THE UNIVERSITY OF TECHNOLOGY IN LODZ

BASIC MECHANICAL DESIGN

[Standard Extracts And Other Materials]

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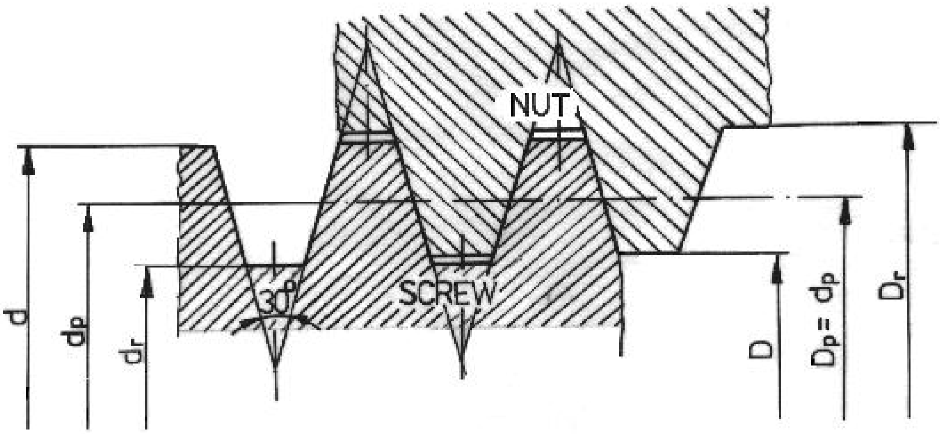
[2008]

[The booklet contains useful materials for Mechanical Engineering Design and Workshop subject for students of International Faculty of Engineering]

CONTENTS

METRIC TRAPEZOIDAL THREADS

PN – ISO 2904: 1996



Thread Size Diameter mm	Pitch mm	Major Dia of Nut, D_r mm	Major Dia of Screw, *d* mm	Pitch Dia of Thread, D_p=d_p mm	Minor Dia of Nut, *D* mm	Minor Dia of Screw, d_r mm
1	2	3	4	5	6	7
8	1.5	8.30	8.00	7.25	6.50	6.20
9	1.5	9.30	9.00	8.25	7.50	7.20
	2	9.50	9.00	8.00	7.00	6.50
10	1.5	10.30	10.00	9.25	8.50	8.20
	2	10.50	10.00	9.00	8.00	7.50
11	2	11.50	11.00	10.00	9.00	8.50
	3	11.50	11.00	9.50	8.00	7.50
12	2	12.50	12.00	11.00	10.00	9.50
	3	12.50	12.00	10.50	9.00	8.50
14	2	14.50	14.00	13.00	12.00	11.50
	3	14.50	14.00	12.50	11.00	10.50
16	2	16.50	16.00	15.00	14.00	13.50
	4	16.50	16.00	14.00	12.00	11.50
18	2	18.50	18.00	17.00	16.00	15.50
	4	18.50	18.00	16.00	14.00	13.50
20	2	20.50	20.00	19.00	18.00	17.50
	4	20.50	20.00	18.00	16.00	15.50
	3	22.50	22.00	20.50	19.00	18.50
22	5	22.50	22.00	19.50	17.00	16.50
	8	23.00	22.00	18.00	14.00	13.00
	3	24.50	24.00	22.50	21.00	20.50
24	5	24.50	24.00	21.50	19.00	18.50
	8	25.00	24.00	20.00	16.00	15.00
	3	26.50	26.00	24.50	23.00	22.50
26	5	26.50	26.00	23.50	21.00	20.50
	8	27.00	26.00	22.00	18.00	17.00
	3	28.50	28.00	26.50	25.00	24.50
28	5	28.50	28.00	25.50	23.00	22.50
	8	29.00	28.00	24.00	20.00	19.00
	3	30.50	30.00	28.50	27.00	26.50
30	6	31.00	30.00	27.00	24.00	23.00
	10	31.00	30.00	25.00	20.00	19.00
	3	32.50	32.00	30,50	29.00	28.50
32	6	33.00	32.00	29.00	26.00	25.00
	10	33.00	32.00	27.00	22.00	21.00

METRIC TRAPEZOIDAL THREADS cont.
PN – ISO 2904: 1996

Thread Size Diameter mm	Pitch mm	Major Dia of Nut, D_r mm	Major Dia of Screw, d mm	Pitch Dia of Thread, D_p=d_p mm	Minor Dia of Nut, D mm	Minor Dia of Screw, d_r mm
1	**2**	**3**	**4**	**5**	**6**	**7**
34	3	34.50	34.00	32.50	31.00	30.50
	6	35.00	34.00	31.00	28.00	27.00
	10	35.00	34.00	29.00	24.00	23.00
36	3	36.50	36.00	34.50	33.00	32.50
	6	37.00	36.00	33.00	30.00	29.00
	10	37.00	36.00	31.00	26.00	25.00
38	3	38.50	38.00	36.50	35.00	34.50
	7	39.00	38.00	34.50	31.00	30.00
	10	39.00	38.00	33.00	28.00	27.00
40	3	40.50	40.00	38.50	37.00	36.50
	7	41.00	40.00	36.50	33.00	32.00
	10	41.00	40.00	35.00	30.00	29.00
42	3	42.50	42.00	40.50	39.00	38.50
	7	43.00	42.00	38.50	35.00	34.00
	10	43.00	42.00	37.00	32.00	31.00
44	3	44.50	44.00	42.50	41.00	40.50
	7	45.00	44.00	40.50	37.00	36.00
	12	45.00	44.00	38.00	32.00	31.00
46	3	46.50	46.00	44.50	43.00	42.50
	8	47.00	46.00	42.00	38.00	37.00
	12	47.00	46.00	40.00	34.00	33.00
48	3	48.50	48.00	46.50	45.00	44.50
	8	49.00	48.00	44.00	40.00	39.00
	12	49.00	48.00	42.00	36.00	35.00
50	3	52.50	50.00	48.50	47.00	46.50
	8	51.00	50.00	46.00	42.00	41.00
	12	51.00	50.00	44.00	38.00	37.00
52	3	52.50	52.00	50.50	49.00	48.50
	8	53.00	52.00	48.00	44.00	43.00
	12	53.00	52.00	46.00	40.00	39.00
55	3	55.50	55.00	53.50	52.00	51.50
	9	56.00	55.00	50.50	46.00	45.00
	14	57.00	55.00	48.00	41.00	39.00
60	3	60.50	60.00	58.50	57.00	56.50
	9	61.00	60.00	55.50	51.00	50.00
	14	62.00	60.00	53.00	46.00	44.00

RECOMMENDED TOLERANCE FOR TRAPEZOIDAL THREAD

(in accordance with PN-ISO 2903/Ak)

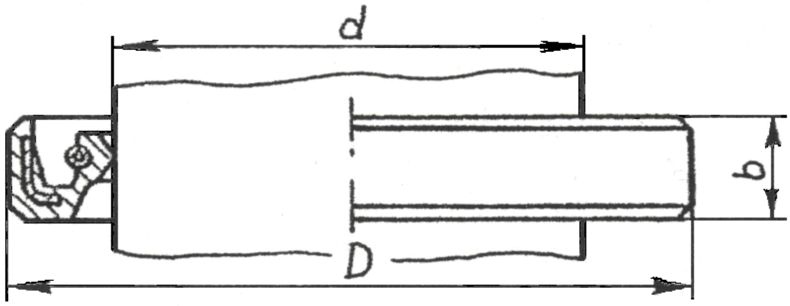
Class of thread	Internal thread		External thread		
	Length of engagement				
	N	L	N		L
	Fields of thread tolerance				
Fine	6H	7H	6e	6g	7e
Middle	7H	8H	7e	7g	8e
Coarse	8H	9H	8c	8e	9c

<u>Note:</u> Preferred fits are in the bolded frames.

N – normal (like for nut)

L – large.

LIP SEALS
PN-72/M-86964

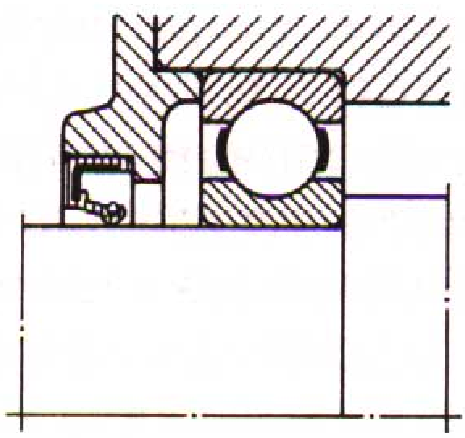


Designation of a radial oil seal that is A kind and possesses: inside diameter (diameter of the shaft) d = 30 mm, outside diameter D = 50 mm, height b = 10 mm:

LIP SEAL A 30x50x10 PN-72/M-86964

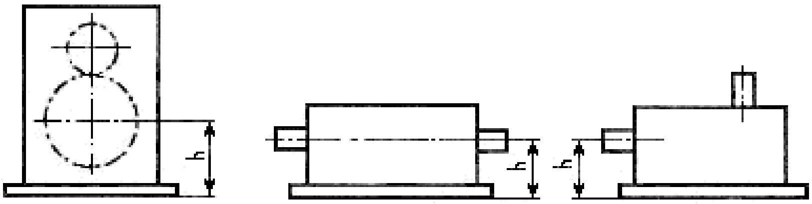
D	35	40	(47)	50	(52)	55	(62)	65	70	72	75	80	85	90	100	110	120
d	**b**																
20	7	10															
25	7	7	10	10	10												
30		7	10	10	10	10											
35			7	7	10	10	10										
40					7	7	10	10		10							
45							10	10		10		10					
50								8	10	10	10	10					
55									8		10	10	10	10			
60											8		10	10			
70														10	10	12	
80															10	10	
90																12	12
100																	12

If the main purpose of the seal is to prevent lubricant from leaving the housing, the seal should be fitted with the lip facing inwards (see figure below).



SHAFT LIFTS OF GEAR REDUCERS

PN-79/M-88507



1st Choice [mm]	2nd Choice [mm]	Deviation [mm]
63		0.5
	71	
80		
	90	
100		
	112	
125		
	140	
160		
	180	
200		
	220	
250		
	280	
315		-1.0
	355	

Note: 3rd choice is omitted

RECOMMENDED DIAMETERS FOR JOURNALS OF SHAFT ENDS IN GEAR REDUCERS

PN-M-85000: 1998

Table 1. Diameters and max torques for journals of high speed shaft ends

d [mm]	T_{in} [Nm]	d [mm]	T_{in} [Nm]	d [mm]	T_{in} [Nm]	d [mm]	T_{in} [Nm]
10	8.0	30	200	60	1600	125	16000
12	16.0	32	350	65	2240	130	18000
14	22.4	35	355	70	2800	140	22400
16	31.5	38	400	75	3150	150	25000
18	45.0	40	500	80	4000	160	31500
20	63.0	42	560	85	4500	180	45000
22	90.0	45	710	90	5600	200	63000
25	125.0	50	1000	100	8000		
28	180.0	55	1400	110	11200		

<u>Note:</u> Max transverse force loading the journal in its middle should not exceed

$$250 \cdot \sqrt{T_{in}} \quad \text{[N]}$$

Table 2. Diameters and max torques for journals of slow speed shaft ends

d [mm]	T_{out} [Nm]	d [mm]	T_{out} [Nm]	d [mm]	T_{out} [Nm]	d [mm]	T_{out} [Nm]
18	31.5	35	2350	70	2000	140	15000
20	45	40	355	75	2240	160	22400
22	63	45	500	80	2800	180	31500
25	90	48	560	90	4000	200	45000
28	125	50	710	100	5600	220	63000
30	140	55	1000	110	8000	250	90000
32	180	60	1120	125	11200	280	125000

<u>Note:</u> Max transverse force loading the journal in its middle should not exceed:

1. $125 \cdot \sqrt{T_{in}}$ **[N] for one-stage gear reducers, and**
2. $250 \cdot \sqrt{T_{in}}$ **[N] for multi-stages gear reducers.**

RECOMMENDED GEAR RATIOS

PN – 76/ M-88513

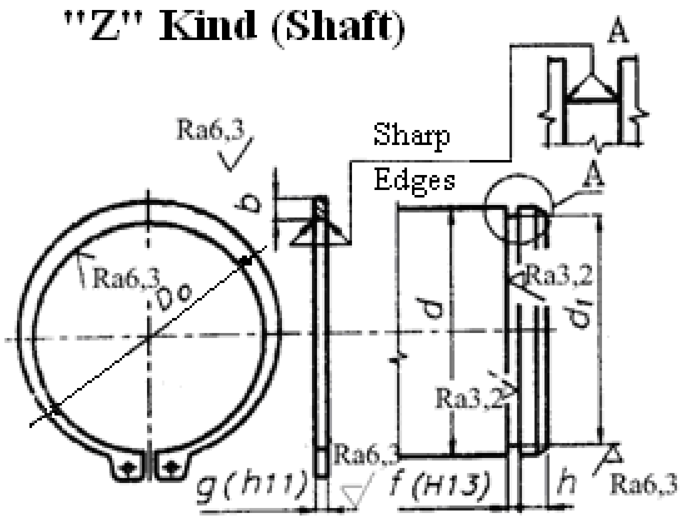
1st choice	2nd choice	1st choice	2nd choice	1st choice	2nd choice
1	—	2.5	—	6.3	—
—	1.12	—	2.8	—	7.1
1.25	—	3.15	—	8	—
—	1.4	—	3.55	—	9
1.6	—	4	—	10	—
—	1.8	—	4.5	—	11.2
2	—	5	—	12.5	—
—	2.24	—	5.6	—	14

SURFACE QUALITY ACCORDING PN – EN ISO 1302: 2004

Class	Roughness [μ]			Procedure
	Ra	Rz	Rt	
N1	0.025	0.3	0.6	
N2	0.05	0.6	1	
N3	0.1	1.1	1	Lapped/Polished
N4	0.2	1.8	1.6	Lapped/Polished
N5	0.4	2.8	2.5	Honed
N6	0.8	4.8	2.5	Ground
N7	1.6	8	4	Turned with diamond
N8	3.2	16	4	Milled
N9	6.3	32	8	Turned
N10	12.5	57	16	
N11	25.0	110	16	Sawed
N12	50.0	220	25	

RETAINING RINGS

PN-81/M-85111

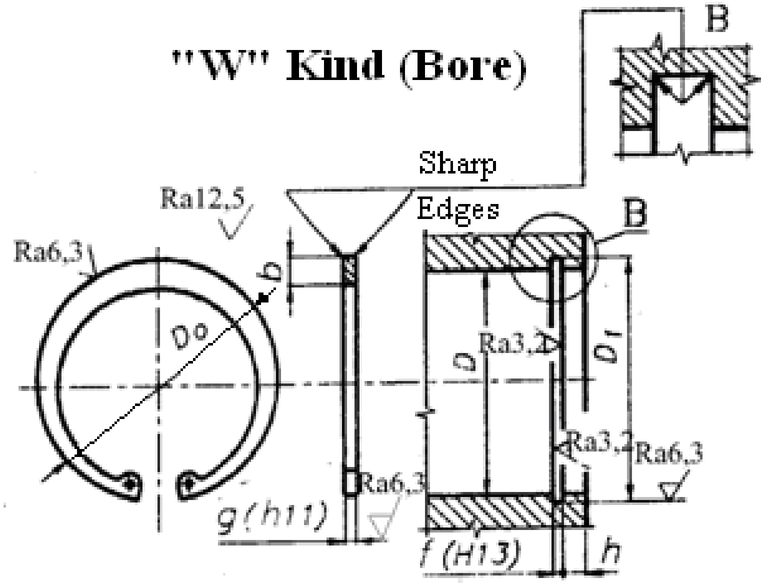


<table>
<tr><th>d</th><th>D_0</th><th>D_1</th><th>b</th><th>g</th><th>f</th><th>h</th><th>S[kN]</th></tr>
<tr><td>**17**</td><td>15.7</td><td>16.2</td><td>2.3</td><td>1.0</td><td>1.1</td><td>1.2</td><td>5.1</td></tr>
<tr><td>**18**</td><td>16.5</td><td>17.0</td><td>2.4</td><td rowspan="7">1.2</td><td rowspan="7">1.3</td><td rowspan="3">1.5</td><td>6.7</td></tr>
<tr><td>**20**</td><td>18.5</td><td>19.0</td><td>2.6</td><td>7.5</td></tr>
<tr><td>**22**</td><td>20.5</td><td>21.0</td><td>2.8</td><td>8.3</td></tr>
<tr><td>**24**</td><td>22.2</td><td>22.9</td><td>3.0</td><td rowspan="3">1.7</td><td>9.9</td></tr>
<tr><td>**25**</td><td>22.2+0.21</td><td>23.9</td><td>3.0</td><td>10.5</td></tr>
<tr><td>**26**</td><td>24.2-0.42</td><td>24.9</td><td>3.1</td><td>10.8</td></tr>
<tr><td>**28**</td><td>25.9</td><td>26.6</td><td>3.2</td><td rowspan="4">1.5</td><td rowspan="4">1.6</td><td rowspan="2">2.1</td><td>14.7</td></tr>
<tr><td>**30**</td><td>27.9</td><td>28.6</td><td>3.5</td><td>15.9</td></tr>
<tr><td>**32**</td><td>29.6</td><td>30.3</td><td>3.6</td><td>2.6</td><td>20.6</td></tr>
<tr><td>**35**</td><td>32.2+0.25</td><td>33.0</td><td>3.9</td><td rowspan="3">3.0</td><td>26.2</td></tr>
<tr><td>**36**</td><td>33.2+0.50</td><td>34.0</td><td>4.0</td><td rowspan="6">1.75</td><td rowspan="6">1.85</td><td>27.1</td></tr>
<tr><td>**38**</td><td>35.2</td><td>36.0</td><td>4.2</td><td>28.5</td></tr>
<tr><td>**40**</td><td>36.5</td><td>37.5</td><td>4.4</td><td rowspan="4">3.8</td><td>37.3</td></tr>
<tr><td>**42**</td><td>38.5+0.39</td><td>39.5</td><td>4.5</td><td>39.2</td></tr>
<tr><td>**45**</td><td>41.5-0.78</td><td>42.5</td><td>4.7</td><td>42.1</td></tr>
<tr><td>**48**</td><td>44.5</td><td>45.5</td><td>5.0</td><td>45.1</td></tr>
<tr><td>**50**</td><td>45.8</td><td>47</td><td>5.1</td><td rowspan="5">2.0</td><td rowspan="5">2.15</td><td rowspan="9">4.5</td><td>55.9</td></tr>
<tr><td>**55**</td><td>50.8</td><td>52</td><td>5.4</td><td>61.7</td></tr>
<tr><td>**56**</td><td>51.8</td><td>53</td><td>5.5</td><td>62.7</td></tr>
<tr><td>**60**</td><td>55.8+0.46</td><td>57</td><td>5.8</td><td>67.6</td></tr>
<tr><td>**63**</td><td>58.8-0.92</td><td>60</td><td>6.2</td><td>68.8</td></tr>
<tr><td>**65**</td><td>60.8</td><td>62</td><td>6.3</td><td rowspan="4">2.5</td><td rowspan="4">2.65</td><td>73.5</td></tr>
<tr><td>**70**</td><td>65.5</td><td>67</td><td>6.6</td><td>78.9</td></tr>
<tr><td>**72**</td><td>67.5</td><td>69</td><td>6.8</td><td>81.3</td></tr>
<tr><td>**75**</td><td>70.5</td><td>72</td><td>7.0</td><td>84.3</td></tr>
</table>

S = Max axial force loading the retaining ring

RETAINING RINGS Cont.

PN-81/M-85111

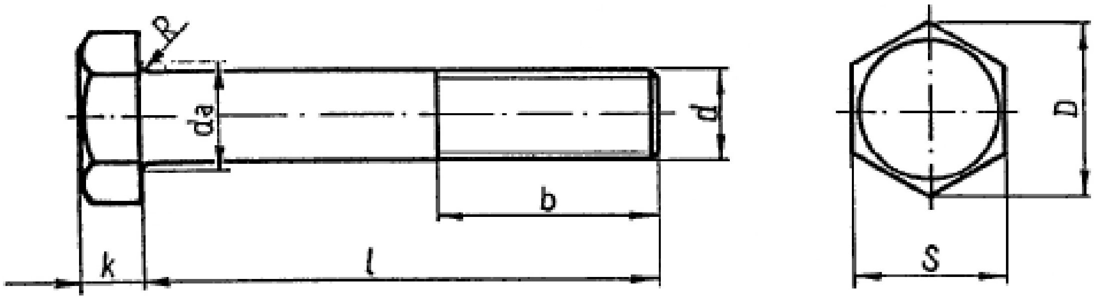


d	D_0	D_1	b	g	F	h	S[kN]
37	39.8+0.50	39.0	3.6				26.6
38	40.8-0.25	40.0	3.7	1.5	1.6	3.0	27.6
40	43.5+0.78	42.5	3.9				39.7
42	45.5-0.39	44.5	4.1				41.7
45	48.5	47.5	4.3	1.75	1.85	3.8	42.2
47	50.5	49.5	4.4				42.7
48	51.5	50.5	4.5				42.9
50	54.2	53	4.6				59.5
55	59.2	58	5.0				62.2
56	60.2+0.92	59	5.1				59.5
60	64.2-0.46	63	5.4	2.0	2.15		60.9
62	66.2	65	5.5				60.5
63	67.2	66	5.6			4.5	60.4
65	69.2	68	5.8				76.6
70	74.5	73	6.2				82.5
75	79.5	78	6.6	2.5	2.65		88.2
80	85.5	83.5	7.0				109.8
85	90.5	88.5	7.2				116.6
88	93.5+1.08	91.5	7.4			5.3	120.5
90	95.5-0.54	93.5	7.6	3.0	3.15		123.5
100	105.5	104	8.4				137.2
105	112	109	8.7				164.6
110	117	114	9.0				172.5
120	127	124	9.7	4.0	4.15	6.0	188.2
130	137+1.26	134	10.2				102.9
140	147-0.63	144	10.7				118.5

S = Max axial force loading the retaining ring

HEXAGON HEADED BOLTS

PN-EN ISO 4014: 2004

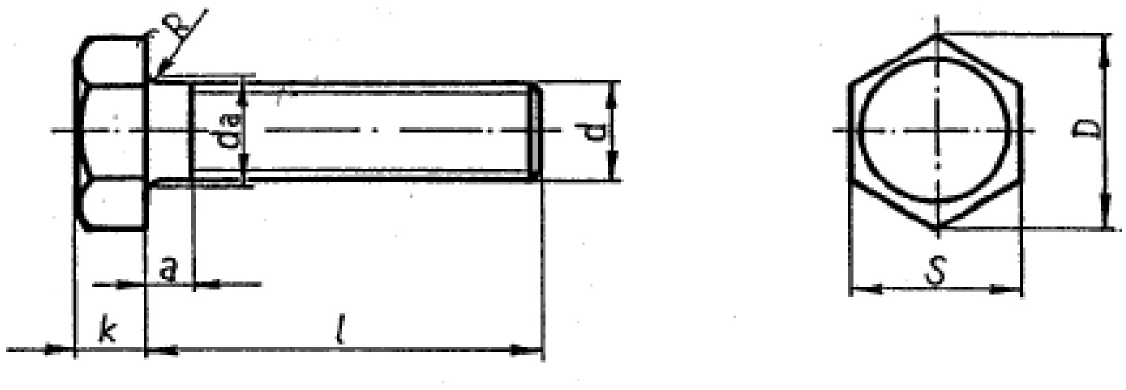


d	M6	M8	M10	M12	M16	M20
S	10	13	16	18	24	30
k	4,0	5,3	6,4	7,5	10	12,5
D min	10,89	14,2	17,59	19,85	26,17	32,95
da max	6,8	9,2	11,2	13,7	17,7	22,4
R min	0,25	0,4	0,4	0,6	0,6	0,8
b, l ≤ 125	18	22	26	30	38	46
b, 125<l<200	–	28	32	36	44	52
l	mass of 1000 bolts, kg					
25	7,04					
30	8,05	15,3				
35	9,1	17,8	29,0			
40	10,2	20,3	32,0			
45	11,2	22,3	35,1	50,1		
50	12,3	24,3	38,2	54,6	105,0	
55	13,3	26,3	41,3	59,1	113,0	
60	14,4	28,3	44,4	63,6	121,0	201,0
70		32,3	50,6	72,6	137,0	
80		36,3	56,8	81,6		249,0
90				90,6	169,0	
100			69,2	99,6	185,0	292,0
120			81,6	117,0	217,0	345,0
130					233,0	

This is only part of the tabulation in the Standard.

HEXAGON HEADED BOLTS

PN-EN ISO 4017: 2004

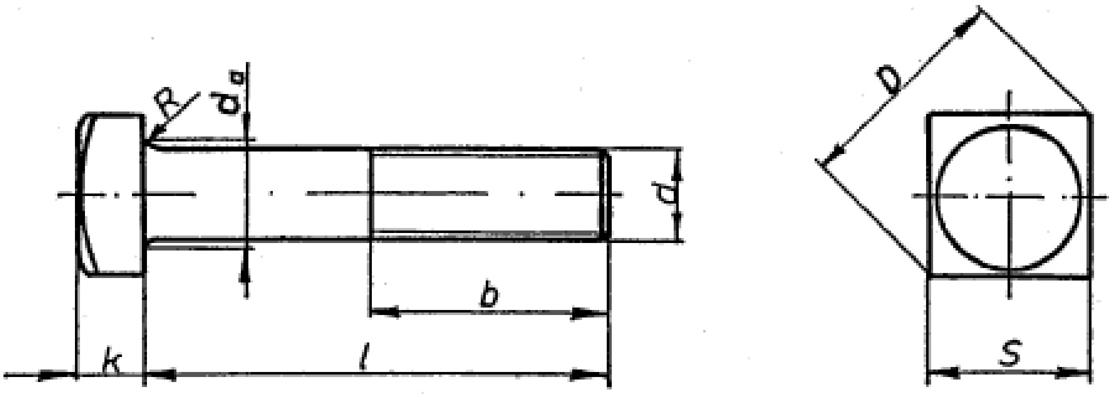


d	M4	M5	M6	M8	M10	M12	M16
S	7	8	10	13	16	18	24
k	2,8	3,5	4	5,3	6,4	7,5	10
a max	2,1	2,4	3	4	4,5	5,3	6
Dmin	7,5	8,63	10,89	14,2	17,59	19,85	26,17
da max	4,7	5,7	6,8	9,2	11,2	13,7	17,7
Rmin	0,2	0,2	0,25	0,4	0,4	0,6	0,6
l	**mass of 1000 bolts, kg**						
10	1,69	2,65	4,12				
12	1,85	2,89	4,46				
16	2,17	3,37	5,14	10,6	18,4		
20		3,85	5,82	11,8	20,4		
25			6,67	13,4	22,9	33,0	
30			7,52	15,0	25,4	36,5	74,9
35				16,6	27,9	40,1	81,4
40				18,2	30,4	43,7	87,9
45						47,3	94,4
50						50,9	102,0

This is only part of the tabulation in the Standard.

SQUARE-HEAD MACHINE BOLTS

PN-86/K-80005

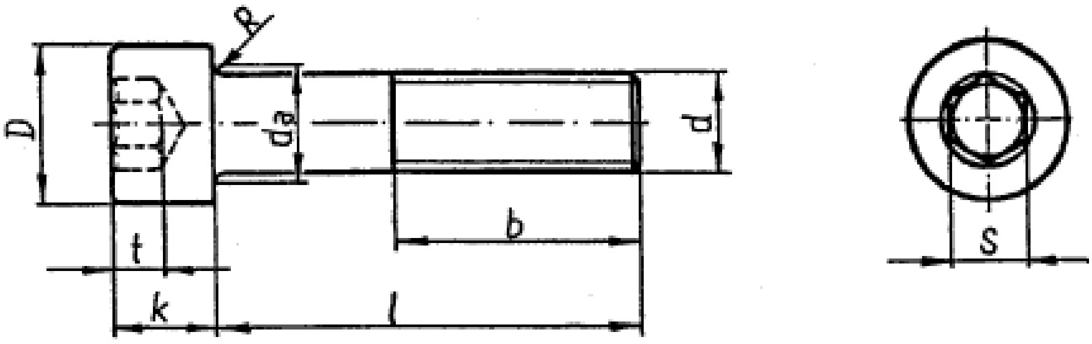


d		M10	M12	M16	M20
s		16	18	24	30
k		7	8	10	13
D_{min}		20,2	22,8	30,1	37,9
$d_{a\,max}$		11,2	13,7	17,7	22,4
R_{min}		0,4	0,6	0,6	0,8
b	$l \leq 125$	26	30	38	46
	$125 < l \leq 200$	32	36	44	52
	$l > 200$	–	49	57	65
l		mass of 1000 bolts, kg			
40		34,7			
50			58,3	111	
60		47,0	67,2	127	
70				142	
80		59,3		158	
90			93,8	174	
100				190	
120			120	221	
140		95,6			
160				283	459
200		132		346	
220			206	374	602
240			223		

This is only part of the tabulation in the Standard.

SOCKET HEAD BOLTS

PN-EN ISO 4762: 2001

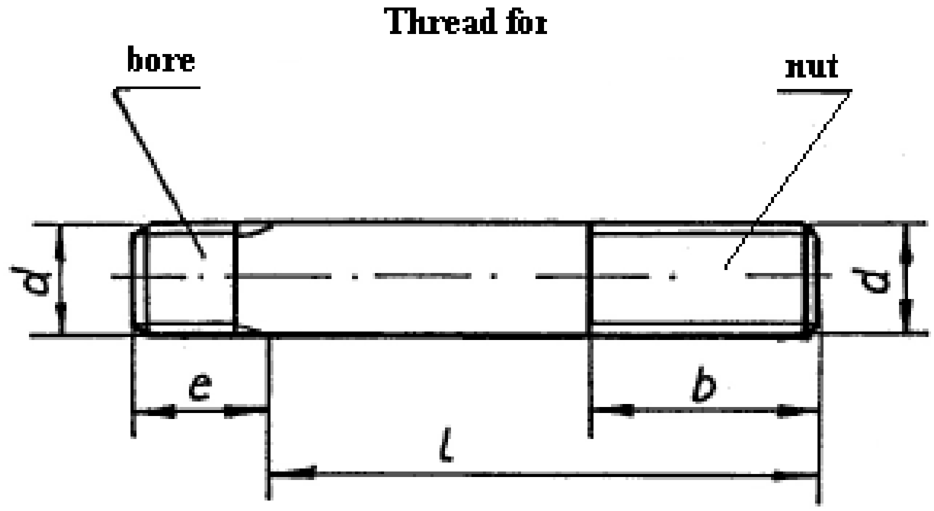


d	M6	M8	M10	M12	M16
D	10	13	16	18	24
S	5	6	8	10	14
k_{max}	6	8	10	12	16
t	3	4	5	6	8
d_a	6,8	9,2	11,2	14,2	18,2
R_{min}	0,25	0,4	0,4	0,6	0,6
b	24	28	32	38	44
l	mass of 1000 bolts, kg				
10	4,70				
12	5,07	10,9			
16	5,81	12,1	20,9		
20	6,55	13,3	22,9	32,1	
25	7,59	15,0	25,4	35,6	
30	8,70	16,8	27,9	39,1	
35	9,81	18,6	31,0	42,9	
40	10,9	20,4	34,1	47,3	
45	12,0	22,2	37,2	51,7	
50	13,1	24,0	40,3	56,1	106
60	15,3	27,6	46,5	64,9	122
70		31,2	52,7	73,7	138

This is only part of the tabulation in the Standard.

STUD BOLTS

PN-ISO 888: 1996

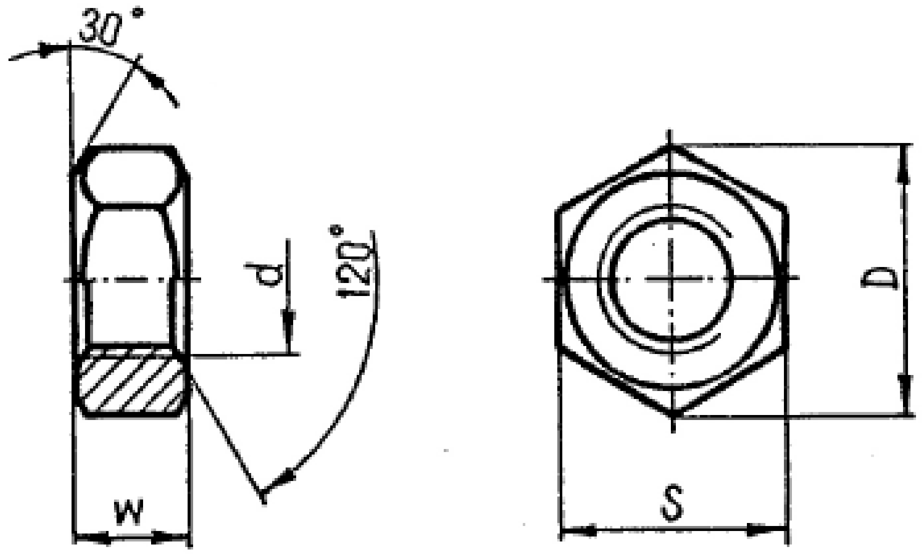


d		M8	M10	M12	M16	M20
e		10	12	15	20	25
b	l ≤ 120	22	26	30	38	46
	120< l ≤ 200		32	36	44	52
l		mass of 1000 bolts, kg				
25		10,8	17,7			
30		12,8	20,8	31,4		
35		14,8		35,8		
40		16,8	27	40,2	78	
45			30,1		86	
50		20,8	33,2	49	94	
55		22,8	36,3		102	
60		24,8	39,4	57,8	110	
70			45,6	66,4	126	
80			51,8	75	142	229
90				83,8	158	253
100					174	277

This is only part of the tabulation in the Standard.

STANDARD HEX NUTS

PN-EN ISO 4032: 2004

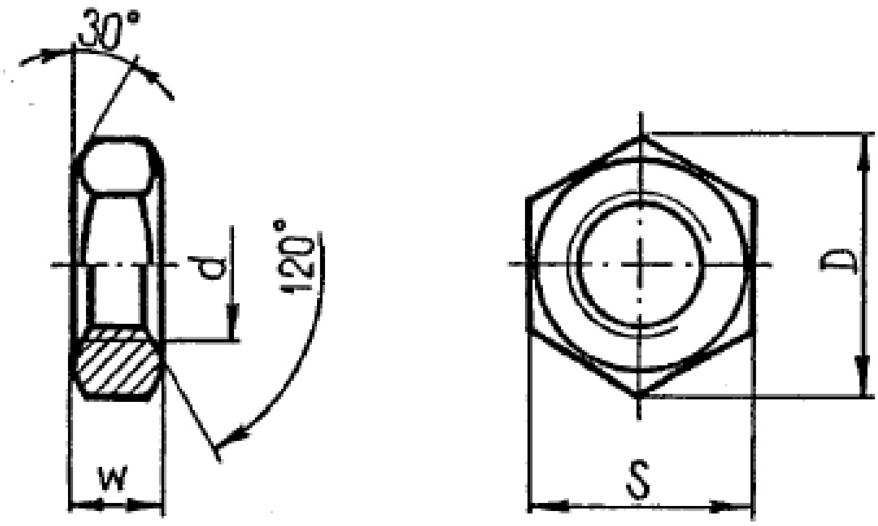


d	S	w	D	Mass of 1000 nuts, kg
mm				
M3	5,5	2,4	5,87	0,361
M4	7	3,2	7,5	0,762
M5	8	4,7	8,63	1,36
M6	10	5,2	10,89	2,46
M8	13	6,8	14,2	5,31
M10	16	8,4	17,59	9,84
M12	18	10,8	19,85	15,0
M16	24	14,8	26,17	36,2
M20	30	18	32,95	69,1
M24	36	21,5	39,55	117
M30	46	25,6	50,85	234

This is only part of the tabulation in the Standard.

HEX JAM NUTS

PN-EN ISO 4035: 2004

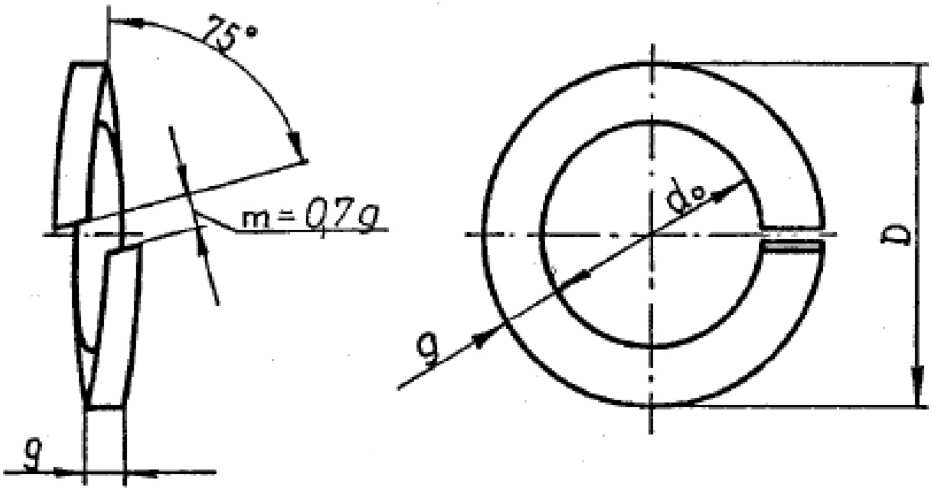


d		S	w	D	Mass of 1000 nuts, kg
Coarse Thread	Fine Thread				
mm					
M8		13	4	14,38	3,12
M10	M10 × 1,25	16	5	17,77	5,86
M12	M12 × 1,25	18	6	20,03	8,37
M16	M16 × 1,5	24	8	26,74	19,6
M20	M20 × 1,5	30	10	33,52	38,4
M24		36	12	39,97	65,7
M30		46	15	51,27	138

This is only part of the tabulation in the Standard.

SPRING LOCK WASHERS

PN-77/M- 82008

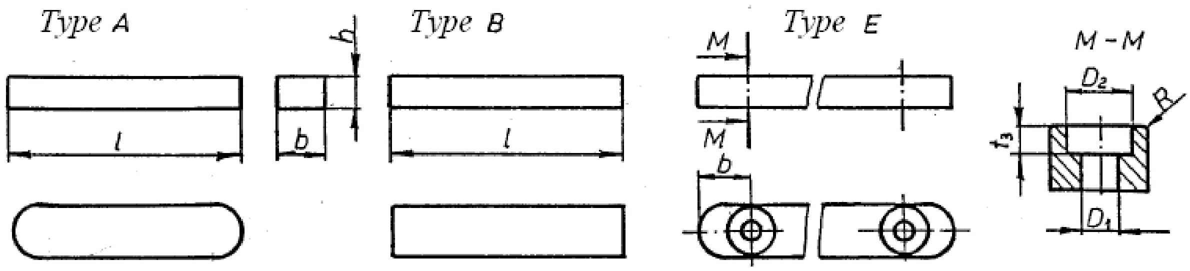


d₀	g	D max	Mass of 1000 pieces, kg	Use with bolts, nuts screws
mm				
3,1	0,8	5,38	0,062	M3
4,1	1,0	6,88	0,130	M4
5,1	1,2	8,28	0,220	M5
6,1	1,4	9,78	0,370	M6
8,2	2,0	13,08	1,00	M8
10,2	2,5	16,20	1,94	M10
12,2	3,0	19,20	3,33	M12
16,3	3,5	24,40	5,94	M16
20,5	4,5	30,74	12,5	M20
24,5	5,5	36,74	22,2	M24
30,5	6,5	45,00	38,4	M30

This is only part of the tabulation in the Standard.

PARALLEL KEYS

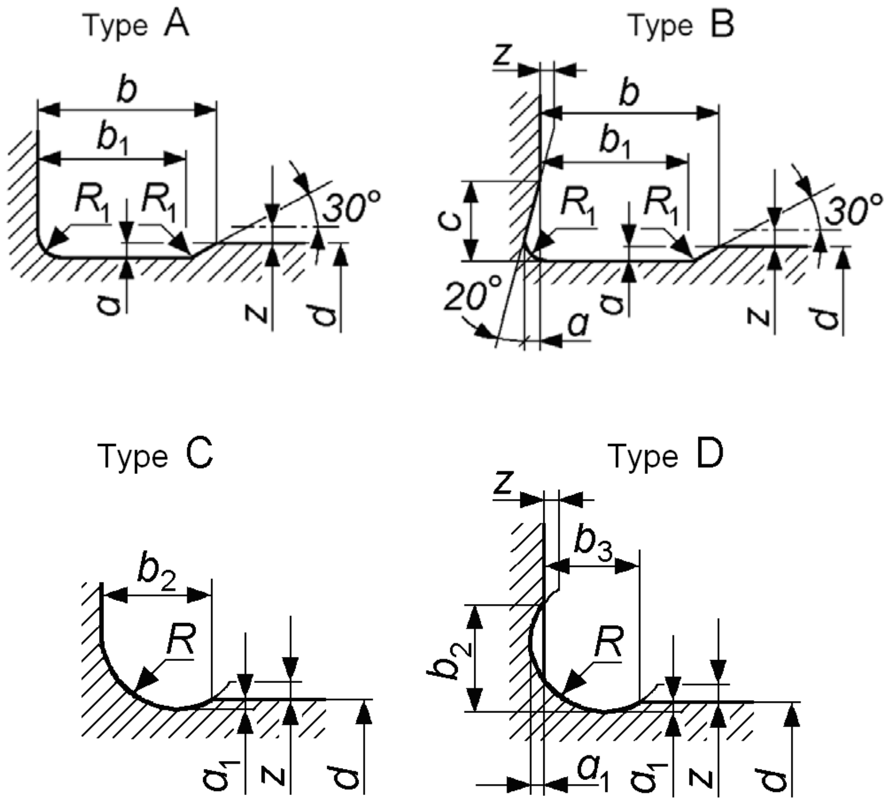
PN-70/M- 86005



b (h9)	5	6	8	10	12	14	16	18	20	22	25	28
h (h11)*	5	6	7	8	8	9	10	11	12	14	14	16
Rmax	0.4			0.6					0.8			
D_1	—	—	3,4		4,5	5,5		6,6			9	11
D_2	—	—	5,5		8	9,5		11			14	16,5
t_3	—	—	2,4		3,4	4,2		4,8			6	7
l	Mass of 1000 keys of type B											
14		3,94										
16	3,14	4,52										
18		5,09	7,93									
20	3,92	5,65	8,80									
25	4,91	7,07	11,0	15,7								
32		9,04	14,1	20,1	24,1							
40	7,85	11,3	17,6	25,1	30,1	39,6						
45	8,83	12,7	19,8	28,3	33,9	44,5						
50		14,1	22,0	31,4	37,7	49,5	62,8	77,7				
56		15,8	24,6	35,2	42,2	55,4		87,0				
63		17,8	27,7	39,6	47,5	62,3	79,1	97,9	119,0	152,0		
70		19,8	30,8	44,0	52,8	69,2				169,0		
80			35,2	50,2	60,3	79,1	100,0	124,0	151,0			
90				56,5	67,8	89,0						
100				62,8	75,4	98,9	126,0	155,0	188,0	242,0		
110				69,1	82,9		138,0					
125					94,2	124,0	157,0	194,0	235,0			
140					106,0				264,0	338,0		
160							201,0	249,0				
200								311,0	377,0	484,0	550,0	703,0
250										604,0	687,0	880,0

SHOUDERS WITH RELIEF GROOVE

PN-58/M- 02043



Dimensions of Relief Grooves												
Diameter d [mm]		Type of the Groove										
from	to	A & B						C & D				
		b	***a***	***z***	b_1	***c***	R_1	***R***	a_1	***z***	b_2	b_3
3	**10**							**---**	**---**		**---**	**---**
10	**18**	**2**	**0.2**		**1.5**	**1**	**0.4**	**1**	**0.2**		**1.6**	**1.4**
18	**30**			**0.1**				**1.6**		**0.1**	**2.5**	**2.2**
30	**80**	**4**	**0.3**		**3.3**	**1.5**	**0.6**		**0.3**			
80	**----**	**6**	**0.4**		**5**	**2.3**	**1**	**2.5**			**3.7**	**3.4**

PREFERED METRIC SIZES

The preferred numbering system has played a major role in the development of metric standards. This is a geometrical series of numbers adopted worldwide. Its first known application was in the 1870's by Charles Renard, a French army captain who reduced the different diameters of rope for military balloons from 425 to 17. The R5, R10 and R20 series refers to the Renard 5 (first choice sizes 60 % increments), Renard 10 (second choice sizes 25 % increments) and Renard 20 (third choice sizes 12 % increments) series of preferred numbers standardized in ISO 3.
Nominal metric sizes are identical where the metric system has been in use for several years. Here is how the preferred metric nominal sizes were developed and how these chosen sizes reflect preferred metric standard sizes for threaded fasteners, steel plates, sheets, bars, etc already in use throughout the world.

Choice			Choice			Choice			Choice			Choice			Choice		
1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
1					5.2			23	65					122			188
	1.1			5.5				24			66		125		190		
1.2					5.8	25				68				128			192
		1.3	6					26	70			130				195	
	1.4				6.2		28			72				132			198
		1.5		6.5		30					74		135		200		
1.6					6.8		32		75					138			205
		1.7		7				34			76	140				210	
	1.8				7.5	35				78				142			215
		1.9	8					36	80				145		220		
2					8.5		38				82			148			225
		2.1		9		40				85		150				230	
	2.2				9.5		42				88			152			235
		2.4	10					44	90				155		240		
2.5				11		45					92			158			245
		2.6	12					46		95		160				250	
2.8					13		48				98			162			255
3				14		50			100				165		260		
		3.2			15		52				102			168			265
	3.5		16					54	105			170				270	
		3.8			17	55					108			172			275
4				18				56	110				175		280		
		4.2			19		58				112			178			285
	4.5		20			60				115		180				290	
		4.8			21		62				118			182			295
5				22				64	120				185		300		

The presentation of preferred sizes gives designers and users a logical selection and the benefits of rational variety reduction. The second-choice size given should only be used when it is not possible to use the first choice, and the third choice should be applied only if a size from the second choice cannot be selected. With this procedure, common usage will tend to be concentrated on a limited range of sizes, and a contribution is thus made to variety reduction. However, the decision to use a particular size cannot be taken on the basis that one is first choice and the other not. Account must be taken of the effect on the design, the availability of tools, and other relevant factors.

RECOMMENDED FIT SYSTEMS & DIAMETER SERIES

1. TOLERANCES IN ACCORDANCE WITH PN-EN 20286-2:1996 STANDARD

Fits of hole basis system

Clearance	H11/d11	Easy running fit
	H7/f7, H8/f9	Running fit
	H8/h8	Slide fit
Transition	H8/js7	Push fit
	H7/k6	Light keying fit
	H7/n6	Heavy keying fit
Close	H7/p6	Very light drive fit
	H7/s7	Drive fit

Fits of shaft basis system

Clearance	D11/h11	Easy running fit
	F9/h8	Running fit
Close	U8/h7	Very heavy drive fit 1
	Z8/h7	Very heavy drive fit 5

2. FIT SYSTEM FOR ROLLING BEARING

H7/js6	For rotational shaft
H7/k6	
K7/h6	For rotational housing
N7/h6	
H8/h8	With adapter sleeve

Notice: The fit systems do not concern keys, taper keys, pins.

Fits:

U8/h7	Steel on steel (cool)
Z8/h7	Cast iron on steel (cool)
Z8/h7	Steel on steel (hot)

3. DIAMETERS

Hub diameters of gears, sprockets, pulleys in accordance with their bores, approximately:

Bore	10	(12)	(15)	(18)	20	(22)	25	30	35	40	45	50	60	65
Hub	20	(25)	(30)	(36)	36	(40)	45	55	60	70	75	80	100	105
Bore	80	90	100											
Hub	120	130	150											

Diameters of shafts, journals & pins

6, 8, 10, 12, (14), (15), 16, (17), (18), 20, (22), 25, (28), 30, (32), 35, 40, 50, 55, 60, 65, 70, 75, 80, (85), 90, (95), 100, (105), 110, (115), 120, 125.

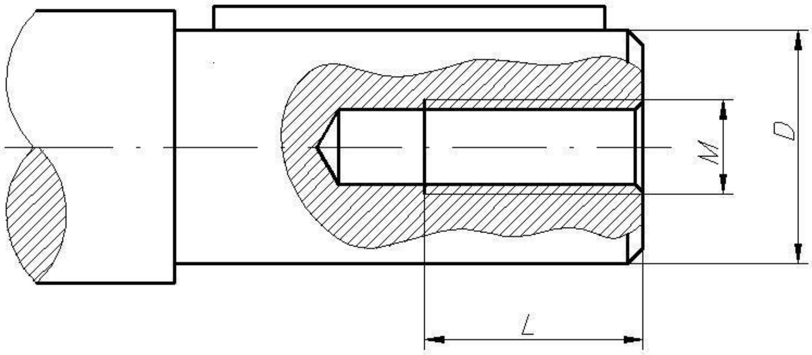
3.3. Bores

6, 8, 10, 12, (14), (15), 16, (18), 20, (22), 25, (28), 30, 32, 35, (38) 40, 42, (45), 47 50, (52), 55, 60, (65), (68) (70), (72), 75, 80, (85), 90, (95), 100, (105), 110, (115), 120, (125), 130, 140, 150, (160), (180), (190), (195), 200, (210), 220, (230).

( ) – not recommended

INSTALLATION OF COMPONENTS ON DRIVE SHAFTS

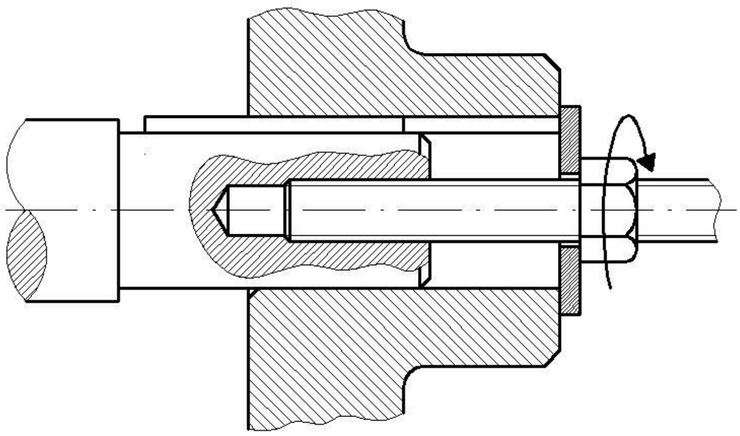
Hammering on the shafts can cause brinelling of the reducer bearings shortening the bearing life. So reducer products should be supplied with a tapped hole on the output shaft of the reducer as an aid when installing couplings and sprockets (see figure below).



The following table shows the shaft diameter range and the available thread size.

Shaft Diameter [mm]	Thread Size	Thread Depth [mm]
Over 16 up to 21	M6	16.0
Over 21 up to 24	M8	19.0
Over 24 up to 30	M10	22.0
Over 30 up to 38	M12	28.0
Over 38 up to 50	M16	36.0
Over 50 up to 85	M20	42.0
Over 85 up to 130	M24	50.0
Over 130	M30	63.0

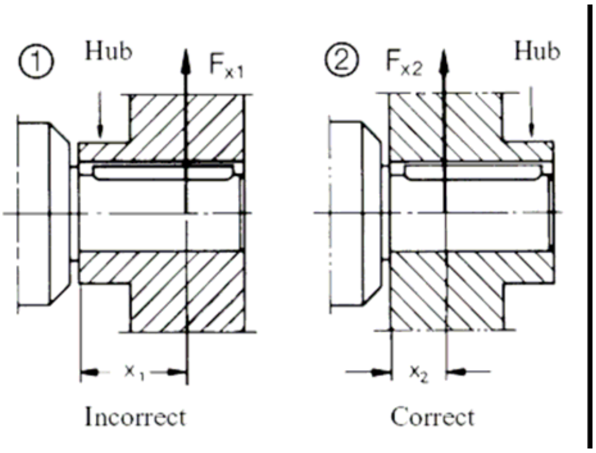
Figure below shows an example of a mounting jig for mounting couplings or hubs onto a reducer output shaft.



In some cases, the thrust bearing at the mounting jig is required.

MOUNTING ARRANGMENT OF A PULLEY OR SPROCKET

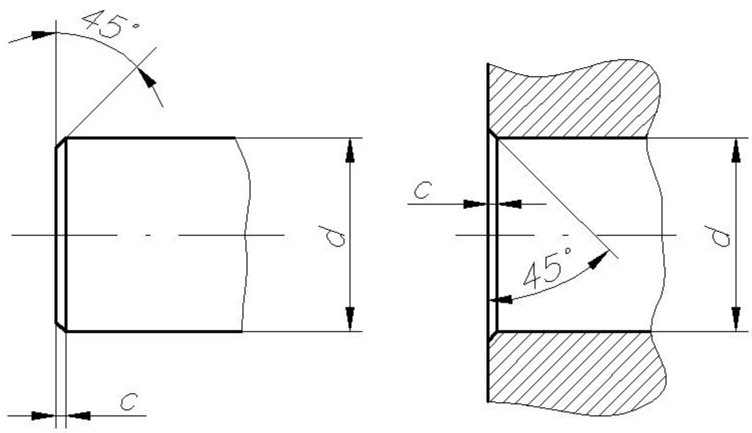
Figure below shows the correct mounting arrangements of a pulley or chain sprocket to avoid excessive overhung loads.



Correct mounting arrangement ② of a pulley or chain wheel to avoid inadmissibly high overhung loads

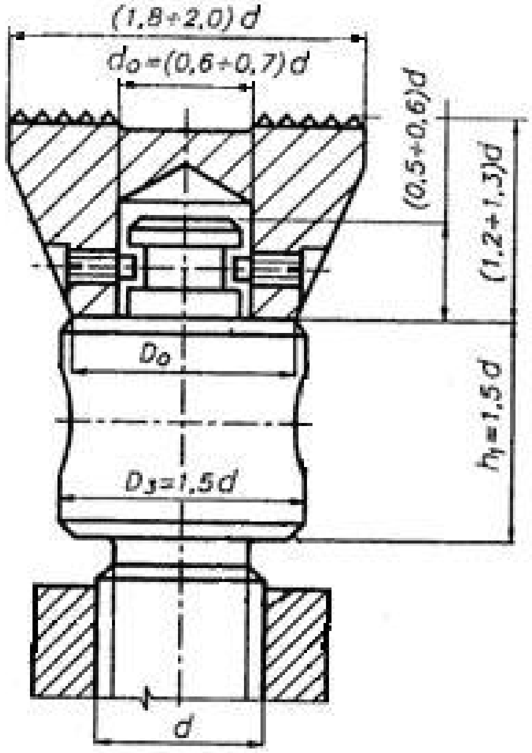
For easier installation use a lubricant (applied to the bore of the hub) or preheat the component to approximately 80°C.

CHAMFERS

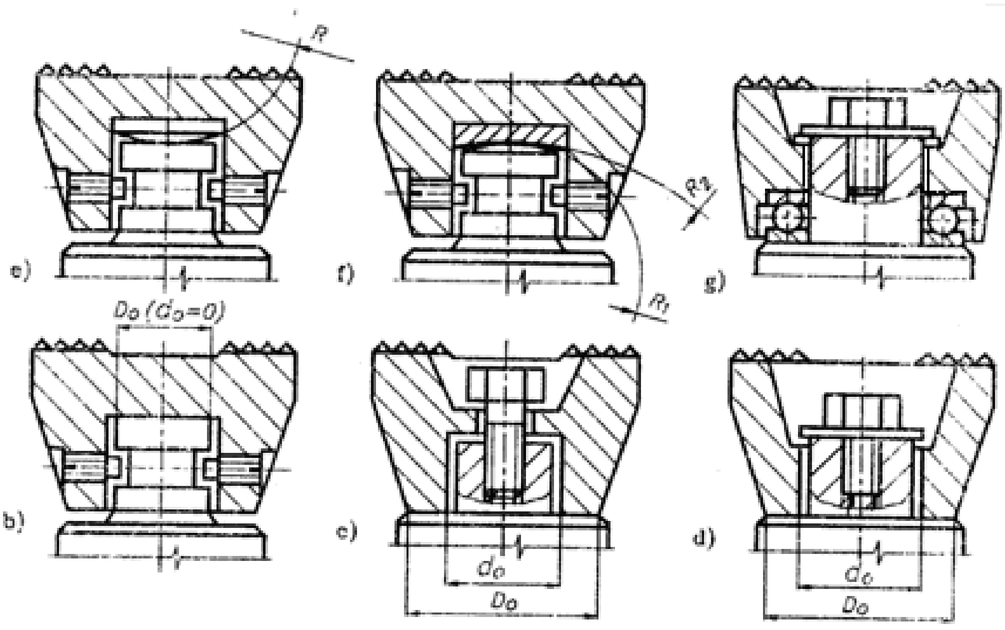


d [mm]		**c [mm]**	**d [mm]**		**c [mm]**
over	**to**		**from**	**to**	
---	16	1	60	80	3
16	20	1	80	100	3
20	30	1.5	100	120	4
30	40	2	120	150	4
40	50	2	150	200	4
50	60	3	200	250	5

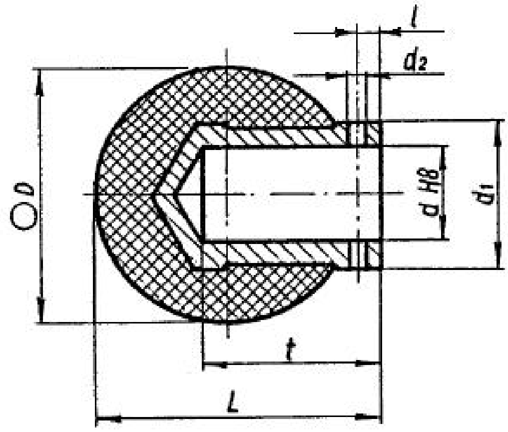
CAP OF A SCREW JACK – MAIN DIMENSIONS

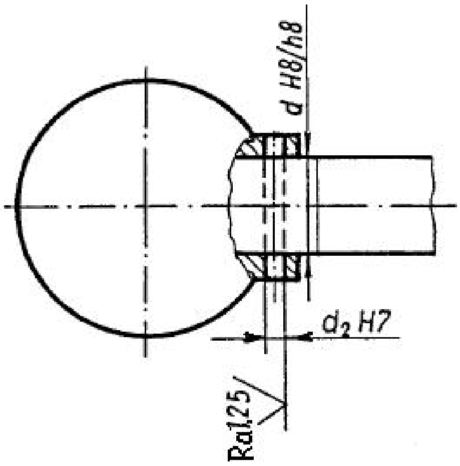


ALTERNATIVE DESIGNS OF THE JACK CAP



BALL KNOBS WITH COLLAR



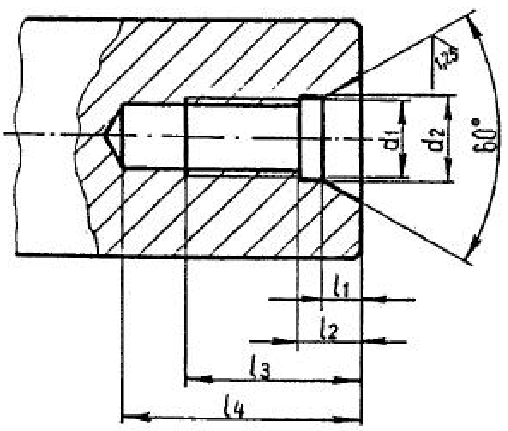


D	d H8	t	d_1	L	d_2 *)	l	Cylindrical Pin according to PN-89/M-85021
16	6	12	10	18	1.9	2.5	2h8 x 10
25	10	18	14	28	2.9	3	3h8 x 16
32	12	22	18	35	2.9	3	3h8 x 20

***) Bores d_2 should be bored during assembly**

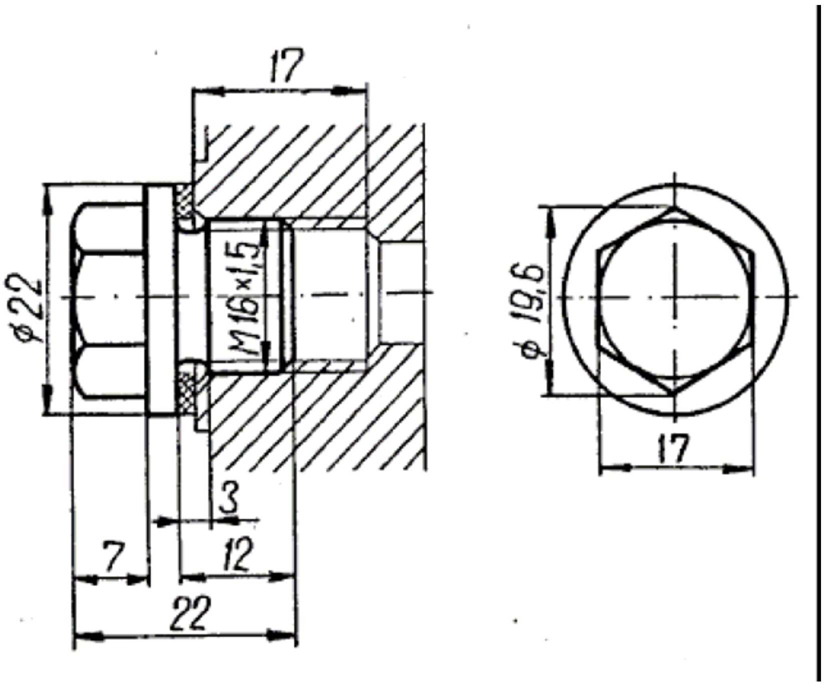
CENTRE HOLES WITH THREAD

(Non-standard ones)

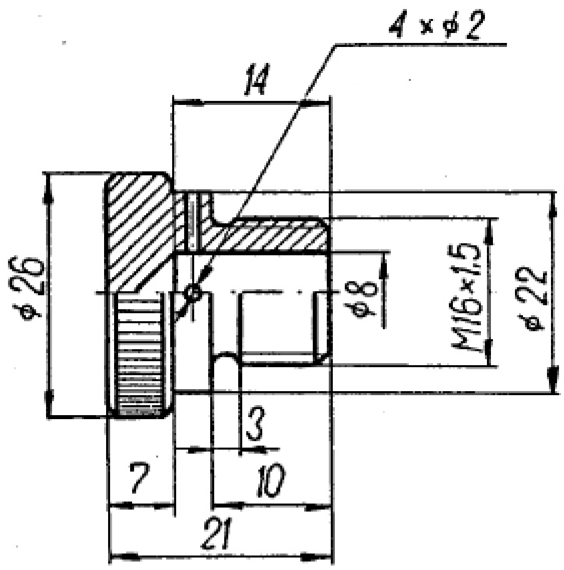


d_1	d_2	l_1	l_2	l_3 min	l_4 min	Shaft Dia.
M8	8.4	3.6	6	19	25	20
M10	10.5	4.7	7.5	22	30	30,35
M12	13	6	9.5	28	37.5	40
M16	17	7	12	36	45	50,60

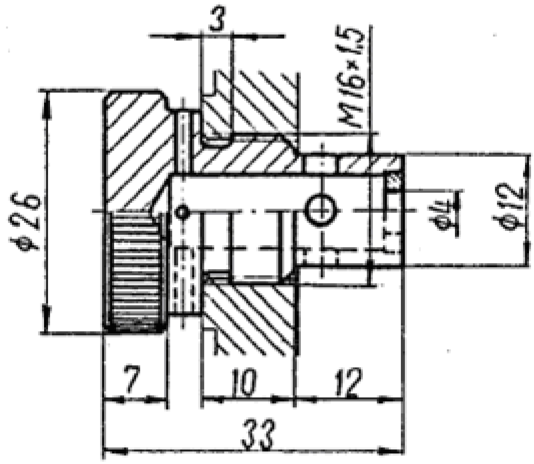
DRAIN PLUG



BREATHERS



Alternative design A

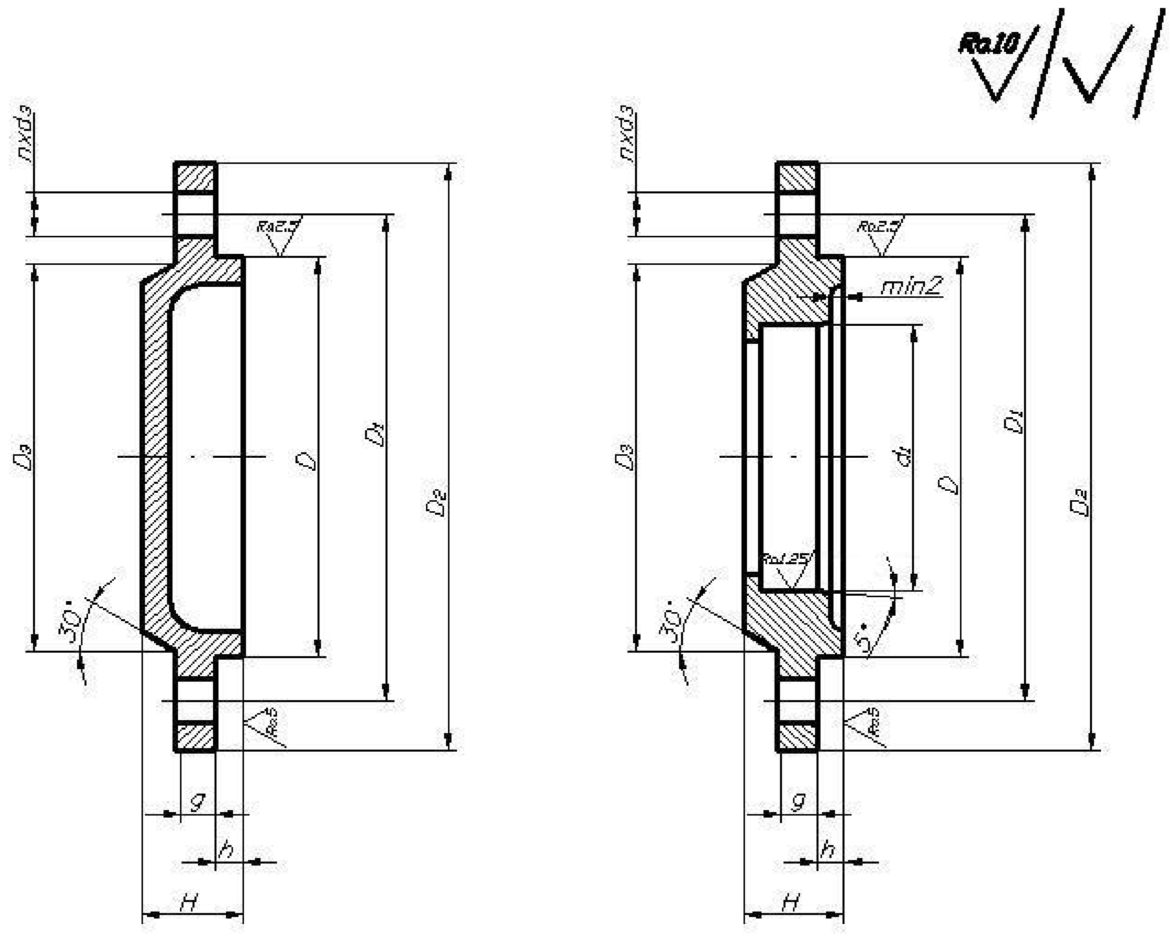


Alternative design B

GUIDE DATE FOR DIMENSIONS OF GEAR CASES

Component		**Designation**	**Note**
Wall thickness	for bottom box for top box	$g = 2\sqrt[4]{0.1T_2} \geq 6\,mm$ $g_1 = 0.9\,g \geq 6\,mm$	T_2 [Nm] – torque of output shaft
Reinforcement & cooling webs	thickness (at foot) height casting slope	$e = (0.8\ldots1.0)g$ $e_1 = (0.8\ldots1.0)g_1$ $h \leq 5g$ $h_1 \leq 5g_1$ 2^0	
Bolt diameters	for foundation for bearings for flange	$d_1 = \sqrt[3]{4T_2} \geq 10\ mm$ $d_2 = 0.8\,d_1 \geq 8\ mm$ $d_3 = (0.7\ldots0.8)d_2$	T_2 [Nm] – torque of output shaft
Flange	thickness width	$s = 1.5\,d_2$ $s_1 = 1.3\,d_2$ $k_1 = 3\,d_2$	
Foundation feet	thickness width	$s_2 = 1.5\,d_1$ $k_2 = 4\,d_1$ $a = k_2 + g$	
Distances	wheel – wall wheel – bottom wheel - wheel	$L \geq 0.6\,g$ $L_1 \geq 2.5\,g$ $L_3 \geq 0.4\,g$	

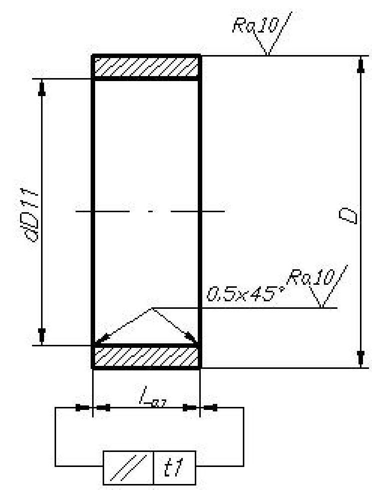
CAPS FOR BEARING HOUSINGS
(Blind and for lip seal ones)

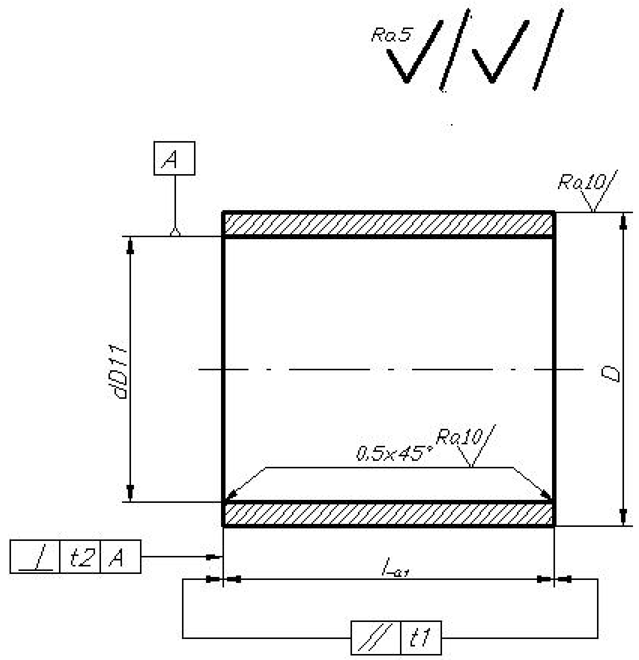


D h11, d11	D_1 ±0.1	D_2	D_3	n	d_3	h -0.1	g	H min	d_1 H8
47	58	72	45						35
50	63	78	50	3		3	5	13	40
60	73	88	58						40
(72)	83	98	70						55
80	91	106	78		6.6			15	65
(85)	96	111	82	4					72
90	101	116	87			4	6		75
100	111	126	97					17	85
110	121	136	106						90
120	133	153	116						100
125	138	158	120		9			20	110
140	153	173	136	6			7		110
160	175	197	153			5			120
180	195	217	173		11			22	—

DISTANCE RINGS AND SLEEVES FOR SHAFTS

Ring l ≤ d **Sleeve l > d**



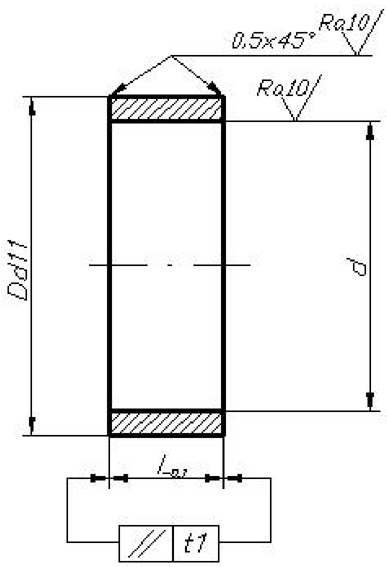


d D11	D	t2	$l_{-0.1}$; t1																	
			Ring											Sleeve						
			2.5	3	4	5	6	7	8	10	12	14	16	20	25	30	35	40	45	50
			t1= 0.025	t1= 0.025	t1 = 0.025	t1 = 0.025	t1 = 0.025	t1 = 0.025	t1 = 0.025	t1 = 0.03	t1 = 0.03	t1 = 0.03	t1 = 0.04	t1 = 0.04	t1 = 0.05	t1 = 0.05	t1 = 0.05	t1 = 0.06	t1 = 0.06	t1 = 0.06
16	21	0.04																		
20	26	0.04																		
25	31	0.05																		
30	37	0.05																		
35	42	0.05																		
40	47	0.06																		
45	52	0.06																		
50	58	0.06																		
60	68	0.06																		
65	73	0.08																		
70	78	0.08																		
80	90	0.08																		
90	100	0.08																		
100	110	0.08																		

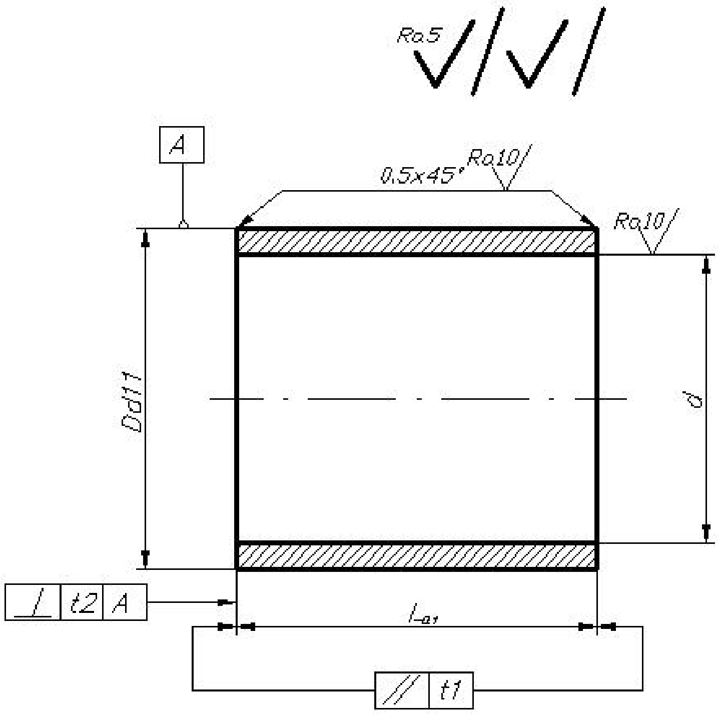
Dimensions non-applied

DISTANCE RINGS AND SLEEVES FOR HAUSINGS

Ring   l ≤ D



Sleeve   l > D



D d11	d	t2	$l_{-0.1}$; t1																	
			Ring																Sleeve	
			2.5	3	4	5	6	7	8	10	12	14	16	20	25	30	35	40	45	50
			t1 = 0.025	t1= 0.025	t1 = 0.025	t1 = 0.025	t1 = 0.025	t1 = 0.025	t1 = 0.025	t1 = 0.03	t1 = 0.03	t1 = 0.03	t1 = 0.04	t1 = 0.04	t1 = 0.05	t1 = 0.05	t1 = 0.05	t1 = 0.06	t1 = 0.06	t1 = 0.06
42	35	0.06																		
47	40	0.06																		
52	45	0.06																		
55	47	0.06																		
62	54	0.06																		
68	60	0.08																		
72	64	0.08																		
(75)	66	0.08																		
80	71	0.08																		
85	75	0.08																		
90	80	0.08																		
(95)	85	0.08																		
100	90	0.1																		
110	100	0.1																		
120	110	0.1																		
140	130	0.1																		
(150)	140	0.1																		
160	150	0.12																		
180	170	0.12																		

Dimensions non-applied

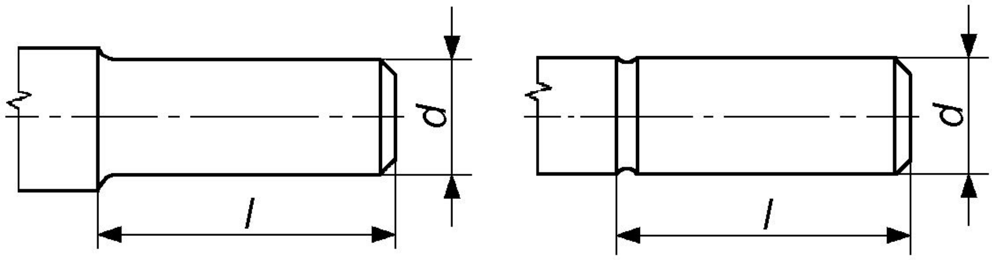
YOUNG'S MODULI FOR VARIOUS METALS

Materials	Young's Modulus, E
------	x 10^5 N/mm^2
Steel	2.07
Stainless Steel	1.90
Ductile Cast Iron	1.66
Titanium	1.14
Brass, Bronze	1.10
Grey Cast Iron	1.04
Aluminum	0.72
Magnesium	0.45

POISSON'S RATIOS FOR VARIOUS METALS

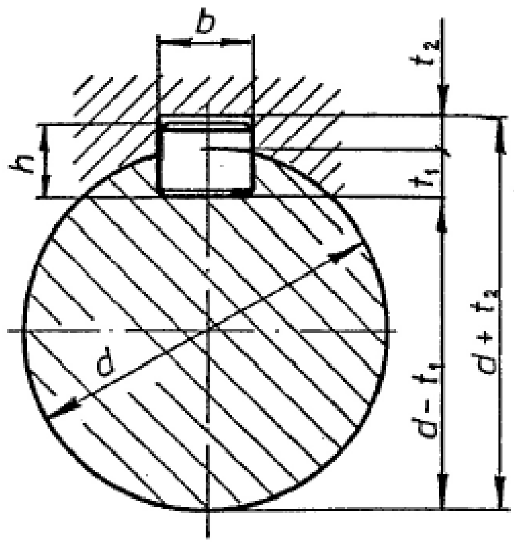
Materials	Poisson's, ν
Steel	0.28
Iron	0.28
Titanium	0.34
Copper	0.35
Aluminum	0.34
Magnesium	0.33

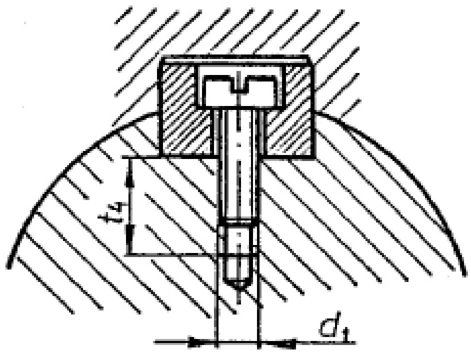
RECOMMENDED JOURNALS OF SHAFT ENDS - CYRINDRICAL ONES



<table>
<tr><th rowspan="2">Diameter, d
mm</th><th colspan="2">Tolerances</th><th colspan="2">Length, l</th></tr>
<tr><th>Field</th><th>Deviations
mm</th><th>Long Journals
mm</th><th>Short Journals
mm</th></tr>
<tr><td>10</td><td rowspan="11">j6 (k6)</td><td>+0.007 (+0.010)
-0.002 (+0.001)</td><td>23</td><td>20</td></tr>
<tr><td>12</td><td rowspan="4">+0.008 (+0.012)
-0.003 (+0.001)</td><td rowspan="2">30</td><td rowspan="2">25</td></tr>
<tr><td>14</td></tr>
<tr><td>16</td><td rowspan="2">40</td><td rowspan="2">28</td></tr>
<tr><td>18</td></tr>
<tr><td>20</td><td rowspan="5">+0.009 (+0.015)
-0.004 (+0.002)</td><td rowspan="2">50</td><td rowspan="2">36</td></tr>
<tr><td>22</td></tr>
<tr><td>25</td><td rowspan="2">60</td><td rowspan="2">42</td></tr>
<tr><td>28</td></tr>
<tr><td>30</td><td rowspan="4">80</td><td rowspan="4">58</td></tr>
<tr><td>32</td><td>+0.011 (+0.018)
-0.005 (+0.002)</td></tr>
<tr><td>35</td><td rowspan="6">k6</td><td rowspan="6">+0.018
+0.002</td></tr>
<tr><td>38</td></tr>
<tr><td>40</td><td rowspan="5">110</td><td rowspan="5">82</td></tr>
<tr><td>42</td></tr>
<tr><td>45</td></tr>
<tr><td>50</td></tr>
<tr><td>55</td><td rowspan="10">m6</td><td rowspan="5">+0.030
+0.011</td></tr>
<tr><td>60</td><td rowspan="3">140</td><td rowspan="3">105</td></tr>
<tr><td>70</td></tr>
<tr><td>75</td></tr>
<tr><td>80</td><td rowspan="3">170</td><td rowspan="3">130</td></tr>
<tr><td>85</td><td rowspan="4">+0.035
+0.013</td></tr>
<tr><td>90</td></tr>
<tr><td>100</td><td rowspan="3">210</td><td rowspan="3">165</td></tr>
<tr><td>110</td></tr>
<tr><td>125</td><td>+0.040
+0.015</td></tr>
</table>

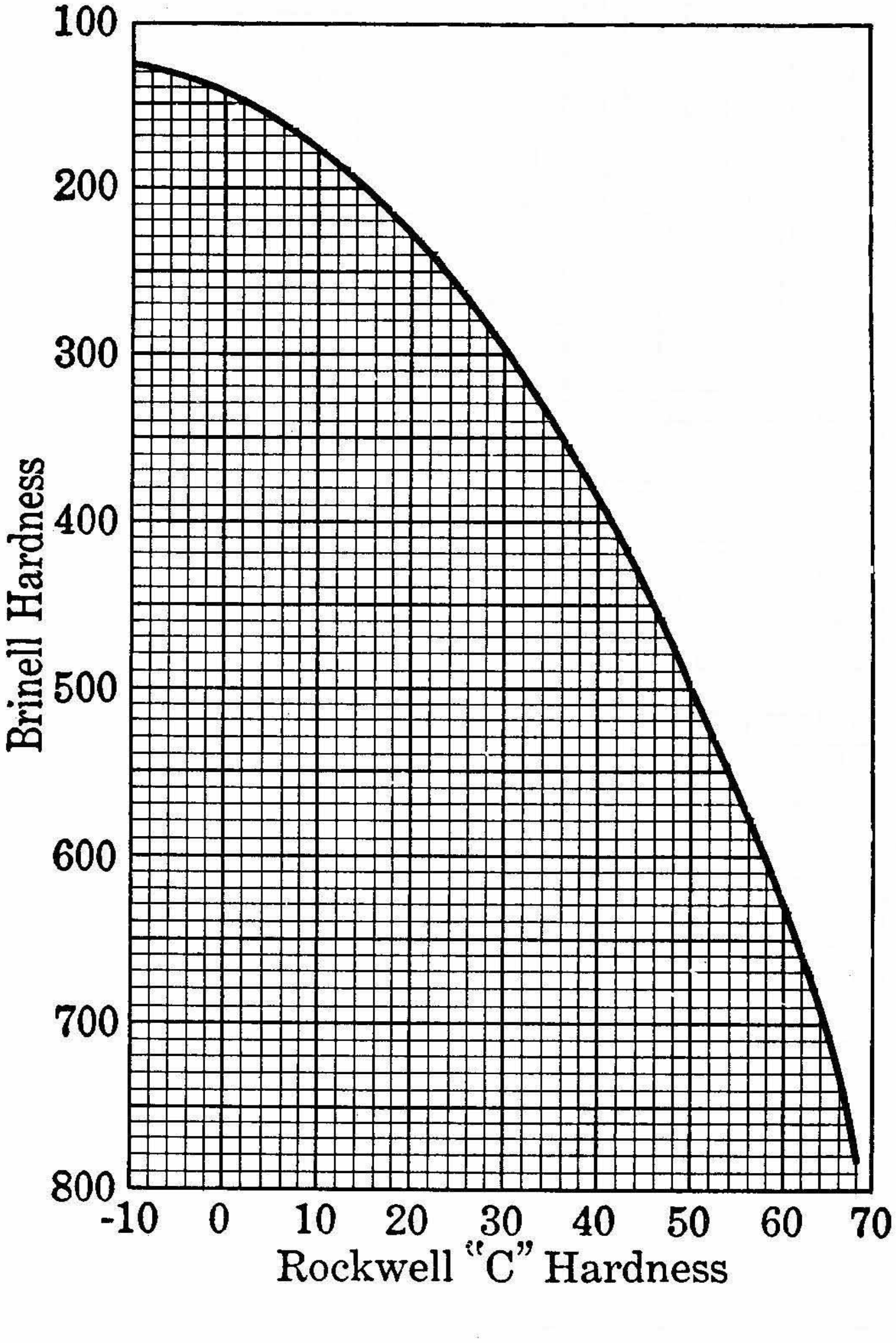
DIMENSIONS OF KEYSEATS





Shaft	Key	Keyseat										
d	b×h	Fits					t_1		t_2		t_4	d_1
above – to		Clearence Fit		Common Fit		Interference Fit						
		Shaft	Hub	Shaft	Hub	Shaft & Hub						
12 – 17	5×5	H9	D10	N9	Js9	P9	3	+ 0,1	2,3	+ 0,1	—	—
17 – 22	6×6						3,5		2,8		—	—
22 – 30	8×7						4	+ 0,2	3,3	+ 0,2	7	M3
30 – 38	10×8						5				8	
38 – 44	12×8						5				10	M4
44 – 50	14×9						5,5		3,8			M5
50 – 58	16×10						6		4,3			
58 – 65	18×11						7		4,4		12	M6
65 – 75	20×12						7,5		4,9		11	
75 – 85	22×14						9		5,4		13	
85 – 95	25×14						9				15	M8
95 – 110	28×16						10		6,4		15	M8

RELATION OF HARDNESS NUMBERS



RECOMMENDED NUMBER OF PINION TEETH ACCORDING TO NIEMANN

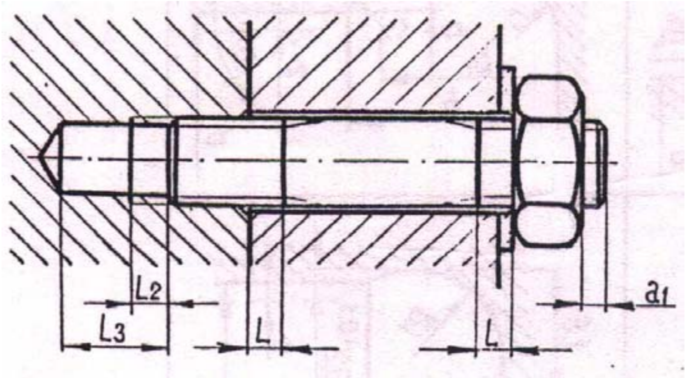
Proposed treatment	Gear ratio			
	1:1	2:1	4:1	8:1
Heat treated up to 230 BHN	32…60	29…55	25…50	22…45
More than 300 BHN	30…50	27…45	23…40	20…35
Grey iron	26…45	23…40	21…35	18…30
Nitrided	24…40	21…35	19…31	16…26
Case hardened	21…32	19…29	16…25	14…22

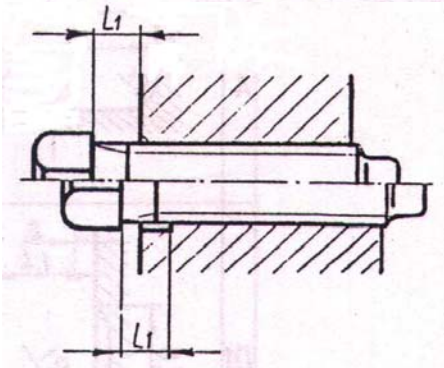
SPUR GEAR DESIGN FORMULAS

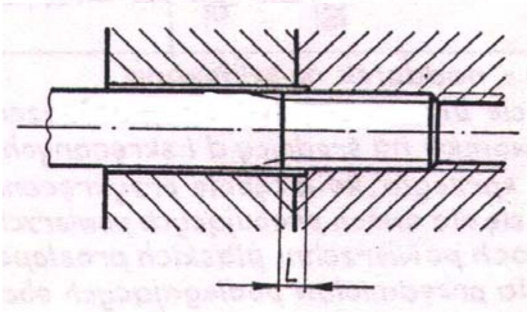
To Obtain	From Known	Use This Formula*)
Pitch diameter	Module	$D = m \cdot N$
Circular pitch	Module	$p_c = m \cdot \pi = (D \cdot \pi)/m$
Module	Diametral pitch	$m = 25.4/P_d$
No. of teeth	Module and pitch diameter	$N = D/m$
Addendum	Module	$a = m$
Dedendum	Module	$b = 1.25 \cdot m$
Outside diameter	Module and pitch diameter or number of teeth	$D_o = D+2 \cdot m = m(N+2)$
Root diameter	Pitch diameter and module	$D_r = D-2.5 \cdot m$
Base circle diameter	Pitch diameter and pressure angle	$D_b = D \cdot \cos\varphi$
Base pitch	Module and pressure angle	$p_b = m \cdot \pi \cdot \cos\varphi$
Tooth thickness at standard pitch diameter	Module	$T = 0.5 \cdot \pi \cdot m$
Center distance	Module and number of teeth	$C = 0.5 \cdot m(N_1+N_2)$
Contact ratio	Outside radii, base circle radii, center distance, pressure angle	$m_p = \frac{\sqrt{R_{o1} - R_{b1}} + \sqrt{R_{o2} - R_{b2}} - C \sin\varphi}{m \cdot \pi \cdot \cos\varphi}$
Backlash (linear)	Change in center distance	$B = 2(\Delta C)\tan\varphi$
Backlash (linear)	Change in tooth thickness	$B = \Delta T$
Backlash (linear) along line-of-action	Linear backlash above pitch circle	$B_{LA} = B \cdot \cos\varphi$
Backlash, angular	Linear backlash	$B^* = 6.88(B/D)$ (arc minutes)
Min. number teeth for no undercutting	Pressure angle	$N_c = 2/\sin^2\varphi$

*) All linear dimensions in millimeters

LENGHT EXCESSES RECOMMENDED FOR THREADS







Thread pitch, *p*	Excess				
	L	**min L_1**	**min L_2**	**min L_3**	**min a_1**
0.5	1	2	1	4	0.8
0.7	1	2.5	1.5	5	1.0
0.8	2	3	1.5	5.5	1.2
1.0	2	4	2	8	1.5
1.25	2	5	2.5	10.5	1.8
1.5	2	6	3	12	2.2
1.75	3	7	3.5	14.5	2.5
2.0	3	8	4	15	3.0
2.5	3	10	5	17	3.5
3.0	4	12	6	21	4.5
3.5	4	13	7	24	5.0
4.0	4	14	8	27	6.0

CASTING RIB DESIGN