
10	14	9	18,5	1,1	9	1,15		2	800	2000
11	15	10	20	1,2	10	1,25		2	900	2200
13	18	12	23	1,3	12	1,35		2,5	1000	2400
16	24	15	29	1,5	15	1,55		3	1300	3000

1) For one directional axial load the tolerance of the groove m may be increased.

Table 139/1 : Tapered Keys

SHAFT DIAMETER d		KEY			LENGTH	GROOVE DIMENSION					
		b	h	h_t		SHAFT			HUB		d_1 3)
from	to	tol h9			L 1)4)	t_1	tol	r	t_2	tol.	
10	12	4	4	7	8... 45	2,5	+0,1 0	,08... 0,16	1,2	+0,1 0	d + 4
12	17	5	5	8	10... 56	3			1,7		d + 5
17	22	6	6	10	14... 70	3,5		0,16... 0,25	2,2		d + 6
22	30	8	7	11	18... 90	4	+0,2 0	0,25... 0,40	2,4	+0,2 0	d + 8
30	38	10	8	12	22... 110	5			2,4		d + 8
38	44	12	8	12	28... 140	5			2,4		d + 8
44	50	14	9	14	36... 160	5,5			2,9		d + 9
50	58	16	10	16	45... 180	6			3,4		d + 11
58	65	18	11	18	50... 200	7			3,4		d + 11
65	75	20	12	20	56... 220	7,5		0,60	3,9		d + 12
75	85	22	14	22	63... 250	9			4,4		d + 14
85	95	25	14	22	70... 280	9			4,4		d + 14
95	110	28	16	25	80... 320	10			5,4		d + 16

1) Nominal Key length : 6, 10, 12, 14, 16, 18, 20, 22, 25, 28, 32, 36, 40, 50, 56, 63, 70, 80, 90, 100, 110, 125, 140, 160, 180, 200, 220, 250, 280, 320 mm

2) Tolerances for groove width shaft/hub
D10/D10 (loose key connection)
P9/P9 (forced key connection)

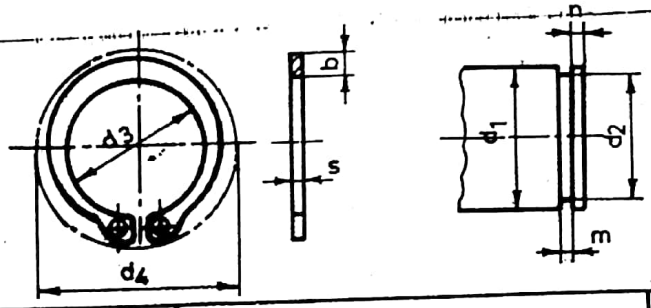
3) Smallest bore, which can be slided over the shaft with fitted key.

4) Tolerance of the length L for Form A (mm)

LENGTH	8... 28	32... 80	90... 320
GROOVE	$^{+0,3}_{+0,1}$	$^{+0,4}_{0,1}$	$^{+0,7}_{+0,2}$
KEY	$^{0}_{-0,2}$	$^{0}_{-0,3}$	$^{0}_{-0,5}$

4.9.2 Circlips for Shafts: Normal Type

Table 141/1: Circlips for Shafts



Norminal dimension		Circlip dimension			Groove dimension				Allowed axial load in N
Shaft diameter d_1	Ring thickness s tol. h11	b ≈	d_3	d_4 stressed	d_2	tolerance	$m^{1)}$ H13	n min	max
12	1	1,8	11	19,6	11,5	h11	1,1	0,75	2300
14		2,1	12,9	22	13,4			0,9	3250
15		2,2	13,8	23,2	14,3			1,1	4000
16			14,7	24,4	15,2			1,2	4900
17		2,3	15,7	25,6	16,2				5200
18	1,2	2,4	16,5	26,8	17		1,3	1,5	6900
20		2,6	18,5	29	19	h12			7700
22		2,8	20,5	31,4	21				8450
25		3	23,2	34,8	23,9			1,7	10600
28	1,5	3,2	25,9	38,4	26,6		1,6	2,1	15000
30		3,5	27,9	41	28,6				16200
32		3,6	29,6	43,4	30,3			2,6	21000
35		3,9	32,2	47,2	33			3	26700
36	1,75	4	33,2	48,2	34		1,85		27600
40		4,4	36,5	53	37,5			3,8	38100
45		4,7	41,5	59,4	42,5				43000
50	2	5,1	45,8	64,8	47		2,15	4,5	57000
55		5,4	50,8	70,4	52				63000
60		5,8	55,8	75,8	57				69000
65	2,5	6,3	60,8	81,6	62		2,65		75000
70		6,6	65,5	87,2	67				80500
75		7	70,5	92,8	72				86000
80		7,4	74,5	98,2	76,5			5,3	107000

1) For one directional loads the tolerance of the groove width m may be increased.