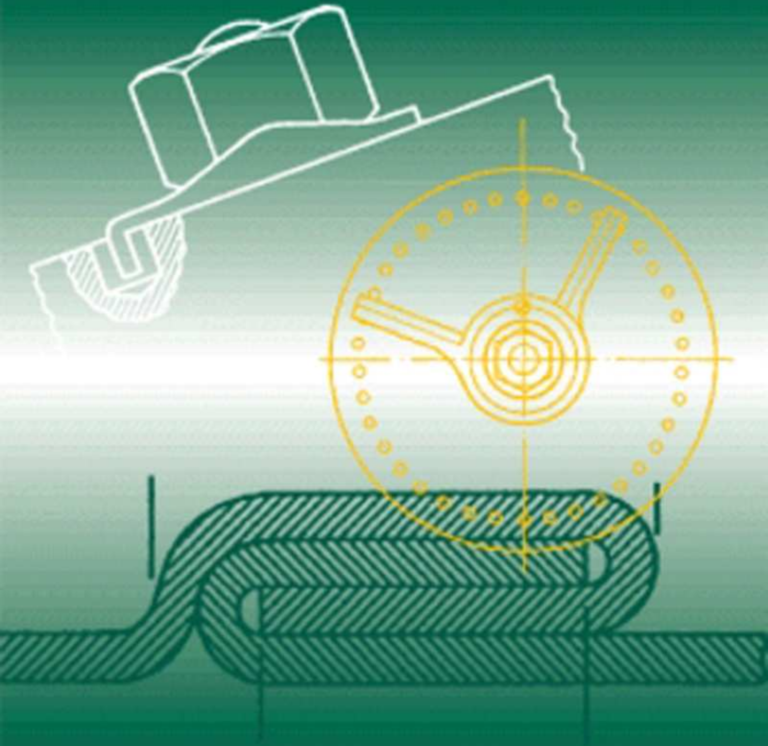
NEWNES

Workshop Engineer's

POCKET BOOK



ROGER TIMINGS

Newnes Workshop Engineer's Pocket Book

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Newnes Workshop Engineer's Pocket Book

Roger Timings

Newnes

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Part 4 Miscellaneous

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Preface

This pocket book has been prepared as an aid to practising workshop engineers. The tables have been selected to provide a quick day-to-day reference for useful workshop information. For this reason many of the highly prescriptive British and ISO Standards, necessary for design engineers and managers, have been abridged and simplified in this book. However, wherever this has been done, the reference code for the full Standard is included should this be required.

For easy reference this book is divided into four parts, namely:

1. workshop calculations and conversion tables;
2. threaded fastenings;
3. cutting tools;
4. miscellaneous.

Within these parts, the material has been assembled in a logical sequence for easy reference, and a comprehensive list of contents has been provided which leads the reader directly to the item required. There is also a comprehensive alphabetical index.

Currently, many revisions of the British Standards is taking place. These revisions range from relatively minor amendments to complete withdrawal and replacement. This is necessary to reflect technological changes and to ensure harmonization with international (ISO) requirements. The currency and validity of any Standard can be identified as set out in the following notes which preface the catalogue issued by the British Standards Institute (BSI).

How to use the BSI catalogue basic details of entries

The list of BSI publications in their catalogue is arranged in numerical order, within each series. The series can be identified from the alphabetical characters which precede the number of the Standard.

For example: BS AU = automobile series, or BSEN = European Standards adopted as British Standards.

Current publications can be identified by the use of bold type for the number of the publication and its title. The revision of any publication automatically supersedes all previous editions of the publication. Only the current editions are listed.

Withdrawn publications can be identified by the use of light type for the number of the publication and its title, and the word 'withdrawn' in parentheses.

Definitions of entries in the catalogue

An entry appears in the catalogue as in the example below. The various elements are labelled A–J. The key explains each element.

A B C D

BS 1361 : 1971 (1986) ≠ IEC 269-1

Specification for cartridge fuses for a.c. circuits in domestic and similar premises.
Requirements, ratings and tests for fuse links, fuse bases and carriers. Dimensions and time/current zones for fuse links. Type I-rate 240 V and 5 A to 45 A for replacement by domestic consumers; Type II-rated 415 V and 60 A, 80 A or 100 A for use by the supply authority in the incoming unit of domestic and similar premises.

AMD 4171, January 1983 (Gr 0)[R] 00000821
AMD 4795, January 1985 (Gr 2)[R] 00000833 — E
AMD 6692, January 1991 (FOC) 00000845

J — A5, 44 pages 00000818 GR7 PEL/32

I H G F

A	**BS 1361**	Product identifier.
B	1971	Original publication date.
C	(1986)	Confirmed in 1986, indicating the continuing currency of the Standard without full revision.
D	≡	An identical Standard: a BSI publication identical in every detail with a corresponding European and/or international Standard.
or	=	A (technically) equivalent Standard: a BSI publication in all technical respects the same as a corresponding European and/or international Standard, though the wording and presentation may differ quite extensively.
or	≠	A related but not equivalent Standard: a BSI publication that covers subject matters similar to that covered by a European and/or international Standard. The content however is short of complete identity or technical equivalence.
E	00000833	Unique product code for the amendment.
F	PEL/32	BSI Technical Committee responsible for this publication.
G	*R*	Amendment incorporated in the reprinted text. No 'R' means the amendment is not part of the text.
H	Gr7	The group price: refer to the flap on the inside back cover of the catalogue.

I	00000818	Unique product code.
J	A5, 44 pages	Most new and revised Standards are published in A4 size. Sizes other than A4 are listed.

Amendments

All separate amendments to date of despatch are included with any main publication ordered. Prices are available on application. With the next reprint of the publication the amendment is incorporated into the text which then carries a statement drawing attention to this and includes an indication in the margin at the appropriate places on the amended pages.

Review

The policy of BSI is for every Standard to be reviewed by the technical committee responsible not more than five years after publication, to establish whether it is still current and, if it is not, to identify and set in hand appropriate action. Circumstances may lead to an earlier review.

When reviewing a Standard, a committee has four options available:

Withdrawal: indicating that the Standard is no longer current.

Declaration of obsolescence: indicting by amendment that the Standard is not recommended for use in new equipment, but needs to be retained to provide for the servicing of existing equipment that is expected to have a long working life.

Revision: involving the procedure for new projects.

Confirmation: indicating the continuing currency of the Standard without full revision. Following confirmation of a publication, stock copies are overstamped with the month and year of confirmation.

The latest issue of Standards should always be used in new product designs and equipment. However many products are still being manufactured to obsolescent and obsolete Standards to satisfy a still buoyant demand. This is not only for maintenance purposes but also for current manufacture where market forces have not yet demanded an update in design. This is particularly true of screwed fasteners. For this reason the traditional screw thread tables have been retained and stand alongside the new BS EN requirements.

This pocket book is not a textbook but is a compilation of useful data. The author is indebted to the British Standards Institution for their cooperation in providing up-to-date data in so many technical areas. Unfortunately, limitations of space have allowed only abstracts to be included from the wealth of material provided. The tables in this pocket book should be adequate for day-to-day workshop use. However, where additional information is required, the reader is strongly recommended to consult the complete Standard, industrial manuals or catalogues after an initial perusal of the tables of data found in this book. To this end, an appendix is provided listing the names and addresses of the libraries and institutions where the complete Standards may be consulted or purchased. Many industrial manuals are available free of charge to bona fide users.

Within the restraints of commercial viability, it is still the intention of the author and the publisher to update this book from time to time. Therefore, the author would appreciate (via the publishers) suggestions from the users of this book for additions and/or deletions to be taken into account when producing new editions.

Roger Timings

Part 1

Conversion Tables and Workshop Calculations

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1.1 Conversion table: fractions to decimals

Fraction	*Decimal*	*Fraction*	*Decimal*	*Fraction*	*Decimal*
1/64	0.015 625	11/32	0.343 750	43/64	0.671 875
1/32	0.031 250	23/64	0.359 375	11/16	0.687 500
3/64	0.046 875	3/8	0.375 000	45/64	0.703 125
1/16	0.062 500	25/64	0.390 625	23/32	0.718 750
5/64	0.078 125	13/32	0.406 250	47/64	0.734 375
3/32	0.093 750	27/64	0.421 875	3/4	0.750 000
7/64	0.109 375	7/16	0.437 500	49/64	0.765 625
1/8	0.125 000	29/64	0.453 125	25/32	0.781 250
9/64	0.140 625	15/32	0.468 750	51/64	0.796 875
5/32	0.156 250	31/64	0.484 375	13/16	0.812 500
11/64	0.171 875	1/2	0.500 000	53/64	0.828 125
3/16	0.187 500	33/64	0.515 625	27/32	0.843 750
13/64	0.203 125	17/32	0.531 250	55/64	0.859 375
7/32	0.218 750	35/64	0.546 875	7/8	0.875 000
15/64	0.234 375	9/16	0.562 500	57/64	0.890 625
1/4	0.250 000	37/64	0.578 125	29/32	0.906 250
17/64	0.265 625	19/32	0.593 750	59/64	0.921 875
9/32	0.281 250	39/64	0.609 375	15/16	0.937 500
19/64	0.296 875	5/8	0.625 000	61/64	0.953 125
5/16	0.312 500	41/64	0.640 625	31/32	0.968 750
21/64	0.328 125	21/32	0.656 250	63/64	0.984 375

1.2 Conversion table: millimetres to inches

mm	in	mm	in	mm	in
0.01	0.000 394	36	1.417 323	89	3.503 937
0.02	0.000 787	37	1.456 693	90	3.543 307
0.03	0.001 181	38	1.496 063	91	3.582 677
0.04	0.001 575	39	1.535 433	92	3.622 047
0.05	0.001 969	40	1.574 803	93	3.661 417
0.06	0.002 362	41	1.614 173	94	3.700 788
0.07	0.002 756	42	1.653 543	95	3.740 158
0.08	0.003 150	43	1.692 913	96	3.779 528
0.09	0.003 543	44	1.732 283	97	3.818 898
0.10	0.003 937	45	1.771 654	98	3.858 268
0.20	0.007 874	46	1.811 024	99	3.897 638
0.30	0.011 810	47	1.850 394	100	3.937 008
0.40	0.015 748	48	1.889 764	200	7.874 016
0.50	0.019 685	49	1.929 134	300	11.811 02
0.60	0.023 622	50	1.968 504	400	15.748 03
0.70	0.027 559	51	2.007 874	500	19.685 04
0.80	0.031 496	52	2.047 244	600	23.622 05
0.90	0.035 433	53	2.086 614	700	27.559 06
1	0.039 370	54	2.125 984	800	31.496 06
2	0.078 740	55	2.165 354	900	35.433 07

(*continued*)

1.2 (*continued*)

mm	in	mm	in	mm	in
3	0.118 110	56	2.204 725	1000	39.370 08
4	0.157 480	57	2.244 095	1100	43.307 09
5	0.196 850	58	2.283 465	1200	47.244 09
6	0.236 221	59	2.322 835	1300	51.181 10
7	0.275 591	60	2.362 205	1400	55.118 11
8	0.314 961	61	2.401 575	1500	59.055 12
9	0.354 331	62	2.440 945	1600	62.992 13
10	0.393 701	63	2.480 315	1700	66.929 14
11	0.433 071	64	2.519 685	1800	70.866 14
12	0.472 441	65	2.559 055	1900	74.803 15
13	0.511 811	66	2.598 425	2000	78.740 16
14	0.551 181	67	2.637 795	2100	82.677 17
15	0.590 551	68	2.677 166	2200	86.614 17
16	0.629 921	69	2.716 536	2300	90.551 19
17	0.669 291	70	2.755 906	2400	94.488 19
18	0.708 661	71	2.795 276	2500	98.425 2
19	0.748 032	72	2.834 646	2600	102.362 2
20	0.787 402	73	2.874 016	2700	106.299 2
21	0.826 772	74	2.913 386	2800	110.236 2
22	0.866 142	75	2.952 756	2900	114.173 2
23	0.905 512	76	2.992 126	3000	118.110 2
24	0.944 882	77	3.031 496	3100	122.047 2
25	0.984 252	78	3.070 866	3200	125.984 3
26	1.023 622	79	3.110 236	3300	129.921 3
27	1.062 992	80	3.149 606	3400	133.858 3
28	1.102 362	81	3.188 977	3500	137.795 3
29	1.141 732	82	3.228 347	3600	141.732 3
30	1.181 102	83	3.267 717	3700	145.669 3
31	1.220 472	84	3.307 087	3800	149.606 3
32	1.259 843	85	3.346 457	3900	153.543 3
33	1.299 213	86	3.385 827	4000	157.480 3
34	1.338 583	87	3.425 197	4100	161.417 3
35	1.377 953	88	3.464 567	4200	165.354 3

1.3 Conversion table: minutes of arc to degrees

min.	degree	min.	degree	min.	degree
0.1	0.001 667	14	0.233 333	38	0.633 333
0.2	0.003 333	15	0.250 000	39	0.650 000
0.25	0.004 167	16	0.266 667	40	0.666 667
0.3	0.005 000	17	0.283 333	41	0.683 333

0.4	0.006 667	18	0.300 000	42	0.700 000
0.5	0.008 333	19	0.316 667	43	0.716 667
0.6	0.010 000	20	0.333 333	44	0.733 333
0.7	0.011 667	21	0.350 000	45	0.750 000
0.75	0.012 500	22	0.366 667	46	0.766 667
0.8	0.013 333	23	0.383 333	47	0.783 333
0.9	0.015 000	24	0.400 000	48	0.800 000
1	0.016 667	25	0.416 667	49	0.816 667
2	0.033 333	26	0.433 333	50	0.833 333
3	0.050 000	27	0.450 000	51	0.850 000
4	0.066 667	28	0.466 667	52	0.866 667
5	0.083 333	29	0.483 333	53	0.883 333
6	0.100 000	30	0.500 000	54	0.900 000
7	0.116 667	31	0.516 667	55	0.916 667
8	0.133 333	32	0.533 333	56	0.933 333
9	0.150 000	33	0.550 000	57	0.950 000
10	0.166 667	34	0.566 667	58	0.966 667
11	0.183 333	35	0.583 333	59	0.983 333
12	0.200 000	36	0.600 000	60	1.000 000
13	0.216 667	37	0.616 667		

1.4 Circles: areas and circumferences

Dia.	*Area*	*Cir.*	*Dia.*	*Area*	*Cir.*	*Dia.*	*Area*	*Cir.*
1	0.785 4	3.142	34	907.92	106.8	67	3525.7	210.5
2	3.141 6	6.283	35	962.11	110.0	68	3631.7	213.6
3	7.068 6	9.425	36	1017.9	113.1	69	3739.3	216.8
4	12.566	12.57	37	1075.2	116.2	70	3848.5	219.9
5	19.635	15.71	38	1134.1	119.4	71	3959.2	223.1
6	28.274	18.85	39	1194.6	122.5	72	4071.5	226.2
7	38.485	21.99	40	1256.6	125.7	73	4185.4	229.3
8	50.265	25.13	41	1320.3	128.8	74	4300.8	232.5
9	63.617	28.27	42	1385.4	131.9	75	4417.9	235.6
10	78.540	31.42	43	1452.2	135.1	76	4536.5	238.8
11	95.033	34.56	44	1520.5	138.2	77	4656.6	241.9
12	113.10	37.70	45	1590.4	141.4	78	4778.4	245.0
13	132.73	40.84	46	1661.9	144.5	79	4901.7	248.2
14	153.94	43.98	47	1734.9	147.7	80	5026.5	251.3
15	176.71	47.12	48	1809.6	150.8	81	5153.0	254.5
16	201.06	50.27	49	1885.7	153.9	82	5381.0	257.6
17	226.98	53.41	50	1963.5	157.1	83	5410.6	260.8
18	254.47	56.55	51	2042.8	160.2	84	5541.8	263.9
19	283.53	59.69	52	2123.7	163.4	85	5674.5	267.0
20	314.16	62.83	53	2206.2	166.5	86	5808.8	270.2
21	346.36	65.97	54	2290.2	169.6	87	5944.7	273.3
22	380.13	69.11	55	2375.8	172.8	88	6082.1	276.5
23	415.48	72.26	56	2463.0	175.9	89	6221.1	279.6
24	452.39	75.40	57	2551.8	179.1	90	6361.7	282.7
25	490.87	78.54	58	2642.1	182.2	91	6503.9	285.9
26	530.93	81.68	59	2734.0	185.4	92	6647.6	289.0

(*continued*)

Dia.	*Area*	*Cir.*	*Dia.*	*Area*	*Cir.*	*Dia.*	*Area*	*Cir.*
27	572.56	84.82	60	2827.4	188.4	93	6792.9	292.2
28	616.75	87.96	61	2922.5	191.6	94	6939.8	295.3
29	660.52	91.11	62	3019.1	194.8	95	7088.2	298.5
30	706.86	94.25	63	3117.2	197.9	96	7238.2	301.6
31	754.77	97.39	64	3217.0	201.1	97	7389.8	304.7
32	804.25	100.5	65	3318.3	204.2	98	7543.0	307.9
33	855.30	103.7	66	3421.2	207.3	99	7697.7	311.0

area of a circle $= \pi r^2$ or $\pi \frac{d^2}{4}$
circumference of a circle $= 2\pi r$ or πd
where: r = radius of the circle
d = diameter of the circle

1.5 Twist drills: nearest equivalent sizes

Drill designation				*Size*	
Number	*Fraction*	*Letter*	*Metric*	Inches	mm
80	—	—	—	0.013 5	0.343
—	—	—	0.35	0.013 8	0.350
79	—	—	—	0.014 5	0.368
—	1/64	—	—	0.015 6	0.396
—	—	—	0.40	0.015 8	0.400
78	—	—	—	0.016 0	0.406
—	—	—	0.45	0.017 7	0.450
77	—	—	—	0.018 0	0.457
—	—	—	0.50	0.019 7	0.500
76	—	—	—	0.020 0	0.508
—	—	—	0.52	0.020 5	0.520
75	—	—	—	0.021 0	0.533
—	—	—	0.55	0.021 7	0.550
74	—	—	—	0.022 5	0.572
—	—	—	0.58	0.022 8	0.580
—	—	—	0.60	0.023 6	0.600
73	—	—	—	0.024 0	0.610
—	—	—	0.62	0.024 4	0.620
72	—	—	—	0.025 0	0.635
—	—	—	0.65	0.025 6	0.650
71	—	—	—	0.026 0	0.660
—	—	—	0.70	0.027 6	0.700
70	—	—	—	0.028 0	0.711
69	—	—	—	0.029 2	0.742
—	—	—	0.75	0.029 5	0.750

68	—	—	—	0.031 0	0.787
—	1/32	—	—	0.031 2	0.792
—	—	—	0.80	0.031 5	0.800
67	—	—	—	0.032 0	0.813
66	—	—	—	0.033 0	0.838
—	—	—	0.85	0.033 5	0.850
65	—	—	—	0.035 0	0.889
—	—	—	0.90	0.035 4	0.900
64	—	—	—	0.036 0	0.914
63	—	—	—	0.037 0	0.940
—	—	—	0.95	0.037 4	0.950
62	—	—	—	0.038 0	0.965
61	—	—	—	0.039 0	0.991
—	—	—	1.00	0.039 4	1.000
60	—	—	—	0.040 0	1.016
59	—	—	—	0.041 0	1.041
—	—	—	1.05	0.041 3	1.050
58	—	—	—	0.042 0	1.069
57	—	—	—	0.043 0	1.092
—	—	—	1.10	0.043 3	1.100
—	—	—	1.15	0.045 3	1.150
56	—	—	—	0.046 5	1.181
—	3/64	—	—	0.046 9	1.191
—	—	—	1.20	0.047 2	1.200
—	—	—	1.25	0.049 2	1.250
—	—	—	1.30	0.051 2	1.300
55	—	—	—	0.052 0	1.321
—	—	—	1.35	0.053 1	1.350
54	—	—	—	0.055 0	1.397
—	—	—	1.40	0.055 1	1.400
—	—	—	1.45	0.057 1	1.450
—	—	—	1.50	0.059 1	1.500
53	—	—	—	0.059 5	1.511
—	—	—	1.55	0.061 0	1.550
—	1/16	—	—	0.062 5	1.587
—	—	—	1.60	0.063 0	1.600
52	—	—	—	0.063 5	1.613
—	—	—	1.65	0.065 0	1.650
—	—	—	1.70	0.066 9	1.700
51	—	—	—	0.067 0	1.702
—	—	—	1.75	0.068 9	1.750
50	—	—	—	0.070 0	1.778
—	—	—	1.80	0.070 9	1.800
—	—	—	1.85	0.072 8	1.850
49	—	—	—	0.073 0	1.854

(*continued*)

1.5 (*continued*)

Drill designation				*Size*	
Number	*Fraction*	*Letter*	*Metric*	Inches	mm
—	—	—	1.90	0.074 8	1.900
48	—	—	—	0.076 0	1.930
—	—	—	1.95	0.076 8	1.950
—	5/64	—	—	0.078 1	1.984
47	—	—	—	0.078 5	1.994
—	—	—	2.00	0.078 7	2.000
—	—	—	2.05	0.080 7	2.050
46	—	—	—	0.081 0	2.057
45	—	—	—	0.082 0	2.083
—	—	—	2.10	0.082 7	2.100
—	—	—	2.15	0.084 6	2.150
44	—	—	—	0.086 0	2.184
—	—	—	2.20	0.086 6	2.200
—	—	—	2.25	0.088 6	2.250
43	—	—	—	0.089 0	2.261
—	—	—	2.30	0.090 6	2.300
—	—	—	2.35	0.092 5	2.350
42	—	—	—	0.093 5	2.375
—	3/32	—	—	0.093 7	2.380
—	—	—	2.40	0.094 5	2.400
41	—	—	—	0.096 0	2.438
—	—	—	2.45	0.096 5	2.450
40	—	—	—	0.098 0	2.489
—	—	—	2.50	0.098 4	2.500
39	—	—	—	0.099 5	2.527
38	—	—	—	0.101 5	2.578
—	—	—	2.60	0.102 4	2.600
37	—	—	—	0.104 0	2.642
—	—	—	2.70	0.106 3	2.700
36	—	—	—	0.106 5	2.705
—	—	—	2.75	0.108 3	2.750
—	7/64	—	—	0.109 4	2.779
35	—	—	—	0.110 0	2.794
—	—	—	2.80	0.110 2	2.800
34	—	—	—	0.111 0	2.819
33	—	—	—	0.113 0	2.870
—	—	—	2.90	0.114 2	2.900
32	—	—	—	0.116 0	2.946
—	—	—	3.00	0.118 1	3.000
31	—	—	—	0.120 0	3.048

—	—	—	3.10	0.122 0	3.100
—	1/8	—	—	0.125 0	3.175
—	—	—	3.20	0.126 0	3.200
—	—	—	3.25	0.128 0	3.250
30	—	—	—	0.128 5	3.264
—	—	—	3.30	0.129 9	3.300
—	—	—	3.40	0.133 9	3.400
29	—	—	—	0.136 0	3.454
—	—	—	3.50	0.137 8	3.500
28	—	—	—	0.140 5	3.569
—	9/64	—	—	0.140 6	3.571
—	—	—	3.60	0.141 7	3.600
27	—	—	—	0.144 0	3.658
—	—	—	3.70	0.145 7	3.700
26	—	—	—	0.147 0	3.734
—	—	—	3.75	0.147 6	3.750
25	—	—	—	0.149 5	3.797
—	—	—	3.80	0.149 6	3.800
24	—	—	—	0.152 0	3.861
—	—	—	3.90	0.153 5	3.900
23	—	—	—	0.154 0	3.912
—	5/32	—	—	0.156 2	3.967
22	—	—	—	0.157 0	3.998
—	—	—	4.00	0.157 5	4.000
21	—	—	—	0.159 0	4.039
20	—	—	—	0.161 0	4.089
—	—	—	4.10	0.161 4	4.100
—	—	—	4.20	0.165 4	4.200
19	—	—	—	0.166 0	4.216
—	—	—	4.25	0.167 3	4.250
—	—	—	4.30	0.163 9	4.300
18	—	—	—	0.169 5	4.305
—	11/64	—	—	0.171 9	4.366
17	—	—	—	0.173 0	4.394
—	—	—	4.40	0.173 2	4.400
16	—	—	—	0.177 0	4.496
—	—	—	4.50	0.177 2	4.500
15	—	—	—	0.180 0	4.572
—	—	—	4.60	0.181 1	4.600
14	—	—	—	0.182 0	4.623
13	—	—	4.70	0.185 0	4.700
—	—	—	4.75	0.187 0	4.750
—	3/16	—	—	0.187 5	4.762

(*continued*)

1.5 (*continued*)

Drill designation				*Size*	
Number	*Fraction*	*Letter*	*Metric*	Inches	mm
12	—	—	4.80	0.1890	4.800
11	—	—	—	0.1910	4.851
—	—	—	4.90	0.1929	4.900
10	—	—	—	0.1935	4.915
9	—	—	—	0.1960	4.978
—	—	—	5.00	0.1968	5.000
—	—	—	5.05	0.1990	5.050
8	—	—	—	0.2000	5.080
—	—	—	5.10	0.2008	5.100
7	—	—	—	0.2010	5.105
—	13/64	—	—	0.2031	5.159
6	—	—	—	0.2040	5.182
—	—	—	5.20	0.2047	5.200
5	—	—	—	0.2055	5.220
—	—	—	5.25	0.2067	5.250
—	—	—	5.30	0.2087	5.300
4	—	—	—	0.2090	5.309
—	—	—	5.40	0.2126	5.400
3	—	—	—	0.2130	5.410
—	—	—	5.50	0.2165	5.500
—	7/32	—	—	0.2187	5.555
—	—	—	5.60	0.2205	5.600
2	—	—	—	0.2210	5.613
—	—	—	5.70	0.2244	5.700
—	—	—	5.75	0.2264	5.750
1	—	—	—	0.2280	5.791
—	—	—	5.80	0.2283	5.800
—	—	—	5.90	0.2323	5.900
—	—	A	—	0.2340	5.944
—	15/64	—	—	0.2344	5.954
—	—	—	6.00	0.2362	6.000
—	—	B	—	0.2380	6.045
—	—	—	6.10	0.2402	6.100
—	—	C	—	0.2420	6.147
—	—	—	6.20	0.2441	6.200
—	—	D	—	0.2460	6.248
—	—	—	6.25	0.2461	6.250
—	—	—	6.30	0.2480	6.300
—	1/4	E	—	0.2500	6.350
—	—	—	6.40	0.2520	6.400

—	—	—	6.50	0.255 9	6.500
—	—	F	—	0.257 0	6.528
—	—	—	6.60	0.259 8	6.600
—	—	G	—	0.261 0	6.629
—	—	—	6.70	0.263 8	6.700
—	17/64	—	—	0.265 6	6.746
—	—	—	6.75	0.265 7	6.750
—	—	H	—	0.266 0	6.756
—	—	—	6.80	0.267 7	6.800
—	—	—	6.90	0.271 7	6.900
—	—	I	—	0.272 0	6.909
—	—	—	7.00	0.275 6	7.000
—	—	J	—	0.277 0	7.036
—	—	—	7.10	0.279 5	7.100
—	—	K	—	0.281 0	7.137
—	9/32	—	—	0.281 2	7.142
—	—	—	7.20	0.283 4	7.200
—	—	—	7.25	0.285 4	7.250
—	—	—	7.30	0.287 4	7.300
—	—	L	—	0.290 0	7.366
—	—	—	7.40	0.291 3	7.400
—	—	M	—	0.295 0	7.493
—	—	—	7.50	0.295 3	7.500
—	19/64	—	—	0.296 9	7.541
—	—	—	7.60	0.299 2	7.600
—	—	N	—	0.302 0	7.671
—	—	—	7.70	0.303 1	7.700
—	—	—	7.75	0.305 1	7.750
—	—	—	7.80	0.307 1	7.800
—	—	—	7.90	0.311 0	7.900
—	5/16	—	—	0.312 5	7.937
—	—	—	8.00	0.315 0	8.000
—	—	O	—	0.316 0	8.026
—	—	—	8.10	0.318 9	8.100
—	—	—	8.20	0.322 8	8.200
—	—	P	—	0.323 0	8.204
—	—	—	8.25	0.324 8	8.250
—	—	—	8.30	0.326 8	8.300
—	21/64	—	—	0.328 1	8.334
—	—	—	8.40	0.330 7	8.400
—	—	Q	—	0.332 0	8.433
—	—	—	8.50	0.334 6	8.500
—	—	—	8.60	0.338 6	8.600
—	—	R	—	0.339 0	8.611

(*continued*)

1.5 (*continued*)

Drill designation				*Size*	
Number	*Fraction*	*Letter*	*Metric*	Inches	mm
—	—	—	8.70	0.342 5	8.700
—	11/32	—	—	0.343 7	8.730
—	—	—	8.75	0.344 5	8.750
—	—	—	8.80	0.346 5	8.800
—	—	S	—	0.348 0	8.839
—	—	—	8.90	0.350 4	8.900
—	—	—	9.00	0.354 3	9.000
—	—	T	—	0.358 0	9.093
—	—	—	9.10	0.358 3	9.100
—	23/64	—	—	0.359 4	9.129
—	—	—	9.20	0.362 2	9.200
—	—	—	9.25	0.364 2	9.250
—	—	—	9.30	0.366 1	9.300
—	—	U	—	0.368 0	9.347
—	—	—	9.40	0.370 1	9.400
—	—	—	9.50	0.374 0	9.500
—	3/8	—	—	0.375 0	9.525
—	—	V	—	0.377 0	9.576
—	—	—	9.60	0.378 0	9.600
—	—	—	9.70	0.381 9	9.700
—	—	—	9.75	0.383 9	9.750
—	—	—	9.80	0.385 8	9.800
—	—	W	—	0.386 0	9.804
—	—	—	9.90	0.389 8	9.900
—	25/64	—	—	0.390 6	9.921
—	—	—	10.00	0.393 7	10.000
—	—	X	—	0.397 0	10.084
—	—	—	10.10	0.397 6	10.100
—	—	—	10.25	0.403 5	10.250
—	—	Y	—	0.404 0	10.262
—	13/32	—	—	0.406 2	10.317
—	—	Z	—	0.413 0	10.490
—	—	—	10.50	0.413 4	10.500
—	27/64	—	—	0.421 9	10.716
—	—	—	10.75	0.423 2	10.750
—	—	—	11.00	0.433 1	11.000
—	7/16	—	—	0.437 5	11.112
—	—	—	11.25	0.442 9	11.250
—	—	—	11.50	0.452 8	11.500

—	29/64	—	—	0.453 1	11.509
—	—	—	11.75	0.462 6	11.750
—	15/32	—	—	0.468 7	11.905
—	—	—	12.00	0.472 4	12.000
—	—	—	12.25	0.482 3	12.250
—	31/64	—	—	0.484 4	12.304
—	—	—	12.50	0.492 1	12.500
—	1/2	—	—	0.500 0	12.700
—	—	—	12.75	0.502 0	12.750

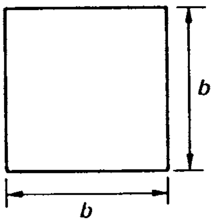
1.6 Wire gauge equivalents

Standard Wire Gauge (SWG) for sheet metal, wire and rods.

SWG No.	*Size*, in	*Size*, mm	*SWG No.*	*Size*, in	*Size*, mm
1	0.300	7.62	16	0.064	1.62
2	0.276	7.06	17	0.056	1.42
3	0.252	6.40	18	0.048	1.22
4	0.232	5.89	19	0.040	1.02
5	0.212	5.38	20	0.036	0.91
6	0.192	4.88	21	0.032	0.81
7	0.176	4.46	22	0.028	0.71
8	0.160	4.06	23	0.024	0.61
9	0.144	3.66	24	0.022	0.56
10	0.128	3.24	25	0.020	0.51
11	0.116	2.94	26	0.018	0.46
12	0.104	2.64	27	0.016	0.41
13	0.092	2.34	28	0.014 8	0.376
14	0.080	2.03	29	0.013 6	0.345
15	0.072	1.83	30	0.012	0.304

1.7 Mensuration of plane figures

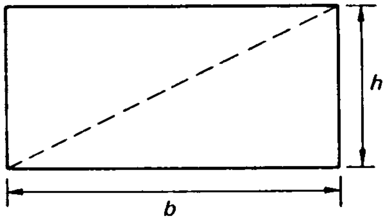
Square



$$\text{area} = b^2$$

$$\text{length of diagonal} = \sqrt{(2)} \times b$$

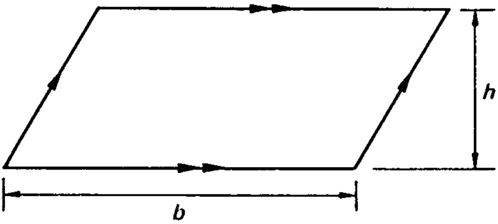
Rectangle



$$\text{area} = b \times h$$

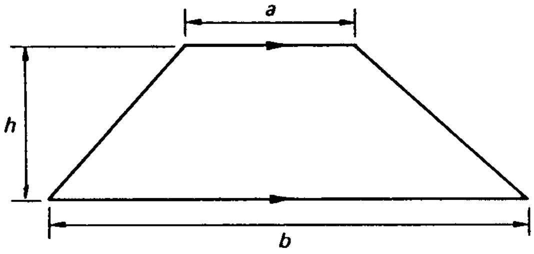
$$\text{length of diagonal} = \sqrt{(b^2 + h^2)}$$

Parallelogram



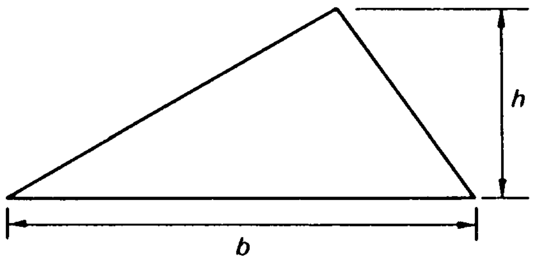
$$\text{area} = b \times h$$

Trapezium



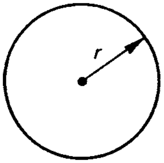
$$\text{area} = \tfrac{1}{2} \times (a + b) \times h$$

Triangle



$$\text{area} = \tfrac{1}{2} \times b \times h$$

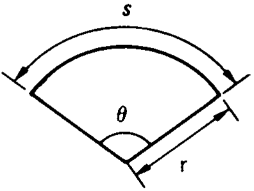
Circle



$$\text{area} = \pi \times r^2$$

$$\text{perimeter} = 2 \times \pi \times r$$

Sector of circle

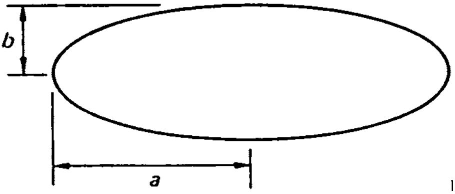


$$\text{area} = \frac{1}{2} \times r^2 \times \theta$$

$$\text{arc length } s = r \times \theta$$

(θ is in radians)

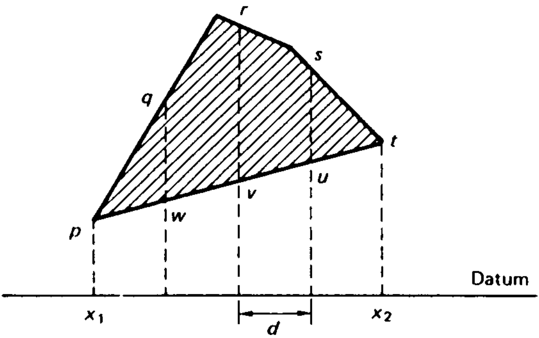
Ellipse



$$\text{area} = \pi \times a \times b$$

$$\text{perimeter} = \pi \times (a + b)$$

Irregular plane



Several methods are used to find the shaded area, such as the mid-ordinate rule, the trapezoidal rule and

Simpon's rule. As an example of these, Simpson's rule is as shown. Divide x_1x_2 into an even number of equal parts of width d. Let p, q, r, ... be the lengths of vertical lines measured from some datum, and let A be the approximate area of the irregular plane, shown shaded. Then

$$A = \frac{d}{3}[(p+t) + 4(q+s) + 2r] - \frac{d}{3}[(p+t) + 4(u+w) + 2v]$$

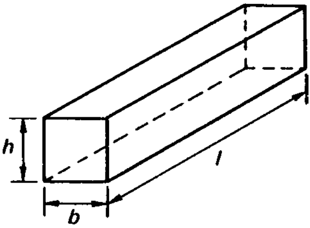
In general, the statement of Simpson's rule is

approximate area = $(d/3) \times$ [(first + last) + 4 $\times$ (sum of evens) + 2 $\times$ (sum of odds)]

where first, last, evens, odds refer to ordinate lengths and d is the width of the equal parts of the datum line.

1.8 Mensuration of solids

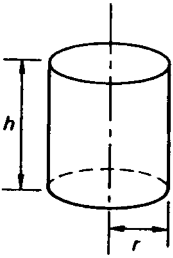
Rectangular prism



$$\text{volume} = bhl$$

$$\text{total surface area} = 2(bh + hl + lb)$$

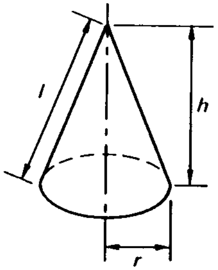
Cylinder



$$\text{volume} = \pi r^2 h$$

$$\text{total surface area} = 2\pi r(r + h)$$

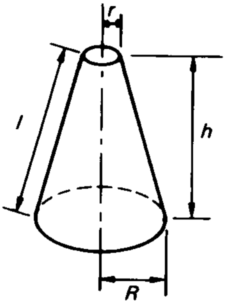
Cone



$$\text{volume} = (1/3)\pi r^2 h$$

$$\text{total surface area} = \pi r(l + r)$$

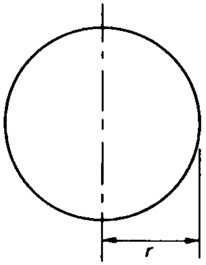
Frustrum of cone



$$\text{volume} = (1/3)\pi h(R^2 + Rr + r^2)$$

$$\text{total surface area} = \pi l(R + r) + \pi(R^2 + r^2)$$

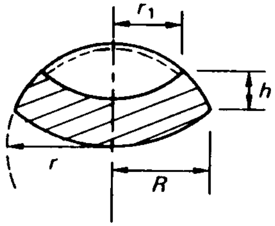
Sphere



$$\text{volume} = (4/3)\pi r^3$$

$$\text{total surface area} = 4\pi r^2$$

Zone of sphere

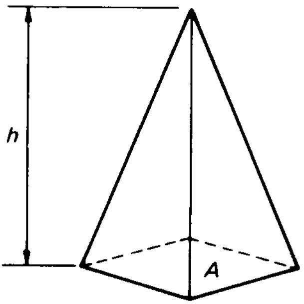


$$\text{volume} = (\pi h/6)(h^2 + 3R^2 + 3r_1^2)$$

$$\text{total surface area} = 2\pi rh + \pi(R^2 + r_1^2)$$

where r is the radius of the sphere

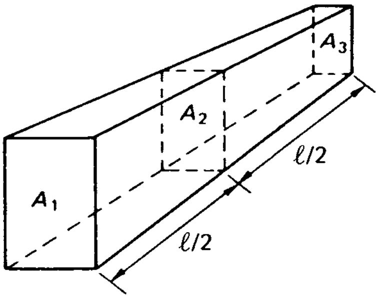
Pyramid



$$\text{volume} = (1/3)Ah$$

where A is the area of the base and h is the perpendicular height

Regular solids

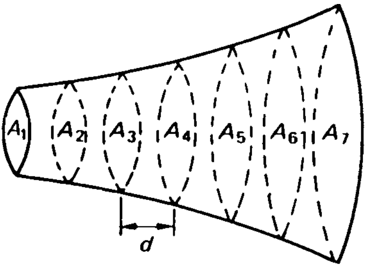


The volume of any regular solid can be found by using the prismoidal rule. Three parallel planes of areas A_1, A_3, A_2, are considered to be at the ends and at the centre of the solid respectively. Then

$$\text{volume} = (l/6)(A_1 + 4A_2 + A_3)$$

where l is the length of the solid.

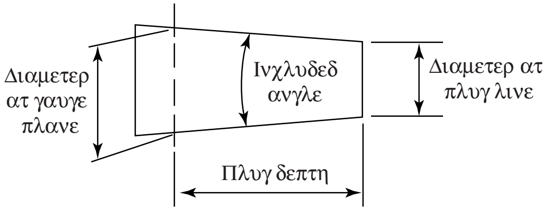
Irregular solids



Various methods can be used to determine volumes of irregular solids; one of these is by applying the principles of Simpson's rule (see Section 1.7). The solid is considered to be divided into an even number of sections by equally spaced, parallel planes, distance d apart and having areas of $A_1, A_2, A_3, \ldots$. Assuming, say, seven such planes, then approximate volume $= (d/3)[(A_1 + A_7) + 4(A_2 + A_4 + A_6) + 2(A_3 + A_5)]$.

1.9 Taper systems (metric units)

1.9.1 Self-holding tapers



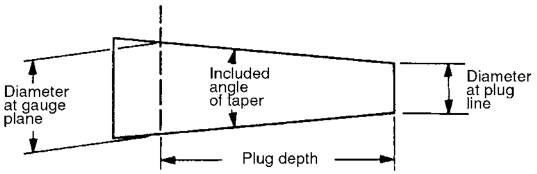
Taper designation	Taper ratio	Included angle of taper	Diameter at gauge plane	Plug depth	Diameter at plug line
No. 4 metric 5%	1:20 = 0.05	2°51.85′	4.0	23.0	2.9
No. 6 metric 5%	1:20 = 0.05	2°51.85′	6.0	32.0	4.4
No. 0 Morse	1:19.212 = 0.052 05	2°52.54′	9.045	50.0	6.4
No. 1 Morse	1:20.047 = 0.049 88	2°51.45′	12.065	53.5	9.4
No. 2 Morse	1:20.020 = 0.049 95	2°51.68′	17.780	64.0	14.6
No. 3 Morse	1:19.922 = 0.050 20	2°52.52′	23.825	81.0	19.8
No. 4 Morse	1:19.254 = 0.051 94	2°58.51′	31.267	102.5	25.9
No. 5 Morse	1:19.002 = 0.052 63	3°00.87′	44.399	129.5	37.6
No. 6 Morse	1:19.180 = 0.052 14	2°69.19′	63.348	182.0	53.9
No. 1 B & S	1:23.904 = 0.041 83	2°23.79′	6.076	23.813	5.080
No. 2 B & S	1:23.904 = 0.041 83	2°23.79′	7.612	30.163	6.350
No. 3 B & S	1:23.904 = 0.041 83	2°23.79′	9.530	38.100	7.938
No. 80 metric 5%	1:20 = 0.05	2°51.85′	80.0	196.0	70.2
No. 100 metric 5%	1:20 = 0.05	2°51.85′	100.0	232.0	88.4
No. 120 metric 5%	1:20 = 0.05	2°51.85′	120.0	268.0	106.6
No. 160 metric 5%	1:20 = 0.05	2°51.85′	160.0	340.0	143.0
No. 200 metric 5%	1:20 = 0.05	2°51.85′	200.0	412.0	179.4

Note: B & S = Brown and Sharpe taper system.

1.9.2 Quick-release tapers (milling machine tapers for spindle nozes)

Taper designation	*Taper ratio*	*Included angle of taper*	*Diameter at gauge plane*	*Plug depth*	*Diameter at plug line*
No. 30 MMT	7:24	16°35.68′	31.75	47.625	17.859
No. 40 MMT	7:24	16°35.68′	44.45	68.250	24.539
No. 50 MMT	7:24	16°35.68′	69.85	101.600	40.208
No. 60 MMT	7:24	16°35.68′	107.95	161.925	60.721

1.10 Taper systems (inch units)



1.10.1 Self-holding tapers

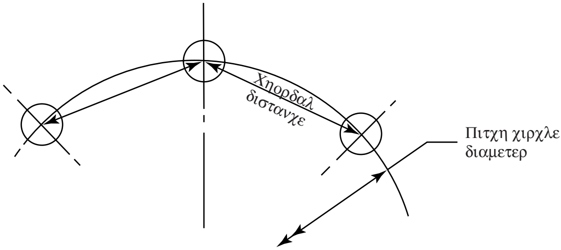
Designation of taper	*Taper per foot on diameter*	*Taper per inch on diameter*	*Included angle of taper*	*Diameter at gauge plane*	*Plug depth*	*Diameter at plug line*
No. 2 metric	0.600 0	0.050 0	2°51.85′	0.078 7 (2 mm)	0.472 4 (12 mm)	0.055 1
No. 3 metric	0.600 0	0.050 0	2°51.85′	0.118 1 (3 mm)	0.669 3 (17 mm)	0.084 6
No. 4 metric	0.600 0	0.050 0	2°51.85′	0.157 5 (4 mm)	0.905 5 (23 mm)	0.112 2
No. 1 B & S	0.502 0	0.041 8	2°23.79′	0.239 2	15/16	0.200 0
No. 2 B & S	0.502 0	0.041 8	2°23.79′	0.299 7	13/16	0.250 0
No. 3 B & S	0.502 0	0.041 8	2°23.79′	0.375 2	11/2	0.312 5
No. 1 Morse	0.598 6	0.049 9	2°51.45′	0.475 0	21/8	0.369 0
No. 2 Morse	0.599 4	0.049 9	2°51.68′	0.700 0	29/16	0.572 0
No. 3 Morse	0.602 3	0.050 2	2°52.52′	0.938 0	33/16	0.778 0
No. 4 Morse	0.623 3	0.051 9	2°58.51′	1.231 0	41/16	1.020 0
No. 5 Morse	0.631 5	0.052 6	3°00.87′	1.748 0	53/16	1.475 0
No. 6 Morse	0.625 6	0.052 1	2°59.19′	2.494 0	71/4	2.116 0

Note: B & S = Brown and Sharpe taper system.

1.10.2 Quick-release tapers (milling machines)

Designation of taper	*Taper per foot on diameter*	*Taper per inch on diameter*	*Included angle of taper*	*Diameter at gauge plane*	*Plug depth*	*Diameter at plug line*
No. 30 MMT	3.500	0.291 7	16°35.56′	1.250	1.875	0.703 1
No. 40 MMT	3.500	0.291 7	16°35.56′	1.750	2.687	0.966 1
No. 50 MMT	3.500	0.291 7	16°35.56′	2.750	4.000	1.583 3
No. 60 MMT	3.500	0.291 7	16°35.56′	4.250	6.375	2.390 6

1.11 Chordal distances on pitch circles



To calculate the chordal distance, for any given number of chords, multiply the pitch circle diameter by the factor given in the following table.

Example 1.11.1

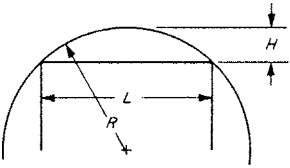
Calculate the chordal distance for the equal spacing of 8 holes (8 chords) on a pitch circle of 100 mm diameter.

From the table the factor for 8 chords is 0.382 7, therefore the chordal distance = 100 mm × 0.382 7 = <u>38.27 mm</u>

No. of chords	*Multiply dia. by*	*No. of chords*	*Multiply dia. by*	*No. of chords*	*Multiply dia. by*	*No. of chords*	*Multiply dia. by*	*No. of chords*	*Multiply dia. by*
3	0.866 0	23	0.136 2	43	0.073 0	63	0.049 9	83	0.037 8
4	0.707 1	24	0.130 5	44	0.071 3	64	0.049 1	84	0.037 4
5	0.587 8	25	0.125 3	45	0.069 8	65	0.048 3	85	0.037 0
6	0.500 0	26	0.120 5	46	0.068 2	66	0.047 6	86	0.036 5
7	0.433 9	27	0.116 1	47	0.066 8	67	0.046 9	87	0.036 1
8	0.382 7	28	0.112 0	48	0.065 4	68	0.046 2	88	0.035 7
9	0.342 0	29	0.108 1	49	0.064 1	69	0.045 5	89	0.035 3
10	0.309 0	30	0.104 5	50	0.062 8	70	0.044 9	90	0.034 9
11	0.281 7	31	0.101 2	51	0.061 6	71	0.044 2	91	0.034 5
12	0.258 8	32	0.098 0	52	0.060 4	72	0.043 6	92	0.034 1
13	0.239 3	33	0.095 1	53	0.059 2	73	0.043 0	93	0.033 8
14	0.222 5	34	0.092 3	54	0.058 1	74	0.042 4	94	0.033 4
15	0.207 9	35	0.089 6	55	0.057 1	75	0.041 9	95	0.033 1
16	0.195 1	36	0.087 2	56	0.056 1	76	0.041 3	96	0.032 7
17	0.183 8	37	0.084 8	57	0.055 1	77	0.040 8	97	0.032 4
18	0.173 6	38	0.082 6	58	0.054 1	78	0.040 3	98	0.032 1
19	0.164 6	39	0.080 5	59	0.053 2	79	0.039 8	99	0.031 7
20	0.156 4	40	0.078 5	60	0.052 3	80	0.039 3	100	0.031 4
21	0.149 0	41	0.076 5	61	0.051 5	81	0.038 8		
22	0.142 3	42	0.074 7	62	0.050 7	82	0.038 3		

1.12 Useful workshop formulae

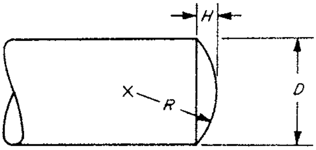
1.12.1 Heights above keyways



$$H = R - \sqrt{\left(R^2 - \frac{L^2}{4}\right)}$$

$$L = \sqrt{[4H(2R - H)]}$$

1.12.2 Radii on bolt ends

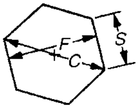


$$H = R - \sqrt{\left(R^2 - \frac{D^2}{4}\right)}$$

$$R = \frac{D^2 + 4H^2}{8H}$$

$$D = \sqrt{[4H(2R - H)]}$$

1.12.3 Hexagon: distance across corners



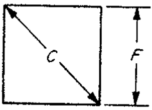
$$C = F \times 1.155$$

$$F = C \times 0.866$$

$$S = \frac{C}{2}$$

where: F = distance across flats (A/F)
C = distance across corners

1.12.4 Square: distance across corners

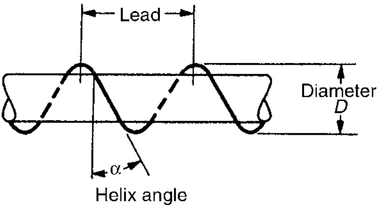


$$F = C \times 0.707$$

$$C = F \times 1.414$$

1.12.5 Helix angles

$$\tan \alpha = \frac{\text{lead}}{\pi \times D}$$



1.12.6 Cutting speeds (inch units)

$$N = \frac{12S}{\pi d}$$

where: N = spindle speed in rev/min
S = cutting speed in ft/min
d = cutter or work diameter (in)
$\pi = 3.142$

1.12.7 Cutting speeds (metric units)

$$N = \frac{1000S}{\pi d}$$

where: N = spindle speed in rev/min
S = cutting speed in m/min
d = cutter or work diameter (mm)
$\pi = 3.142$

1.12.8 Typical cutting speeds for HSS tools

Material	*ft/min*	*m/min*
Aluminum	230–325	70–100
Brass	115–165	35–50
Bronze (phosphor)	65–115	20–35
Cast iron (grey)	80–130	25–40
Copper	115–145	35–45
Steel (mild)	95–130	30–40
Steel (medium carbon)	65–95	20–30
Steel (alloy: high-tensile)	15–25	5–8
Thermosetting plastics (Low speed due to abrasive properties of the filter material.)	65–95	20–30

- For carbide tipped tools, see manufacturers' literature.
- If the calculated spindle speed is not available on the machine gearbox, always use the next lower speed, never use a higher speed.
- The above are average values when using a coolant. Experience may show that under some circumstances higher or lower speeds may be desirable.

Example 1.12.1

Calculate the spindle speed when turning a grey iron casting 12 inches diameter using a high-speed steel cutting tool.

$$
\begin{aligned}
N &= \frac{12S}{\pi d} \\
&= \frac{12 \times 90}{3.142 \times 12} \\
&\simeq \underline{29\,\text{rev/min}}
\end{aligned}
$$

where: $S = 90$ ft/min (previous table)
$d = 12$ inches

Since the nearest gearbox speed lower than this would be selected $\pi = 3$ would be a suitable approximation and the answer would then be 30 rev/min.

Example 1.12.2

Calculate the spindle speed in rev/min for a high-speed steel drill 12 mm diameter, cutting mild steel.

$$N = \frac{1000S}{\pi d}$$

where: $N =$ spindle speed in rev/min
$S =$ cutting speed in m/min
$d =$ drill diameter (mm)
$\pi = 3.14$

From the above table, a suitable cutting speed (S) for mild steel is 30 m/min, thus:

$$
\begin{aligned}
N &= \frac{1000 \times 30}{3.14 \times 12} \\
& \underline{796.2\,\text{rev/min}}
\end{aligned}
$$

A spindle speed between 750 and 800 rev/min would be satisfactory.

To avoid having to make calculations under workshop conditions the following tables may be found helpful.

Inch Series			CUTTING SPEEDS Approximate					Inch Series
Ft/min	30	40	50	60	70	80	90	100
M/min	9	12	15	18	21	24	27	30
Dia. Ins.				*Revolutions per minute*				
1/64	7328	9760	12 224	14 656	17 088	19 520	22 000	24 448
1/32	3664	4880	6112	7328	8544	9760	10 998	12 224
3/64	2448	3264	4064	4896	5696	6528	7328	8130
1/16	1832	2440	3056	3664	4272	4880	5496	6112
5/64	1464	1952	2448	2928	3424	3904	4400	4896
3/32	1224	1632	2032	2448	2848	3264	3664	4078
1/8	916	1220	1528	1832	2136	2440	2750	3056
5/32	732	976	1224	1464	1712	1952	2200	2448
3/16	612	816	1016	1224	1424	1632	1832	2040
7/32	524	700	872	1048	1224	1400	1570	1744
1/4	458	610	764	916	1068	1220	1376	1528
5/16	366	488	612	732	856	976	1100	1224
3/8	306	408	508	612	712	816	916	1020
7/16	262	350	436	524	612	700	784	872

(*continued*)

(*continued*)

Inch Series				**CUTTING SPEEDS** Approximate				Inch Series
Ft/min	30	40	50	60	70	80	90	100
M/min	9	12	15	18	21	24	27	30
Dia. Ins.				*Revolutions per minute*				
$^{1}/_{2}$	229	305	382	458	534	610	688	764
$^{9}/_{16}$	204	272	340	408	476	544	612	680
$^{5}/_{8}$	183	244	306	366	428	488	550	612
$^{11}/_{16}$	167	222	278	334	388	444	500	556
$^{3}/_{4}$	153	204	254	306	356	408	458	510
$^{13}/_{16}$	141	188	234	282	330	376	424	470
$^{7}/_{8}$	131	175	218	262	306	350	392	436
$^{15}/_{16}$	122	163	204	244	286	326	366	408
1	114	152	191	229	267	305	344	382
$1\,^{1}/_{8}$	102	136	170	204	238	272	306	340
$1\,^{1}/_{4}$	91.5	122	153	183	214	244	275	306
$1\,^{3}/_{8}$	83.5	111	139	167	194	222	250	278
$1\,^{1}/_{2}$	76.5	102	127	153	178	204	229	255
$1\,^{5}/_{8}$	70.5	94	117	141	165	188	212	235

1 3/4	65.5	87.5	109	131	153	175	196	218
1 7/8	61	81.5	102	122	143	163	183	204
2	57.5	76.5	95.5	114	133	152	172	191
2 1/8	54	72	90	108	126	144	162	180
2 1/4	51	68	85.5	102	119	136	153	170
2 3/8	48.5	64.5	80.5	96.5	113	129	145	161
2 1/2	46	61	76.5	91.5	107	122	138	153
2 5/8	43.5	58	72.5	87	102	116	131	145
2 3/4	41.5	55.5	69.5	83.5	97	111	125	139
2 7/8	39.5	53	66	79	92.5	106	119	132
3	38	51	63.5	76.5	89	102	114	127
3 1/4	35	47	58.5	70	82	93.5	105	117
3 1/2	32.5	43.5	54.5	65.5	76.5	87.5	98	109
3 3/4	30.5	41	51	61	71.5	81.5	92	102
4	28.5	38	48	57.5	67	76.5	86	95.5
5	23	30.5	38	46	53.5	61	69	76.5
6	19	25.5	32	38	44.5	51	57	63.5
7	16.5	22	27.5	32.5	38	43.5	49	54.5
8	14.5	19	24	28.5	33.5	38	43	48
9	12.5	17	21	25.5	29.5	34	38	42.5

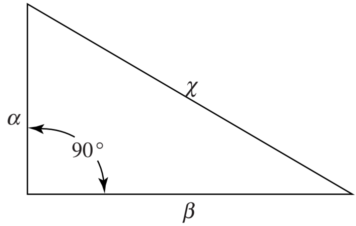
CUTTING SPEEDS
Approximate

Metric Series								Metric Series
Ft/min	30	40	50	60	70	80	90	100
M/min	9	12	15	18	21	24	27	30
Dia. mm	*Revolutions per minute*							
0.5	5817	7756	9695	11634	13573	15512	17451	19390
1.0	2909	3878	4847	5817	6786	7756	8725	9695
1.5	1942	2589	3237	3884	4532	5179	5826	6474
2.0	1456	1942	2427	2912	3397	3883	4369	4854
3.0	970	1294	1617	1940	2264	2587	2911	3234
4.0	728	970	1213	1455	1698	1940	2183	2425
5.0	582	777	970	1164	1359	1553	1747	1941
6.0	485	647	808	970	1132	1294	1455	1617
7.0	416	555	693	832	970	1109	1248	1386
8.0	364	485	606	728	849	970	1091	1213
9.0	324	431	539	647	755	862	970	1078
10.0	291	388	485	582	679	776	873	970
11.0	265	353	441	529	617	706	794	882

12.0	243	324	404	485	566	647	728	808
13.0	224	299	373	448	522	597	672	746
14.0	208	277	346	416	485	554	623	693
15.0	194	259	323	388	453	517	582	647
16.0	182	243	303	364	424	485	546	606
17.0	171	228	285	342	399	456	513	571
18.0	162	216	269	323	377	431	485	539
19.0	153	204	255	306	357	408	459	511
20.0	146	194	242	291	340	388	436	485
21.0	139	185	231	277	323	370	416	462
22.0	133	177	220	265	309	353	397	441
23.0	127	169	211	253	295	337	380	422
24.0	121	162	202	242	283	323	364	404
25.0	117	155	194	233	272	310	349	388

1.13 Solution of triangles

1.13.1 Pythagoras



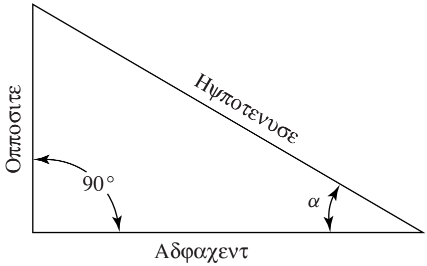
$$c^2 = a^2 + b^2 \text{ or } c = \sqrt{(a^2 + b^2)}$$
$$a^2 = c^2 - b^2 \text{ or } a = \sqrt{(c^2 - b^2)}$$
$$b^2 = c^2 - a^2 \text{ or } b = \sqrt{(c^2 - a^2)}$$

e.g. Let $a = 3$, $b = 4$ and $c = 5$

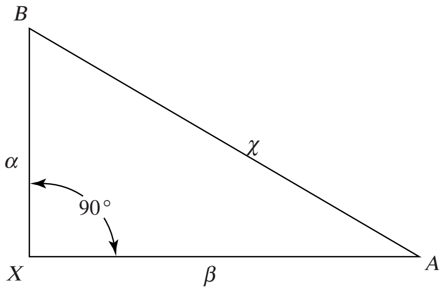
Then $3^2 + 4^2 = 5^2$ or $9 + 16 = 25$

Note: The 3 : 4 : 5 ratio is useful for setting out square carrier.

1.13.2 Trigonometry (right-angled triangles)



$$\text{Sine } \alpha = \frac{\text{opposite}}{\text{hypotenuse}}$$
$$\text{Cosine } \alpha = \frac{\text{adjacent}}{\text{hypotenuse}}$$
$$\text{Tangent } \alpha = \frac{\text{opposite}}{\text{adjacent}}$$



Sin A $= a/c$ $\quad a = b \times \tan A \quad c = \dfrac{a}{\sin A}$

Sin B $= b/c$ $\quad a = c \times \cos B$

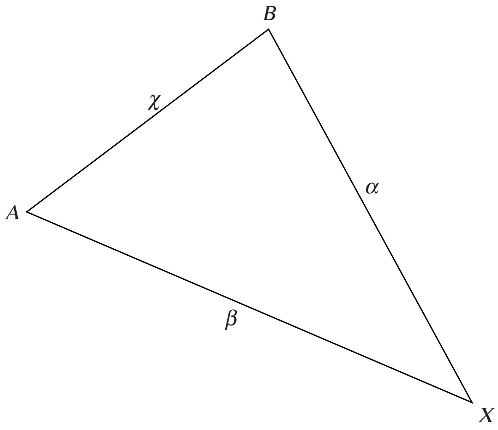
Cos A $= b/c$ $\quad a = c \times \sin A$

Cos B $= a/c$ $\quad b = c \times \tan B \quad C = \dfrac{b}{\cos A}$

Tan A $= a/b$ $\quad b = c \times \cos A$

Tan B $= b/a$ $\quad b = c \times \sin B$

1.13.3 Trigonometry (any triangle)



(i) cosine rule

$$a^2 = b^2 + c^2 - 2bc\cos A$$

$$b^2 = a^2 + c^2 - 2ac\cos B$$

$$c^2 = b^2 + a^2 - 2ab\cos C$$

(ii) sine rule

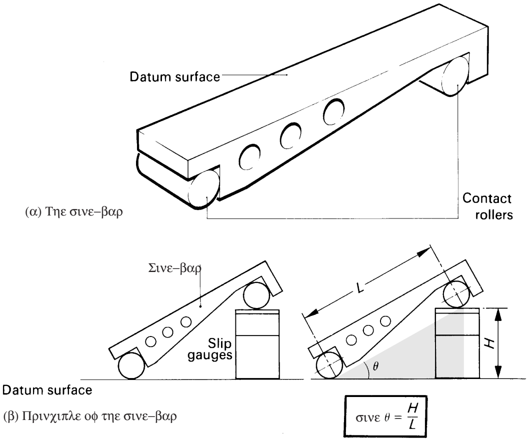
$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}, \text{ e.g. } \sin A = \frac{a\sin B}{b}$$

(iii) Area

$$\text{Area} = \tfrac{1}{2}ab\sin C = \tfrac{1}{2}bc\sin A$$
$$= \tfrac{1}{2}ca\sin B$$

Also: $$\text{Area} = \sqrt{[s(s-a)(s-b)(s-c)]}$$
$$\text{where } s = \tfrac{1}{2}(a+b+c)$$

1.14 Sine-bar (principle)



(α) Τηε σινε–βαρ

(β) Πρινχιπλε οφ τηε σινε–βαρ

The *sine-bar* provides a simple means of measuring angles to a high degree of accuracy. Figure (a), above, shows a typical sine-bar, and for accurate results it is essential that:

(a) the contact rollers must be of equal diameter and true geometric cylinders;
(b) the distance between the roller axes must be precise and known, and these axes must be mutually parallel;
(c) the upper surface of the bar must be flat and parallel with the roller axes, and equidistant from each.

The principle of the sine-bar is shown in Fig. (b) above. The sine-bar, slip gauges and datum surface on which they stand form a right-angled triangle. The sine-bar itself forms the hypotenuse of that triangle and the slip gauges form the side *opposite* the required angle.

$$\text{Since: sine } \theta = \frac{\text{opposite side}}{\text{hypotenuse}}$$

$$\text{Then: sine } \theta = \frac{\text{height of slip gauges}}{\text{length of sine-bar}}$$

$$= \frac{H}{L}$$

Example 1.14.1

Calculate the slip gauges required to give an angle of 25° when using a 250 mm sine-bar.

$$\text{sine } \theta = \frac{H}{L}$$

$$H = L \text{ sine } \theta$$

$$= 250 \times 0.4226$$

$$= \underline{105.65\,\text{mm}}$$

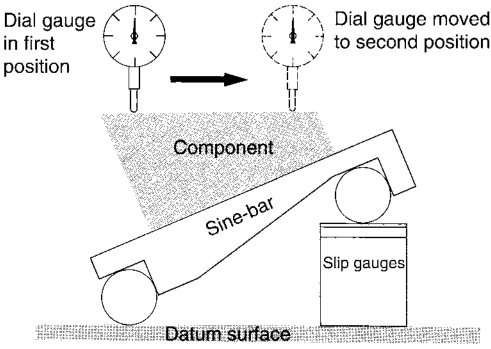
where: $\theta = 25°$

$L = 250\,\text{mm}$

Note: The four-figure mathematical tables used by students are only of limited accuracy. Except when working examples for practice, always use an electronic calculator or the ready-worked *sine-bar constants* found in Section 1.16.

(Courtesy Addison Wesley Longman.)

1.15 Sine-bar (use of)



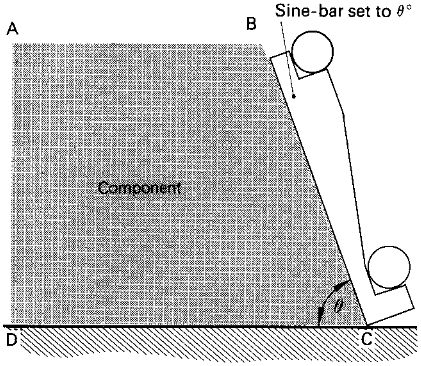
The above figure shows how the sine-bar is used to check small components that may be mounted upon it. The dial test indicator (DTI) is mounted upon a suitable stand such as a universal surface gauge (scribing block) or a vernier height gauge (the latter is more rigid and gives more consistant readings). It is moved over the component into the first position as shown above and zeroed. The stand and DTI is then slid along the datum surface to the second position as shown and the DTI reading is noted.

Method 1
The height of the slip gauges is adjusted until the DTI reads zero at both ends of the component. The actual angle is then calculated as explained in Example 1.14.1 and any deviation from the specified angle is the error.

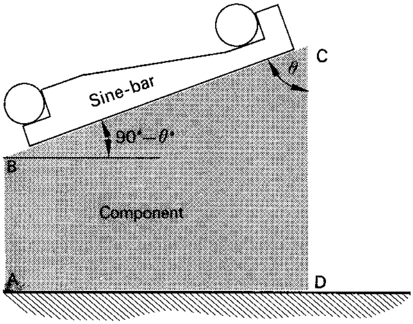
Method 2
The sine-bar is set to the specified angle. The DTI will then indicate any error as a 'run' of so many hundredths of a millimetre along the length of the component. Providing the DTI was set to zero in the first position, the error will be shown as a plus or minus reading at the second position.

Examination of natural sine tables will show that as the angle increases, the accuracy of the tables decreases. Therefore, when measuring angles over 45° the component is turned over – if possible – so that the *complementary angle* can be used as shown below. In Fig. (a) the angle $\theta°$ is considerably over 45° and it will not be possible to obtain sufficient accuracy from natural sine tables. In Fig. (b) the component is re-positioned and the sine-bar is set to the complementary angle of $90° - \theta°$. The sine of this smaller angle can be obtained more accurately from the tables and the angle $\theta°$ can be calculated.

(Courtesy of Addison Wesley Longman.)



(a) Incorrect use of sine-bar



(b) Correct use of sine-bar

1.16 Sine-bar constants (250 mm)

Note: For use with a 125 mm sine-bar the following constants are halved.

(Dimensions in millimetres)

Min.	0°	1°	2°	3°	4°	5°	6°	7°	8°
0	0.000 00	4.363 10	8.724 87	13.083 99	17.439 12	21.788 94	26.132 12	30.467 34	34.793 28
1	0.072 72	4.381 25	8.797 56	13.156 61	17.516 64	21.861 38	26.204 44	30.539 52	34.865 29
2	0.145 43	4.508 51	8.870 21	13.229 22	17.584 19	21.933 81	26.276 74	30.616 76	34.937 30
3	0.218 70	4.581 23	8.942 90	13.301 85	17.656 75	22.006 26	26.349 08	30.683 86	35.009 31
4	0.290 90	4.653 96	9.015 60	13.374 48	17.729 30	22.078 72	26.421 41	30.756 05	35.081 32
5	0.363 59	4.726 64	9.088 24	13.447 10	17.801 81	22.151 14	26.493 71	30.828 20	35.153 30
6	0.436 33	4.799 36	9.160 93	13.519 70	17.874 36	22.223 57	26.566 02	30.900 37	35.225 31
7	0.509 06	4.872 21	9.233 614	13.592 32	17.946 89	22.296 01	26.638 32	30.972 53	35.297 30
8	0.581 76	4.944 76	9.306 26	13.664 92	18.019 42	22.368 42	26.710 62	31.044 68	35.369 28
9	0.654 50	5.017 48	9.378 94	13.754 49	18.091 96	22.440 87	26.782 94	31.116 85	35.441 28
10	0.727 23	5.090 21	9.451 63	13.810 16	18.164 51	22.513 31	26.855 25	31.189 02	35.513 29
11	0.799 93	5.162 88	9.524 28	13.882 77	18.237 02	22.585 71	26.927 53	31.261 16	35.585 25
12	0.872 66	5.235 61	9.596 95	13.955 38	18.309 55	22.658 15	26.999 84	31.333 31	35.657 23
13	0.945 40	5.308 31	9.669 62	14.027 99	18.382 08	22.730 57	27.072 14	31.405 46	35.729 21
14	1.018 09	5.381 00	9.742 27	14.100 58	18.454 59	22.802 97	27.144 41	31.477 59	35.801 17

15	1.090 83	5.453 72	9.814 95	14.173 20	18.527 12	22.875 40	27.216 72	31.549 74	35.873 16
16	1.163 56	5.526 44	9.887 63	14.245 82	18.599 66	22.947 84	27.289 02	31.621 89	35.945 14
17	1.236 27	5.599 12	9.960 27	14.318 39	18.672 15	23.020 22	27.361 29	31.694 00	36.017 09
18	1.308 99	5.671 83	10.032 95	14.391 01	18.744 68	23.092 65	27.433 58	31.766 15	36.089 05
19	1.381 73	5.744 54	10.105 61	14.463 61	18.817 21	23.165 06	27.505 86	31.838 28	36.161 01
20	1.454 42	5.817 09	10.178 27	14.536 06	18.889 70	23.237 45	27.578 12	31.910 41	36.232 95
21	1.527 15	5.889 41	10.250 93	14.608 81	18.962 23	23.309 87	27.650 42	31.982 54	36.304 92
22	1.599 89	5.962 66	10.323 61	14.681 42	19.034 75	23.382 29	27.722 71	32.054 68	36.376 88
23	1.672 58	6.035 33	10.396 24	14.753 98	19.107 23	23.454 66	27.794 95	32.126 77	36.448 80
24	1.745 32	6.108 04	10.468 91	14.826 59	19.179 76	23.527 08	27.867 23	32.198 89	36.520 76
25	1.818 05	6.180 76	10.541 57	14.899 19	19.252 27	23.599 48	27.939 50	32.271 02	36.592 69
26	1.890 61	6.253 43	10.614 21	14.971 76	19.324 75	23.671 86	28.011 75	32.343 11	36.664 62
27	1.963 48	6.326 14	10.686 88	15.044 37	19.397 27	23.744 27	28.084 03	32.415 24	36.736 57
28	2.036 21	6.398 86	10.759 55	15.116 93	19.469 79	23.816 67	28.156 30	32.487 36	36.808 51
29	2.108 90	6.471 53	10.832 19	15.189 55	19.542 26	23.889 05	28.228 55	32.559 43	36.880 43
30	2.181 63	6.544 23	10.904 85	15.262 13	19.614 77	23.961 44	28.300 80	32.631 55	36.952 35
31	2.254 37	6.616 64	10.977 50	15.334 72	19.687 27	24.033 83	28.373 06	32.703 65	37.024 28
32	2.327 06	6.689 62	11.050 15	15.407 29	19.759 75	24.106 19	28.445 29	32.775 73	37.096 05
33	2.399 80	6.762 33	11.122 80	15.479 89	19.832 26	24.178 59	28.517 56	32.847 84	37.168 11
34	2.472 52	6.834 73	11.195 47	15.552 48	19.904 77	24.250 99	28.589 82	32.919 94	37.240 04

(*continued*)

1.16 (*continued*)

Min.	0°	1°	2°	3°	4°	5°	6°	7°	8°
35	2.545 21	6.907 70	11.268 10	15.625 03	19.977 23	24.323 33	28.662 04	32.991 99	37.311 92
36	2.617 95	6.980 41	11.340 74	15.697 63	20.049 73	24.395 72	28.734 29	33.064 09	37.838 36
37	2.690 67	7.053 12	11.413 41	15.770 21	20.122 22	24.468 10	28.806 53	33.136 18	37.455 74
38	2.763 63	7.125 78	11.486 03	15.842 77	20.194 69	24.540 46	28.878 75	33.208 24	37.527 49
39	2.836 10	7.198 49	11.558 68	15.915 36	20.267 19	24.612 84	28.951 00	33.280 33	37.599 53
40	2.908 83	7.271 18	11.631 34	15.988 08	20.339 81	24.685 22	29.023 24	33.352 42	37.671 44
41	2.981 52	7.343 86	11.703 96	16.060 50	20.412 13	24.757 52	29.095 44	33.424 46	37.743 32
42	3.054 25	7.416 56	11.776 61	16.133 08	20.484 63	24.829 94	29.167 68	33.496 55	37.815 21
43	3.126 98	7.489 25	11.849 25	16.205 65	20.557 11	24.902 30	29.239 88	33.568 61	37.887 10
44	3.199 68	7.561 93	11.921 89	16.278 20	20.629 56	24.974 64	29.312 12	33.640 66	37.958 95
45	3.272 40	7.634 63	11.994 53	16.350 78	20.702 05	25.047 02	29.384 35	33.712 73	38.030 85
46	2.908 96	7.707 34	12.067 18	16.423 36	20.774 52	25.119 38	29.456 58	33.784 80	38.102 73
47	3.417 82	7.780 00	12.139 81	16.495 90	20.846 98	25.191 72	29.528 78	33.856 83	38.174 59
48	3.490 55	7.852 70	12.212 44	16.568 48	20.919 46	25.264 07	29.600 99	33.928 89	38.246 46
49	3.563 27	7.925 38	12.285 08	16.641 00	20.991 92	25.336 42	29.673 20	34.000 94	38.318 32
50	3.635 60	7.998 05	12.357 69	16.713 58	21.064 25	25.408 76	29.745 39	34.072 97	38.390 17
51	3.708 69	8.070 75	12.430 34	16.786 16	21.136 85	25.481 11	29.817 61	34.145 03	38.462 04
52	3.781 42	8.143 44	12.502 98	16.858 73	21.209 33	25.553 47	29.889 83	34.217 08	38.533 91
53	3.854 10	8.216 10	12.575 60	16.931 25	21.281 76	25.625 79	29.962 01	34.289 10	38.605 75

54	3.926 83	8.288 80	12.648 23	17.003 82	21.354 23	25.698 13	30.034 21	34.361 14	38.677 60
55	3.999 54	8.361 49	12.720 87	17.076 38	21.426 69	25.770 48	30.106 41	34.433 17	38.749 44
56	4.072 24	8.434 14	12.793 49	17.148 91	21.499 125	25.842 79	30.178 58	34.505 18	38.821 27
57	4.165 80	8.506 84	12.866 12	17.221 48	21.571 59	25.915 135	30.250 78	34.577 22	38.893 12
58	4.217 69	8.579 53	12.938 74	17.294 04	21.644 06	25.987 48	30.322 99	34.649 26	38.964 97
59	4.290 39	8.652 19	13.011 36	17.366 57	21.716 47	26.059 79	30.395 15	34.721 25	39.036 77

Min.	9°	10°	11°	12°	13°	14°	15°	16°	17°
0	39.108 62	43.412 04	47.702 25	51.977 92	56.237 76	60.480 47	64.704 76	68.909 34	73.092 93
1	39.180 44	43.483 66	47.773 63	52.049 06	56.308 62	60.551 03	64.775 00	68.979 24	73.162 47
2	39.252 25	43.555 26	47.844 99	52.120 18	56.379 46	60.621 57	64.845 23	69.049 12	73.231 99
3	39.324 08	43.626 88	47.987 76	52.191 30	56.450 32	60.692 14	64.915 47	69.119 03	73.301 32
4	39.395 91	43.698 49	48.023 44	52.262 42	56.521 16	60.762 68	64.985 69	69.188 92	73.371 07
5	39.467 71	43.770 08	48.059 13	52.333 53	56.591 99	60.833 22	65.055 91	69.258 80	73.440 57
6	39.539 52	43.841 68	48.130 49	52.404 64	56.662 83	60.903 75	65.126 13	69.328 66	73.510 08
7	39.611 32	43.913 28	48.201 85	52.475 75	56.733 66	60.974 28	65.196 34	69.398 53	73.579 59
8	39.683 11	43.984 85	48.273 21	52.546 84	56.804 46	61.044 79	65.266 52	69.468 38	73.649 07
9	39.754 92	44.056 45	48.344 56	52.617 94	56.875 29	61.111 53	65.533 67	69.538 25	73.718 58

(*continued*)

1.16 (*continued*)

Min.	9°	10°	11°	12°	13°	14°	15°	16°	17°
10	39.826 73	44.128 03	48.415 91	52.689 03	56.946 11	61.185 85	65.409 29	69.608 10	73.788 06
11	39.898 51	44.199 61	48.487 24	52.760 12	57.016 91	61.256 34	65.777 11	69.677 94	73.857 54
12	39.970 30	44.271 18	48.558 59	52.831 20	57.087 72	61.326 85	65.547 29	69.747 78	73.927 01
13	40.042 08	44.342 76	48.629 92	52.902 28	57.158 52	61.397 32	65.617 47	69.817 61	73.996 48
14	40.113 85	44.414 31	48.701 25	52.973 34	57.229 29	61.467 82	65.687 63	69.887 42	74.065 90
15	40.185 64	44.485 89	48.772 58	53.044 42	57.300 10	61.538 32	65.757 80	69.957 25	74.135 39
16	40.257 43	44.557 45	48.843 90	53.115 48	57.370 90	61.608 81	65.827 98	70.027 07	74.204 86
17	40.329 19	44.629 00	48.915 22	53.186 54	57.441 66	61.679 28	65.898 11	70.096 87	74.274 28
18	40.400 95	44.700 55	48.986 54	53.257 60	57.512 43	61.749 75	65.968 26	70.166 68	74.343 72
19	40.472 72	44.772 10	49.057 85	53.328 65	57.583 20	61.820 22	66.038 41	70.236 45	74.413 15
20	40.544 47	44.843 63	49.129 14	53.299 68	57.653 95	61.890 67	66.108 53	70.306 12	74.482 43
21	40.616 24	44.915 19	49.200 45	53.470 74	57.724 73	61.961 14	66.178 67	70.376 05	74.551 99
22	40.688 01	44.986 74	49.271 75	53.541 79	57.795 48	62.031 59	66.248 80	70.445 83	74.621 40
23	40.759 73	45.058 24	49.343 04	53.612 80	57.866 23	62.102 02	66.318 91	70.515 60	74.690 80
24	40.831 49	45.129 79	49.413 35	53.683 83	57.936 98	62.172 47	66.389 03	70.585 36	74.760 20
25	40.903 24	45.201 31	49.485 62	53.754 86	58.007 72	62.242 91	66.459 14	70.655 13	74.829 59
26	40.974 96	45.272 82	49.556 89	53.825 86	58.078 44	62.313 32	66.529 22	70.724 87	74.898 97
27	41.046 71	45.344 35	49.628 18	53.896 89	58.149 18	62.383 76	66.593 40	70.794 63	74.968 40
28	41.118 45	45.415 88	49.699 45	53.967 90	58.219 92	62.454 18	66.669 43	70.864 37	75.037 73
29	41.190 17	45.487 37	49.770 72	54.038 90	58.290 62	62.524 59	66.739 51	70.934 11	75.107 09

30	41.261 90	45.558 88	49.841 98	54.109 90	58.361 34	62.595 00	66.809 60	71.003 84	75.176 45
31	41.333 63	45.630 39	49.913 24	54.180 90	58.432 10	62.665 41	66.879 67	71.073 56	75.245 80
32	41.405 33	45.701 87	49.984 49	54.251 88	58.502 74	62.735 79	66.949 72	71.143 27	75.315 14
33	41.477 06	45.773 38	50.055 75	54.322 88	58.573 46	62.806 19	67.019 80	71.219 91	75.384 50
34	41.548 79	45.844 88	50.126 99	54.393 86	58.644 17	62.876 58	67.089 86	71.282 71	75.453 83
35	41.620 48	45.916 35	50.198 24	54.464 84	58.714 84	62.946 96	67.159 91	71.352 40	75.523 15
36	41.692 19	45.987 84	50.269 48	54.535 81	58.785 53	63.017 34	67.229 95	71.422 09	75.592 47
37	41.763 89	46.059 32	50.340 72	54.606 78	58.856 21	63.087 71	67.299 97	71.491 78	75.661 79
38	41.835 57	46.130 78	50.411 94	54.677 74	58.926 87	63.158 06	67.370 02	71.561 45	75.731 08
39	41.907 28	46.202 26	50.483 17	54.748 70	58.997 55	63.322 84	67.440 06	71.631 14	75.800 40
40	41.978 99	46.273 75	50.554 39	54.819 66	59.068 22	63.298 79	67.510 08	71.700 82	75.869 71
41	42.050 66	46.345 19	50.625 61	54.890 60	59.138 88	63.369 14	67.580 10	71.770 47	75.938 98
42	42.122 34	46.416 65	50.696 82	54.961 55	59.209 53	63.439 49	67.650 11	71.840 13	76.008 27
43	42.194 03	46.488 11	50.768 03	55.032 49	59.280 19	63.509 83	67.720 12	71.909 78	76.077 54
44	42.265 69	46.559 55	50.839 22	55.103 43	59.350 82	63.580 14	67.790 10	71.979 43	76.146 81
45	42.337 38	46.631 01	50.910 44	55.174 36	59.421 47	63.650 49	67.860 11	72.049 06	76.216 08
46	42.409 06	46.702 47	50.981 64	55.245 29	59.492 11	63.720 81	67.930 10	72.118 70	76.285 33
47	42.480 71	46.773 89	51.052 82	55.316 21	59.562 74	63.379 11	68.000 08	72.188 33	76.354 58
48	42.552 37	46.845 33	51.124 01	55.387 12	59.633 36	63.861 44	68.070 06	72.257 95	76.423 83
49	42.624 04	46.916 76	51.195 19	55.458 04	59.703 99	63.931 75	68.140 03	72.327 57	76.493 06

(*continued*)

1.16 (*continued*)

Min.	9°	10°	11°	12°	13°	14°	15°	16°	17°
50	42.695 68	46.988 17	51.266 36	55.528 93	59.774 59	64.002 03	68.210 00	72.397 16	76.562 28
51	42.767 34	47.059 61	51.337 55	55.598 48	59.845 21	64.072 34	68.280 00	72.466 78	76.631 52
52	42.839 00	47.131 03	51.408 72	55.670 75	59.915 82	64.142 65	68.349 91	72.536 37	76.700 74
53	42.910 63	47.202 45	51.479 88	55.741 63	59.986 41	64.219 17	68.419 86	72.605 96	76.769 95
54	42.982 28	47.273 86	51.551 05	55.812 53	60.057 01	64.283 20	68.489 81	72.675 55	76.839 15
55	43.053 91	47.345 27	51.622 21	55.883 41	60.127 60	64.353 47	68.559 74	72.745 13	76.908 35
56	43.125 53	47.416 66	51.693 34	55.954 29	60.198 17	64.423 74	68.629 67	72.814 70	76.977 54
57	43.197 18	47.488 07	51.764 50	56.025 17	60.268 77	64.494 00	68.699 60	72.884 27	77.046 73
58	43.268 80	47.559 48	51.835 65	56.096 04	60.339 34	64.564 26	68.769 52	72.953 83	77.115 91
59	43.340 42	47.630 86	51.906 79	56.166 90	60.409 91	64.345 13	68.839 43	73.023 38	77.185 08

Min.	18°	19°	20°	21°	22°	23°	24°	25°	26°
0	77.254 25	81.392 04	85.505 04	89.591 99	93.651 65	97.682 78	101.684 16	105.654 57	109.592 79
1	77.323 41	81.460 80	85.573 37	89.659 87	93.719 07	97.749 72	101.750 59	105.720 47	109.658 14
2	77.392 56	81.529 53	85.641 69	89.727 74	93.786 49	97.816 65	101.817 01	105.786 36	109.723 49
3	77.461 71	81.598 29	85.710 01	89.795 63	93.853 89	97.883 57	101.883 42	105.852 25	109.788 83
4	77.530 86	81.667 03	85.778 34	89.863 50	93.921 29	97.950 48	101.949 83	105.918 13	109.854 16
5	77.599 98	81.735 75	85.846 63	89.931 35	93.988 68	98.017 38	102.016 23	105.983 99	109.919 48

6	77.669 11	81.180 45	85.914 92	89.999 20	94.056 07	98.084 28	102.082 62	106.049 86	109.984 79
7	77.382 29	81.187 32	85.983 21	90.067 05	94.123 44	98.151 17	102.148 99	106.115 71	110.050 09
8	77.807 33	81.941 88	86.051 48	90.134 88	94.190 79	98.218 03	102.215 36	106.181 55	110.115 39
9	77.876 45	82.010 60	86.119 77	90.202 71	94.258 17	98.284 92	102.281 73	106.247 38	110.180 67
10	77.945 55	82.079 31	86.188 04	90.270 53	94.325 52	98.351 78	102.348 08	106.313 20	110.245 95
11	78.014 64	82.147 98	86.256 30	90.338 34	94.392 86	98.418 63	102.414 42	106.379 02	110.311 21
12	78.083 73	82.216 66	86.324 55	90.406 14	94.460 20	98.485 48	102.480 76	106.444 82	110.376 46
13	78.152 81	82.285 34	86.392 80	90.473 94	94.527 52	98.552 32	102.547 09	106.510 62	110.441 71
14	78.221 87	82.353 99	86.461 02	90.541 71	94.594 84	98.619 14	102.613 40	106.576 41	110.506 94
15	78.290 95	82.422 66	86.529 26	90.609 51	94.662 15	98.685 96	102.679 71	106.642 19	110.572 17
16	78.360 01	82.491 31	86.597 49	90.677 29	94.729 46	98.752 78	101.746 02	106.707 96	110.637 39
17	78.429 07	82.559 96	86.665 70	90.745 05	94.796 75	98.819 58	102.812 31	106.773 71	110.702 60
18	78.498 11	82.628 60	86.733 91	90.812 81	94.864 04	98.886 38	102.878 59	106.839 47	110.767 80
19	78.567 16	82.697 23	86.802 12	90.880 56	94.931 32	98.953 16	102.944 86	106.905 21	110.832 99
20	78.636 05	82.765 84	86.870 29	90.948 29	94.998 59	99.019 94	103.011 12	106.970 93	110.898 16
21	78.705 22	82.834 47	86.938 50	91.016 04	95.065 85	99.086 71	103.077 39	107.036 67	110.963 34
22	78.774 24	82.903 08	87.006 68	91.083 77	95.133 11	99.153 48	103.143 64	107.102 38	111.028 50
23	78.843 23	82.971 69	87.074 85	91.151 48	95.200 35	99.220 23	103.209 88	107.168 09	111.093 65
24	78.912 26	83.040 28	87.143 01	91.219 61	95.267 59	99.286 97	103.276 11	107.233 78	111.158 79

(*continued*)

1.16 (*continued*)

Min.	18°	19°	20°	21°	22°	23°	24°	25°	26°
25	78.981 26	83.108 87	87.211 17	91.286 90	95.334 83	99.353 71	103.342 33	107.299 47	111.223 93
26	79.050 24	83.177 44	87.279 32	91.354 58	95.402 05	99.420 44	103.408 54	107.365 14	111.289 05
27	79.119 24	83.246 03	87.347 46	91.422 29	95.469 26	99.487 16	103.474 75	107.430 82	111.354 17
28	79.188 22	83.314 61	87.415 60	91.489 97	95.536 47	99.553 87	103.540 95	107.496 48	111.419 27
29	79.257 18	83.383 16	87.483 72	91.557 64	95.603 67	99.620 57	103.607 13	107.562 13	111.484 37
30	79.326 16	83.451 72	87.551 85	91.625 31	95.670 86	99.687 27	103.673 31	107.627 77	111.549 45
31	79.395 13	83.520 26	87.619 95	91.692 97	95.738 04	99.753 95	103.739 48	107.693 41	111.614 53
32	79.464 07	83.588 79	87.688 05	91.760 61	95.805 21	99.820 63	103.805 63	107.775 90	111.679 58
33	79.533 03	83.657 34	87.756 16	91.828 26	95.872 38	99.887 30	103.871 79	107.824 65	111.744 66
34	79.601 98	83.725 86	87.824 27	91.895 89	95.939 54	99.953 97	103.937 94	107.890 25	111.809 71
35	79.670 89	83.794 38	87.892 34	91.963 52	96.006 69	100.020 61	104.004 07	107.955 85	111.874 74
36	79.739 80	83.862 89	87.960 41	92.031 14	96.073 83	100.087 26	104.070 20	108.021 44	111.939 77
37	79.808 75	83.931 40	88.028 48	92.098 75	96.140 97	100.153 89	104.136 32	108.087 02	112.004 79
38	79.877 66	83.999 88	88.096 53	92.166 35	96.207 96	100.220 51	104.202 41	108.152 58	112.069 80
39	79.946 57	84.068 39	88.164 60	92.233 95	96.275 21	100.287 14	104.268 52	108.218 15	112.134 80
40	80.015 48	84.136 88	88.232 66	92.301 54	96.342 33	100.353 76	104.334 62	108.283 70	112.199 81
41	80.084 40	84.205 34	88.300 68	92.369 12	96.409 42	100.420 35	104.400 69	108.349 24	112.264 78
42	80.152 35	84.273 82	88.368 71	92.436 69	96.476 51	100.486 94	104.466 77	108.414 77	112.329 75
43	80.222 13	84.342 28	88.436 73	92.504 25	96.543 60	100.553 53	104.532 83	108.480 30	112.394 71

44	80.290 99	84.410 72	88.504 74	92.571 80	96.610 67	100.620 10	104.598 88	108.545 80	112.459 67
45	80.359 87	84.479 18	88.572 76	92.639 36	96.677 74	100.686 67	104.664 93	108.613 14	112.524 61
46	80.428 70	84.547 62	88.640 77	92.774 33	96.744 80	100.753 23	104.730 97	108.676 81	112.589 55
47	80.497 58	84.616 05	88.776 74	92.774 43	96.811 85	100.819 78	104.797 00	108.742 30	112.654 47
48	80.566 42	84.684 48	88.776 74	92.841 96	96.878 90	100.886 32	104.863 22	108.807 78	112.719 39
49	80.635 26	84.752 90	88.844 72	92.909 48	96.945 93	100.952 86	104.929 03	108.873 24	112.784 29
50	80.704 081	84.821 30	88.912 68	92.976 99	97.012 95	101.019 38	104.995 02	108.938 70	112.849 18
51	80.772 92	84.889 72	88.980 65	93.044 49	97.079 98	101.085 90	105.061 03	109.004 15	112.914 07
52	80.841 74	84.958 12	89.048 61	93.111 98	97.146 99	101.152 41	105.127 03	109.069 59	112.978 95
53	80.910 55	85.026 50	89.116 56	93.179 47	97.213 99	101.218 91	105.192 99	109.135 03	113.043 82
54	80.979 35	85.094 89	89.184 50	93.246 95	97.280 99	101.285 40	105.258 95	109.200 45	113.108 68
55	81.048 15	85.163 27	89.252 43	93.314 42	97.347 97	101.351 88	105.324 91	109.265 86	113.173 52
56	81.116 93	85.231 63	89.320 36	93.381 88	97.414 94	101.418 35	105.390 86	109.331 26	113.238 36
57	81.185 73	85.299 99	89.388 28	93.449 33	97.481 92	101.484 82	105.456 80	109.396 66	113.303 19
58	81.254 51	85.368 35	89.456 19	93.516 78	97.548 88	101.551 28	105.522 73	109.462 04	113.368 02
59	81.323 27	85.436 69	89.524 09	93.584 22	97.615 84	101.617 72	105.588 65	109.527 42	113.432 82

Min.	27°	28°	29°	30°	31°	32°	33°	34°	35°
0	113.497 62	117.367 89	121.202 41	125.000 00	128.759 52	132.479 82	136.159 76	139.798 23	143.394 11
1	113.562 42	117.432 10	121.266 00	125.062 97	128.821 85	132.541 48	136.220 74	139.858 51	143.453 67

(*continued*)

1.16 (*continued*)

Min.	27°	28°	29°	30°	31°	32°	33°	34°	35°
2	113.627 18	117.496 29	121.329 59	125.125 94	128.884 17	132.603 14	136.281 70	139.918 77	143.513 22
3	113.691 97	117.560 48	121.393 17	125.188 89	128.946 48	132.664 78	136.342 68	139.979 04	143.572 77
4	113.756 73	117.624 65	121.456 74	125.251 83	129.008 77	132.726 42	136.403 63	140.038 93	143.632 29
5	113.821 48	117.688 82	121.520 30	125.314 76	129.071 06	132.788 03	136.464 56	140.099 52	143.691 81
6	113.886 23	117.752 97	121.583 85	125.377 68	129.133 33	132.849 64	136.525 49	140.159 75	143.751 31
7	113.950 96	117.817 12	121.647 38	125.440 59	129.195 59	132.911 24	136.586 41	140.219 96	143.810 81
8	114.015 68	117.881 25	121.710 91	125.503 49	129.257 84	132.972 83	136.647 31	140.280 15	143.870 28
9	114.080 40	117.945 38	121.774 43	125.566 38	129.320 09	133.034 41	136.708 20	140.340 35	143.929 75
10	114.145 12	118.009 49	121.837 93	125.629 26	129.382 32	133.095 97	136.769 08	140.400 53	143.989 21
11	114.209 80	118.073 60	121.901 43	125.692 13	129.444 54	133.157 52	136.829 95	140.460 69	144.048 65
12	114.274 48	118.137 69	121.964 90	125.754 99	129.506 75	133.219 07	136.890 81	140.520 84	144.108 08
13	114.339 16	118.201 78	122.028 39	125.817 83	129.568 95	133.280 60	136.951 66	140.580 99	144.167 50
14	114.403 82	118.265 85	122.091 84	125.880 67	129.631 14	133.342 11	137.012 47	140.641 14	144.226 90
15	114.468 48	118.329 92	122.155 31	125.943 49	129.693 32	133.403 63	137.073 31	140.701 23	144.286 30
16	114.533 13	118.393 97	122.218 76	126.006 31	129.755 48	133.465 13	137.134 12	140.761 30	144.345 66
17	114.597 76	118.458 02	122.282 19	126.069 11	129.817 63	133.526 61	137.194 92	140.821 43	144.405 05
18	114.662 39	118.522 05	122.345 61	126.131 91	129.879 78	133.588 09	137.255 71	140.881 51	144.464 41
19	114.720 06	118.586 08	122.409 03	126.194 69	129.941 91	133.649 55	137.316 48	140.941 58	144.523 75
20	114.791 60	118.650 08	122.472 43	126.257 45	130.004 03	133.711 00	137.377 24	141.001 64	144.583 08
21	114.856 21	118.714 10	122.535 82	126.320 22	130.066 14	133.772 44	137.438 00	141.061 69	144.642 41
22	114.920 80	118.778 09	122.599 21	126.382 97	130.128 24	133.833 88	137.498 74	141.121 73	144.701 71

23	114.985 38	118.420 76	122.662 58	126.445 71	130.190 33	133.895 29	137.559 47	141.181 74	144.761 01
24	115.049 95	118.906 05	122.725 94	126.508 44	130.252 41	133.956 70	137.620 19	141.241 75	144.820 29
25	115.114 51	118.970 02	122.789 29	126.571 16	130.314 47	134.018 09	137.680 89	141.301 75	144.879 57
26	115.179 04	119.033 96	122.852 63	126.633 87	130.376 53	134.079 48	137.741 58	141.361 73	144.938 82
27	115.243 59	119.097 92	122.915 96	126.696 56	130.438 57	134.140 85	137.802 27	141.421 71	144.998 07
28	115.308 12	119.161 85	122.979 28	126.759 25	130.500 61	134.263 56	137.862 94	141.481 67	145.057 31
29	115.372 64	119.225 77	123.042 59	126.821 93	130.562 63	134.263 56	137.923 60	141.541 62	145.116 53
30	115.437 15	119.289 69	123.105 89	126.884 59	130.624 64	134.324 90	137.984 25	141.601 56	145.175 74
31	115.501 65	119.353 59	123.169 18	126.947 25	130.686 64	134.386 23	138.044 88	141.661 49	145.234 94
32	115.566 14	119.417 49	123.232 46	127.009 89	130.748 63	134.447 54	138.105 51	141.721 40	145.294 12
33	115.630 63	119.481 37	123.295 72	127.072 52	130.810 61	134.508 85	138.166 12	141.781 30	145.353 30
34	115.695 10	119.545 25	123.358 98	127.135 14	130.872 58	134.570 14	138.226 72	141.841 19	145.412 46
35	115.759 56	119.609 11	123.422 23	127.197 75	130.934 53	134.631 40	138.287 31	141.901 07	145.471 61
36	115.824 01	119.672 97	123.485 47	127.260 35	130.996 48	134.692 70	138.347 89	141.960 94	145.530 74
37	115.888 50	119.736 81	123.548 69	127.322 94	131.058 41	134.753 96	138.408 45	142.020 79	145.589 87
38	115.952 88	119.800 63	123.611 91	127.385 52	131.120 33	134.815 19	138.469 01	142.080 63	145.648 98
39	116.017 30	119.864 47	123.675 11	127.448 09	131.182 24	134.876 44	138.529 55	142.140 46	145.708 08
40	116.081 72	119.928 28	123.738 32	127.510 66	131.244 15	134.937 68	138.590 08	142.200 28	145.767 17
41	116.146 12	119.992 08	123.801 49	127.573 19	131.306 03	134.998 88	138.650 60	142.260 09	145.826 24
42	116.210 51	120.055 87	123.864 67	127.635 73	131.367 91	135.600 80	138.711 07	142.319 88	145.885 30
43	116.274 90	120.119 66	123.927 83	127.698 25	131.429 78	135.121 27	138.771 60	142.379 66	145.944 35
44	116.339 25	120.183 42	123.990 97	127.760 76	131.491 64	135.182 45	138.832 09	142.439 43	146.003 39
45	116.403 60	120.247 19	124.054 13	127.823 27	131.553 48	135.243 62	138.892 56	142.499 19	146.062 42
46	116.467 99	120.310 95	124.117 25	127.885 76	131.615 32	135.304 78	138.953 02	142.558 94	146.121 43

(*continued*)

1.16 (*continued*)

Min.	27°	28°	29°	30°	31°	32°	33°	34°	35°
47	116.532 33	120.374 69	124.180 38	127.948 24	131.677 14	135.365 90	139.013 47	142.618 67	146.180 43
48	116.596 66	120.438 40	124.243 49	128.010 72	131.738 95	135.427 05	139.073 90	142.678 39	146.239 42
49	116.660 98	120.502 14	124.306 59	128.073 18	131.800 75	135.488 18	139.134 33	142.738 10	146.298 39
50	116.725 29	120.565 85	124.369 68	128.135 62	131.862 53	135.549 28	139.194 74	142.797 80	146.357 36
51	116.789 60	120.629 55	124.432 76	128.198 06	131.924 32	135.610 38	139.255 14	142.857 48	146.416 31
52	116.853 90	120.693 25	124.495 83	128.260 49	131.986 09	135.671 47	139.315 51	142.917 16	146.475 25
53	116.918 18	120.756 93	124.558 89	128.322 91	132.047 84	135.732 55	139.436 28	142.976 82	146.534 18
54	116.982 45	120.820 60	124.621 93	128.385 31	132.095 84	135.793 61	139.362 77	143.036 47	146.593 09
55	117.239 45	120.884 26	124.684 97	128.447 71	132.171 32	135.854 67	139.496 63	143.096 11	146.651 99
56	117.110 96	120.947 91	124.747 99	128.510 09	132.233 03	135.915 71	139.556 97	143.155 73	146.710 88
57	117.175 22	121.011 55	124.811 02	128.572 47	132.294 70	135.976 74	139.617 30	143.215 34	146.769 76
58	117.239 45	121.075 18	124.874 02	128.634 83	132.356 50	136.037 76	139.677 63	143.274 95	146.828 62
59	117.303 68	121.138 80	124.937 02	128.697 18	132.418 10	136.098 76	139.737 93	143.334 53	146.887 47

Min.	36°	37°	38°	39°	40°	41°	42°	43°	44°	45°
0	146.946 31	150.453 76	153.915 37	157.330 10	160.699 02	164.014 76	167.282 65	170.499 59	173.664 60	176.776 70
1	147.005 14	150.511 83	153.972 67	157.386 61	160.752 60	164.069 63	167.336 69	170.552 77	173.716 90	176.828 11
2	147.063 90	150.569 89	154.029 95	157.443 10	160.808 29	164.124 50	167.390 71	170.605 93	173.769 19	176.879 51
3	147.122 76	150.627 93	154.087 23	157.499 59	160.863 97	164.179 35	167.444 70	170.659 08	173.821 46	176.930 89

4	147.181 55	150.685 97	154.144 49	157.556 06	160.919 63	164.234 18	167.498 71	170.712 22	173.873 72	176.982 27
5	147.240 32	150.743 99	154.201 74	157.612 51	160.975 27	164.289 00	167.552 69	170.765 34	173.925 97	177.033 62
6	147.299 09	150.802 00	154.258 97	157.668 95	161.030 91	164.343 81	167.606 66	170.818 44	173.978 20	177.084 96
7	147.357 84	150.859 99	154.316 19	157.725 38	161.086 53	164.398 61	167.660 61	170.871 54	174.030 42	177.136 29
8	147.416 58	150.917 97	154.373 40	157.781 80	161.142 13	164.453 38	167.714 54	170.924 61	174.082 62	177.187 59
9	147.475 31	150.975 95	154.430 59	157.838 20	161.197 73	164.508 15	167.768 47	170.977 68	174.134 80	177.238 90
10	147.534 03	151.033 90	154.487 78	157.894 59	161.253 31	164.562 90	167.822 37	171.030 72	174.186 98	177.290 17
11	147.592 73	151.091 85	154.544 94	157.950 96	161.308 87	164.176 41	167.876 25	171.083 76	174.239 13	177.341 43
12	147.651 42	151.149 78	154.602 10	158.007 33	161.364 42	164.672 37	167.930 15	171.136 78	174.291 28	177.392 68
13	147.710 10	151.207 70	154.659 24	158.063 68	161.412 00	164.727 08	167.984 01	171.189 78	174.343 40	177.443 92
14	147.768 76	151.265 60	154.716 37	158.120 09	161.475 48	164.781 77	168.037 86	171.242 77	174.395 52	177.495 14
15	147.827 41	151.323 50	154.773 49	158.176 33	161.530 99	164.836 45	168.091 70	171.295 75	174.447 60	177.546 34
16	147.886 05	151.381 38	154.830 60	158.232 64	161.586 49	164.891 12	168.145 53	171.348 71	174.499 70	177.597 54
17	147.944 68	151.439 25	154.887 68	158.288 94	161.641 96	164.945 78	168.199 32	171.401 66	174.551 77	177.648 71
18	148.003 30	151.497 10	154.944 76	158.345 22	161.697 45	165.000 42	168.253 13	171.454 59	174.603 82	177.699 86
19	148.061 90	151.554 94	155.001 82	158.401 49	161.752 90	165.055 04	168.306 91	171.507 51	174.655 86	177.751 01
20	148.120 49	151.612 77	155.058 87	158.477 41	161.808 34	165.109 66	168.360 68	171.560 41	174.707 87	177.802 14
21	148.179 07	151.670 59	155.115 91	158.513 98	161.863 77	165.164 26	168.414 43	171.613 30	174.759 89	177.853 26
22	148.237 63	151.728 39	155.172 94	158.570 21	161.919 19	165.218 84	168.468 17	171.666 17	174.811 89	177.904 36
23	148.296 18	151.786 18	155.229 95	158.626 43	161.974 59	165.273 41	168.521 89	171.719 03	174.863 87	177.955 44
24	148.354 72	151.843 96	155.286 95	158.682 63	162.029 98	165.327 97	168.575 60	171.771 88	174.915 84	178.006 51
25	148.413 25	151.901 73	155.343 93	158.738 82	162.085 35	165.382 51	168.629 29	171.824 71	174.967 79	178.057 57

(*continued*)

1.16 (*continued*)

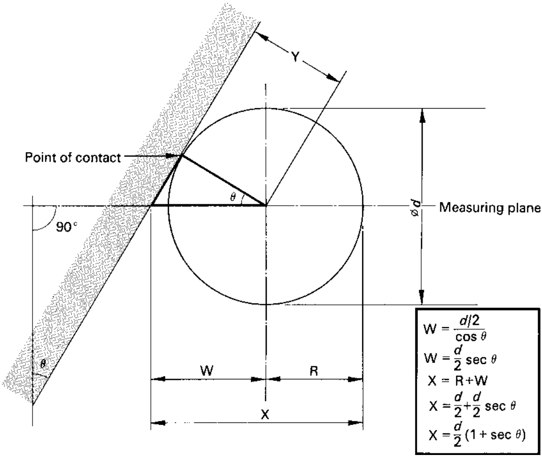
Min.	36°	37°	38°	39°	40°	41°	42°	43°	44°	45°
26	148.471 76	151.959 48	155.400 90	158.794 99	162.140 71	165.437 04	168.682 97	171.877 52	175.019 72	178.108 60
27	148.530 27	152.017 22	155.457 86	158.851 16	162.196 06	165.491 55	168.736 64	171.903 26	175.071 64	178.159 63
28	148.588 76	152.074 94	155.514 81	158.907 30	162.251 39	165.546 05	168.790 29	171.983 11	175.123 55	178.210 64
29	148.647 23	152.132 66	155.571 74	158.963 43	162.306 71	165.600 54	168.843 93	172.035 89	175.175 44	178.261 63
30	148.705 69	152.190 36	155.628 66	159.019 56	162.362 01	165.655 01	168.897 55	172.088 64	175.227 32	178.312 61
31	148.764 15	152.248 05	155.685 57	159.075 66	162.417 30	165.709 47	168.951 16	172.141 39	175.279 18	178.363 58
32	148.822 59	152.305 72	155.742 46	159.131 76	162.472 58	165.763 91	169.004 76	172.194 11	175.331 01	178.414 52
33	148.881 01	152.363 38	155.799 34	159.187 84	162.527 84	165.818 35	169.058 34	172.246 83	175.382 86	178.465 46
34	148.939 43	152.421 03	155.856 20	159.243 90	162.583 10	165.872 76	169.119 04	172.299 53	175.434 68	178.516 38
35	148.997 83	152.478 67	155.913 06	159.299 96	162.638 33	165.927 17	169.165 46	172.352 22	175.486 48	187.567 28
36	149.056 22	152.536 29	155.969 90	159.356 00	162.693 55	165.981 55	169.218 99	172.404 89	175.538 26	178.618 17
37	149.114 60	152.593 90	156.026 73	159.412 02	162.748 76	166.035 93	169.272 52	172.457 54	175.590 04	178.669 04
38	149.172 96	152.651 50	156.083 54	159.468 04	162.803 96	166.090 29	169.326 02	172.510 18	175.641 79	178.719 90
39	149.231 31	152.709 08	156.140 34	159.524 04	162.859 14	166.144 63	169.379 52	172.562 81	175.693 54	178.770 74
40	149.289 66	152.766 67	156.197 13	159.580 02	162.914 31	166.198 98	169.433 01	172.615 43	175.745 27	178.821 57
41	149.347 97	152.824 21	156.253 90	159.635 99	162.969 46	166.253 28	169.486 47	172.668 02	175.796 98	178.872 39
42	149.406 29	152.881 76	156.310 66	159.691 95	163.024 60	166.307 59	169.539 92	172.720 60	175.848 68	178.923 18
43	149.464 59	152.939 29	156.367 41	159.747 90	163.079 73	166.361 88	169.593 36	172.773 17	175.900 36	178.973 97
44	149.522 86	152.996 81	156.424 20	159.803 83	163.134 84	166.416 15	169.646 78	172.825 73	175.952 03	179.024 73

45	149.581 15	153.054 32	156.480 87	159.859 75	163.189 94	166.470 42	169.700 19	172.878 26	176.003 68	179.075 49
46	149.639 41	153.111 81	156.537 58	159.915 66	163.245 02	166.524 67	169.753 58	172.930 79	176.055 32	179.126 22
47	149.697 66	153.169 29	156.594 27	159.971 55	163.300 09	166.578 90	169.806 96	172.983 30	176.106 94	179.176 95
48	149.755 90	153.226 76	156.650 95	160.027 43	163.335 52	166.633 12	169.860 33	173.035 79	176.158 56	179.227 65
49	149.814 12	153.284 22	156.707 62	160.083 29	163.410 19	166.687 32	169.913 68	173.088 27	176.210 15	179.278 34
50	149.987 23	153.341 66	156.764 28	160.139 14	163.465 22	166.741 51	169.967 01	173.140 74	176.261 73	179.329 02
51	149.930 54	153.399 09	156.820 92	160.194 98	163.520 24	166.795 69	170.020 34	173.193 19	176.313 29	179.379 68
52	149.988 72	153.456 51	156.877 55	160.250 80	163.575 24	166.849 86	170.073 65	173.245 63	176.364 84	179.430 33
53	150.046 90	153.513 91	156.934 16	160.306 61	163.630 23	166.904 00	170.126 94	173.298 05	176.416 37	179.480 96
54	150.105 06	153.571 30	156.990 76	160.362 41	163.685 20	166.958 14	170.180 22	173.350 46	176.467 90	179.531 57
55	150.163 21	153.628 68	157.047 35	160.418 19	163.740 16	167.012 26	170.233 48	173.402 85	176.519 40	179.582 18
56	150.221 34	153.686 04	157.103 93	160.473 96	163.795 10	167.066 37	170.286 73	173.455 23	176.570 89	179.632 76
57	150.279 46	153.743 39	157.160 49	160.529 72	163.850 04	167.120 46	170.339 97	173.507 59	176.622 36	179.683 33
58	150.337 58	153.800 73	157.217 04	160.585 46	163.904 96	167.174 54	170.393 19	173.559 94	176.673 82	179.733 89
59	150.395 67	153.858 06	157.273 58	160.641 19	163.959 87	167.228 60	170.446 40	173.612 27	176.725 27	179.784 43

1.17 Measurement over precision balls and rollers

Notes:

(1) Precision balls are used where a *point* contact is required.
(2) Precision rollers are used where a *line* contact is required.



The above figure shows how the distance from the point of measurement to the component can be calculated. It also shows that the point of contact does not always lie in the measuring plane. This figure, together with the following calculations, should be studied carefully as it forms the basis for the subsequent examples.

Referring to the above figure:

W is the hypotenuse of the right-angled triangles
Y is the adjacent side of the angle $\theta°$

Therefore:

$$\frac{Y}{W} = \cos\theta$$

But $Y =$ the radius of the roller

$$\therefore \; Y = \frac{d}{2}$$

Substituting in equation (1),

$$\frac{d/2}{W} = \cos\theta$$

$$\therefore W = \frac{d/2}{\cos\theta}$$

$$\text{or } W = \frac{d}{2}\sec\theta$$

Inverse ratios

$$\frac{1}{\cos\theta} = \sec\theta$$

$$\frac{1}{\sin\theta} = \cos\theta$$

$$\frac{1}{\tan\theta} = \cot\theta$$

But X = radius of roller $(R) + W$

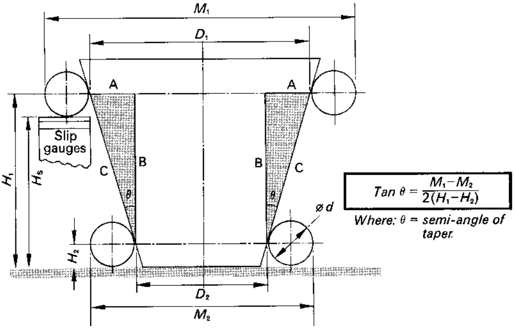
where: $R = \dfrac{d}{2}$

$$= \frac{d}{2} + \left(\frac{d}{2}\sec\theta\right.$$

$$= \frac{d}{2}(1 + \sec\theta)$$

(Courtesy of Addison Wesley Longman.)

1.18 Measurement of external tapers



1.18.1 To find the angle θ (the semi-angle of taper)

Refer to the above figure. The shaded triangles show that:

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{A}{B} \qquad (1)$$

and that:

$$A = \frac{D_1 - D_2}{2}$$

$$B = H_1 - H_2$$

Thus, substituting in equation (1),

$$\tan\theta = \frac{(D_1 - D_2)/2}{H_1 - H_2}$$

$$= \frac{D_1 - D_2}{2(H_1 - H_2)} \qquad (2)$$

Unfortunately, D_1 and D_2 cannot be measured directly, so measurements are taken over rollers to give M_1 and M_2. Conversion from M_1 and M_2 to D_1 and D_2 involves the use of the expressions derived previously. (Note the difference between M and D in both instances is equal to $2x$ in Section 1.17)

$$M_1 = D_1 + 2\frac{d}{2}(1 + \text{secant }\theta)$$

$$= D_1 + d(1 + \text{secant }\theta)$$

Similarly:

$$M_2 = D_2 + 2\frac{d}{2}(1 + \text{secant }\theta)$$

$$= D_2 + d(1 + \text{secant }\theta)$$

$$M_1 = D_1 + 2\ \ \frac{d}{2}(1 + \sec\theta)$$

$$= D_1 + d(1 + \sec\theta)$$

$$M_2 = D_2 + 2\ \ \frac{d}{2}(1 + \sec\theta)$$

$$= D_2 + d(1 + \sec\theta)$$

Since $d(1 + \sec\theta)$ is common to both the above expressions, $M_1 - M_2 = D_1 - D_2$. Substituting in equation (2)

$$\tan\theta = \underline{\frac{M_1 - M_2}{2(H_1 - H_2)}}$$

Example 1.18.1

The following data were obtained when checking a taper plug gauge.

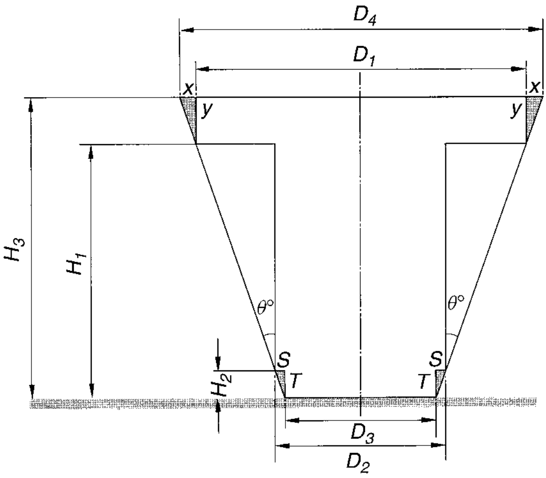
Diameter of rollers	= 10 mm
Micrometer reading over rollers at height H_1	= 70 mm
Micrometer reading over rollers at height H_2	= 65 mm
Height of slip gauge stack (H_s)	= 40 mm

Note: H_1, H_2 and H_s refer to the above figure.

$$\text{Tan}\,\theta = \frac{M_1 - M_2}{2(H_1 - H_2)}$$
$$= \frac{70 - 65}{2(45 - 5)}$$
$$= \frac{5}{80}$$
$$= 0.0625$$

$\therefore$ $\underline{\theta = 3°35'}$ or $\underline{\text{angle of taper}(2\theta) = 7°10'}$

where: $M_1 = 70\,\text{mm}$
$M_2 = 65\,\text{mm}$
$H_1 = (40 + 5) = 45\,\text{mm}$
$H_2 = (0 + 5) = 5\,\text{mm}$



1.18.2 To find the major and minor diameters

Major diameter
Reference to the above figure shows that:

D_4 is obviously bigger than D_1 by an amount equal to $2X$.

But X can be found knowing height Y and the semi-angle of taper θ.

$$X = Y \tan\theta$$

$\therefore \quad X = (H_3 - H_1)\tan\theta$

and $\quad \underline{2X = 2(H_3 - H_1)\tan\theta}$

where: $Y = H_3 - H_1$

Thus: $D_4 = D_1 + 2(H_3 - H_1)\tan\theta$

Thus: $\underline{D_4 = M_1 - d(1 + \text{secant } \theta) + 2(H_3 - H_1)\tan\theta}$

where: $D_1 = M_1 - d(1 + \text{secant } \theta)$

Minor diameter
Reference to the above figure shows that:

D_3 is obviously smaller than D_2 by an amount equal to $2S$.

But S can be found knowing the height T and the semi-angle of taper θ.

Note: H_1 and H_2 are not the point of contact of cylinder and taper, but the point at the same level as the roller centres.

$\therefore \; S = T\tan\theta$

$\therefore \; S = \dfrac{d}{2}\tan\theta$

and $\underline{2S = d\tan\theta}$

where: $\quad T = \dfrac{d}{2}$, when d = roller dismater

Thus: $\quad D_3 = D_2 - d\tan\theta$

Where: $D_2 = M_2 - d(1 + \text{secant } \theta)$ (previously proved)

Thus: $\quad \underline{D_3 = M_2 - d(1 + \text{secant } \theta) - d\tan\theta}$

Example 1.18.2

Calculate the minor diameter (D_3) and the major diameter (D_4) of a taper plug gauge given the following data:

Diameter of rollers	=	10 mm
Micrometer reading M_1	=	70 mm
Micrometer reading M_2	=	65 mm
Height H_2	=	5 mm
Height H_3	=	60 mm
Height H_1	=	45 mm

Angle θ (from Example 1.18.1) $= 3°35'$

Reference should be made to the above figure in the solution of this example.

To find D_3

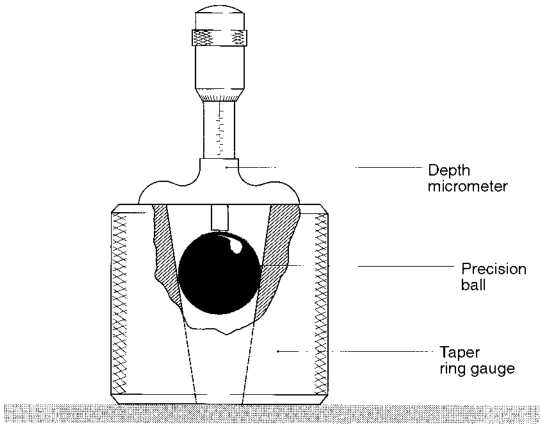
$$
\begin{aligned}
D_3 &= M_2 - d(1 + \text{secant } \theta) - d\tan\theta \\
&= 65 - (10 + 10 \text{ secant } 3°35') - 10\tan 3°35' \\
&= 65 - \left(10 + \frac{10}{\cos 3°35'}\right) - 10\tan 3°35' \\
&= 65 - \left(10 + \frac{10}{0.9982}\right) - 10 \times 0.0625 \\
&= 65 - 20.02 - 0.625 \\
&= \underline{44.355\,\text{mm diameter}}
\end{aligned}
$$

To find D_4

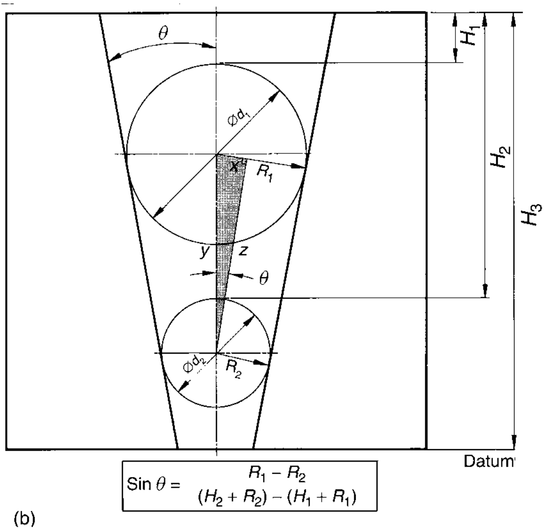
$$
\begin{aligned}
D_4 &= M_1 - d(1 + \text{secant } \theta) + 2(H_3 - H_1)\tan\theta \\
&= 70 - 10(1 + \text{secant } 3°35' + 2(60 - 45) \\
&\qquad \tan 3°35' \\
&= 70 - \left(10 + \frac{10}{\cos 3°35'}\right) + 30\tan 3°35' \\
&= 70 - 20.02 + (30 \times 0.625) \\
&= 70 - 20.02 + 1.875 \\
&= \underline{51.855\,\text{mm diameter}}
\end{aligned}
$$

(Courtesy of Addison Wesley Longman.)

1.19 Measurement of internal tapers



(a)



(b)

1.19.1 To find the angle θ° (the semi-angle of taper)

The above Fig. (a) shows how measurements are taken over two precision balls of different diameters. From a knowledge of the diameter of the balls and the depth to which they sink into the taper, the angle of taper and the major and minor diameters of the bore may be calculated.

It will be seen from Fig. (b) that the semi-angle of taper θ can be obtained from the triangle XYZ.

$$\sin\theta = \frac{X}{Y}$$

But: $X = R_1 - R_2$

where: $R_1 = \frac{d_1}{2}$

$$R_2 = \frac{d_2}{2}$$

and: $Y = (H_2 + R_2) - (H_1 + R_1)$

Thus $\underline{\sin\theta = \frac{R_1 - R_2}{(H_2 + R_2) - (H_1 + R_1)}}$

Example 1.19.1

The following data were obtained when inspecting a taper ring gauge. Calculate the included angle of taper.

$$d_1 = 16\,\text{mm diameter}$$
$$d_2 = 12\,\text{mm diameter}$$
$$H_1 = 6\,\text{mm}$$
$$H_2 = 20\,\text{mm}$$
$$\sin\theta = \frac{R_1 - R_2}{(H_2 + R_1) - (H_1 - R_1)}$$

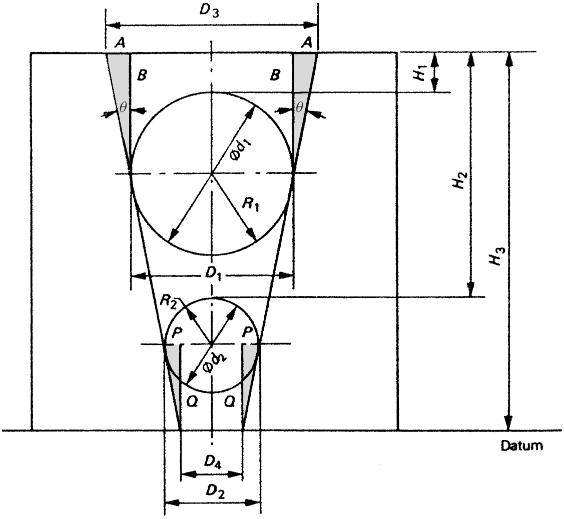
where: $R_1 = \frac{16}{2} = 8\,\text{mm}$

$$R_2 = \frac{12}{2} = 6\,\text{mm}$$
$$= \frac{8 - 6}{(20 + 6) - (6 + 8)}$$
$$= \frac{2}{26 - 14}$$
$$= \frac{2}{12}$$
$$= 0.1667$$

$\therefore$ $\underline{\theta = 9^\circ 36'}$

Thus the included angle of taper $= (2 \times 9^\circ 36') = \underline{19^\circ 12'}$.

1.19.2 To find the major and minor diameters



The major diameter D_3 and the minor diameter D_4 of the taper bore can also be calculated if, in addition to the existing data, the overall height H_3 is also known.

The dimensions D_1 and D_2 are, in fact, twice the dimension W in Section 1.17.

Thus $\quad D_1 = 2\frac{d_1}{2}$ secant θ

$= \underline{d_1 \text{ secant } \theta}$

Similarly, $D_2 = \underline{d_2 \text{ secant } \theta}$

Major diameter

It will be seen from the above figure that D_3 is bigger than D_1 by twice the dimension A.

$$D_3 = D_1 + 2A$$

But $\quad \frac{A}{B} = \tan\theta$

$\therefore \quad A = B\tan\theta \quad$ where: $B = H_1 + R_1$

$\therefore \quad A = (H_1 + R_1)\tan\theta$

Therefore: $\quad \underline{D_3 = D_1 + 2(H_1 + R_1)\tan\theta}$

Minor diameter

It will be seen from the above figure that D_4 is smaller than D_2 by twice the dimension P.

$$D_4 = D_2 - 2P$$

But $\dfrac{P}{Q} = \tan\theta$

$\therefore \quad P = Q\tan\theta \quad$ where: $Q = H_3 - (H_2 + R_2)$

$\therefore \quad P = [H_3 - (H_2 + R_2)]\tan\theta$

Therefore: $\underline{D_4 = D_2 - 2[H_3 - (H_2 + R_2)]\tan\theta}$

Example 1.19.2

Reusing the taper ring gauge data from Example 1.19.1 plus the knowledge that $H_3 = 40\,\text{mm}$ and $\theta = 9°36'$, calculate the major diameter (D_3) and the minor diameter (D_4).

Major diameter

$$\begin{aligned}
D_3 &= D_1 + 2(H_1 + R_1)\tan\theta \\
&= d_1 \text{ secant } \theta + 2(H_1 + R_1)\tan\theta \\
&= 16 \text{ secant } 9°36' + 2(6 + 8)\tan 9°36' \\
&= \frac{16}{\cos 9°36'} + 2(6 + 8)\tan 9°36' \\
&= \frac{16}{0.9860} + 2 \times 14 \times 0.1691 \\
&= 16.23 + 4.735 \\
&= \underline{20.965\,\text{mm diameter}}
\end{aligned}$$

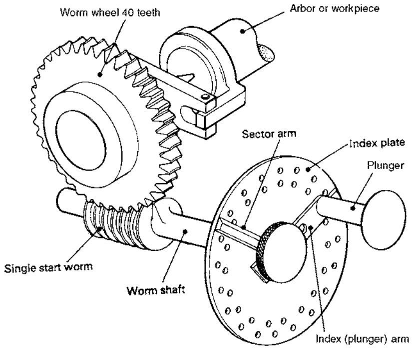
Minor diameter

$$\begin{aligned}
D_4 &= D_2 - 2[H_3 - (H_2 + R_2)]\tan\theta \\
&= d_2 \text{ secant } \theta - 2[(H_3 - (H_2 + R_2)]\tan\theta \\
&= 12 \text{ secant } 9°36' \\
&\quad - 2[(40 - (20 + 6)]\tan 9°36' \\
&= \frac{12}{\cos 9°36'} - 2[40 - (20 + 6)]\tan 9°36' \\
&= \frac{12}{0.9860} - 2 \times 14 \times 0.1691 \\
&= 12.17 - 4.735 \\
&= \underline{7.435\,\text{mm diameter}}
\end{aligned}$$

The examples shown are only an indication of the use of balls and rollers for internal, external and angular measurement. In practice, the applications are limitless, but in every instance the solutions lend themselves to the application of simple trigonometry once the basic triangles have been set up.

(Courtesy of Addison Wesley Longman.)

1.20 The dividing head – simple indexing



Standard gear ratio = 40 : 1

In the above figure the index arm has to be rotated 40 times to rotate the workpiece once.

(a) The total movement of the index arm for any given number of divisions on the workpiece is given by the expression:

$$\text{Index arm setting} = \frac{40}{N}$$

where: N = the number of divisions required

(b) When angular divisions are required, the expression becomes:

$$\text{Index arm setting} = \frac{\text{angle required } (^\circ)}{9}$$

$$\text{since } 1/40 \text{ of a revolution} = \frac{360^\circ}{40} = 9^\circ$$

Example 1.20.1

Calculate the index arm setting to give 17 equally spaced divisions. The index plate has the following hole circles: 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43.

$$\text{Index arm setting} = \frac{40}{N} = \frac{40}{17} = \underline{2\tfrac{6}{17}}$$

By inspection, the actual indexing will be two whole turns and 12 holes in the 34-hole circle.

Example 1.20.2

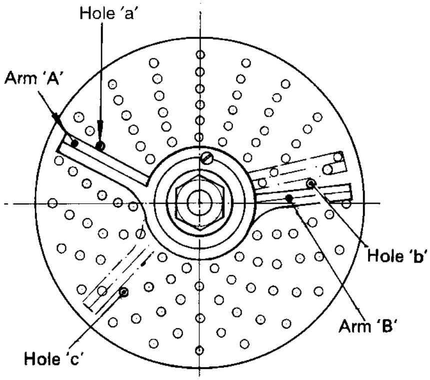
Using the same index plate as in the previous example, calculate the index arm setting to give an angular division of the workpiece of 12°18′.

$$\text{Index arm setting} = \frac{\text{angle required}}{9} = \frac{12°18'}{9}$$
$$= \frac{738'}{9 \times 60} = \frac{82}{60} = \underline{1\,{}^{11}\!/_{30}}$$

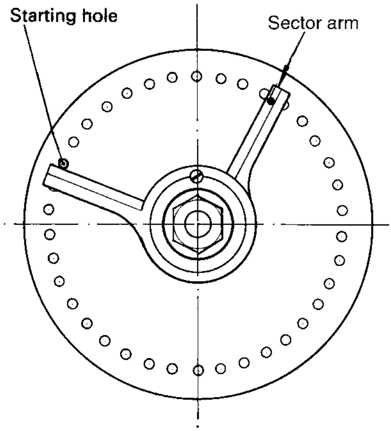
By inspection, the actual indexing will be one whole turn and 11 holes in the 30-hole circle.

Note how the angle was converted to minutes so as to have a common system of units in the numerator. Had the angle included seconds, e.g. 12°18′30″, then the angle would be converted into seconds and the denominator would become 9 × 360.

1.20.1 Sector arms



(a) Showing use of dividing head sector arms



(b) Setting for 152 divisions

To save having to count the holes in the index plate every time the dividing head is operated, *sector arms* are provided, as shown in Fig. (a) above. The method of using the sector arm is as follows:

1. The sector arms are set so that between arm 'A' and arm 'B' there is the required number of holes *plus the starting hole 'a'*.
2. The plunger and index arm is moved from hole 'a' to hole 'b' against sector arm B.
3. The sector arms are rotated so that arm 'A' is now against the plunger in hole 'b'.
4. For the next indexing the plunger is moved to hole 'c' against the newly positioned arm 'B'.
5. The process is repeated for each indexing.

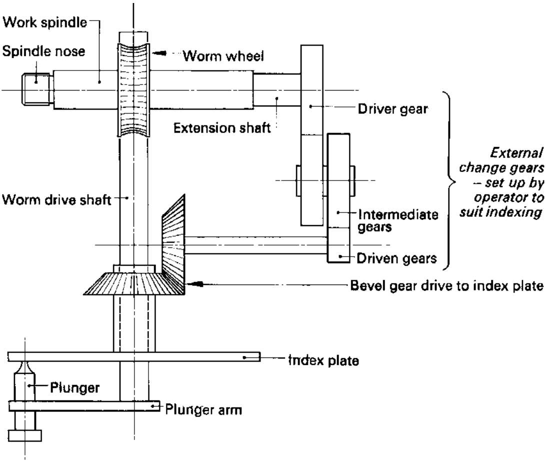
Example 1.20.3

For 152 divisions around the workpiece the indexing would be 10 holes in a 38-hole circle.

The sector arms would have 10 holes plus the starting hole where the indexing plunger is located between them. That is, a total of 11 holes between arm A and arm B.

(Courtesy of Addison Wesley Longman.)

1.21 Differential indexing



Divisions outside the range of a standard index plate can be obtained by *differential indexing*.

Instead of the index plate being clamped to the body of the dividing head, it is coupled to the work spindle by a gear train as shown in the above figure. Thus, as the index arm is rotated through the required number of turns, the index plate is advanced or retarded through a small amount automatically by the external gears.

The following expression is used to obtain the gear ratio of the drive coupling the work spindle to the index plate:

$$\frac{\text{Driver}}{\text{Driven}} = \frac{N_1 - N_2}{N_2} \times 40$$

where: N_1 = required divisions
N_2 = actual divisions available on the index plate

Example 1.21.1

Calculate the gear train to give an indexing of 113 divisions. The index plate available has: 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43 holes. The gears available are: 24(2), 28, 32, 40, 48, 56, 64, 72, 86, 100 teeth.

From Example 1.20.1 it will be seen that the required indexing is:

$$\frac{40}{113}$$

but this is not available with the index plate supplied, therefore a near approximation is selected as a basis for calculation. For example:

$$\frac{40}{120} \text{ which can be indexed as } \frac{14}{42}$$

That is, 14 holes in a 42-hole circle.

$$\frac{\text{Driver}}{\text{Driven}} = \frac{N_1 - N_2}{N_2} \times 40 \quad \text{where: } N_1 = 113$$

$$N_2 = 120$$

$$= \frac{113 - 120}{120} \times 40$$

$$= \frac{-7}{120} \times 40$$

(*Note* : The minus sign can be disregarded as it only indicates the direction of rotation.)

$$= \frac{7}{3}$$

$$= \frac{56}{24} \text{ from the gears available.}$$

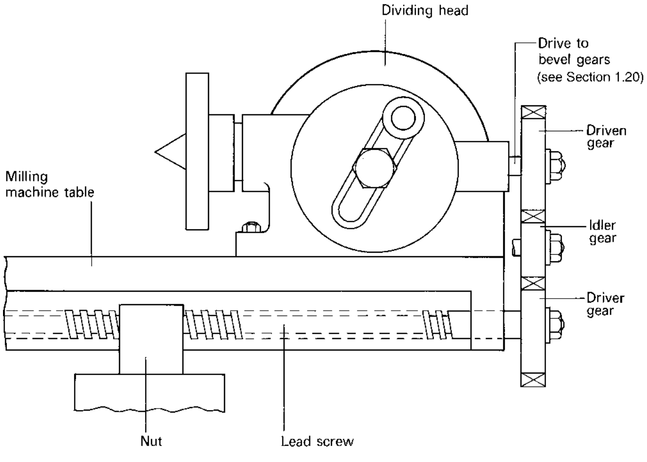
Therefore, when indexing 14 holes in a 42-hole circle with a 56-tooth gear driving a 24-tooth gear, the actual number of divisions on the specimen will be 113, and not 120 that would result if the index plate were fixed.

The *negative* sign in the calculation indicates that the plate rotates *with* the index arm. A *positive* sign indicates that the plate rotates *against* the index arm.

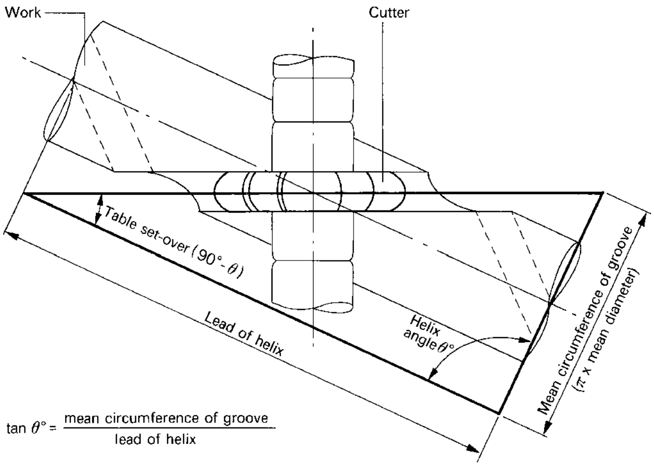
(Courtesy of Addison Wesley Longman.)

1.22 Helical milling

A *helix* can be defined as the locus (path) of a point travelling around an imaginary cylinder in such a manner that its axial and circumferential velocities maintain a constant ratio. In helical milling, the



(a)



(b) Set-over of milling machine table

table lead provides the axial movement and the dividing head provides the circumferential movement. The method of coupling the table lead screw to the dividing head by a gear train is shown in Fig. (a) above.

If the dividing head was coupled to the milling machine table by gears having a ratio of 1:1 then, because of the worm and worm-wheel in the dividing head, the table lead screw would have to rotate 40 times for the workpiece to rotate once. During those 40 revolutions the table and the work would traverse $40p$ millimetres, where p would be the pitch of the table lead screw. Since a single start lead screw is invariably used, pitch is equal to lead in this instance. This distance of $40p$ millimetres is referred to as the *lead of the machine*. For any given helix the ratio of the gears is

$$\frac{\text{Driver}}{\text{Driven}} = \frac{\text{lead of machine}}{\text{lead of helix to be cut}}$$

Example 1.22.1

Calculate the gear train to cut a helix of 540 mm lead on a milling machine fitted with a table lead screw having a lead of 6 mm.

Lead of machine $= 40p = 40 \times 6 = 240\,\text{mm}$

$$\frac{\text{Driver}}{\text{Driven}} = \frac{\text{lead of machine}}{\text{lead of helix to be cut}} = \frac{240}{540} = \frac{4}{9}$$

From the gears normally available a 32-tooth gear would be used to drive a 72-tooth gear.

The number of idler gears introduced between the driver and driven gears will depend upon the 'hand' of the helix being cut. Sometimes the lead being cut cannot be achieved with a *'simple'* gear train and a *'compound'* gear train has to be used – see Sections 1.19 and 1.20.

To prevent the cutter from interfering with the sides of the groove being cut it is necessary to swing the table of the milling machine round until the cutter is lying in the path of the helix as shown above. It is not possible to set over the table of a plain horizontal milling machine, so that helical milling is only possible on *universal* horizontal milling machines which are provided with the requisite table movements.

Even when the table is swung round to the helix angle of the groove it is not possible to mill a groove with straight sides. The only way that straight-sided grooves may be produced is on a vertical milling machine using an end mill or a slot drill. Under these conditions the table does not need to be set over. Unfortunately, the metal removal rate for an end mill is low compared with a side and face milling cutter. For this reason the groove should not be designed with straight sides if quantity production is envisaged.

Example 1.22.2

With reference to Fig. (b) above calculate the angle of set-over when milling a groove with a lead of 540 mm (see Example 1.17.1). The mean diameter of the groove is 40 mm.

$$\tan\theta^\circ = \frac{\text{lead of work}}{\text{mean circumference}}$$

$$= \frac{480}{40 \times \pi}$$

$$= 3.8197$$

$$\therefore \quad \theta^\circ = 75.33^\circ$$

$$\text{Set-over angle} = 90^\circ - \theta^\circ$$

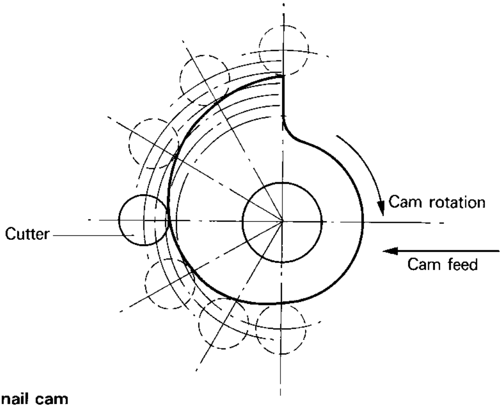
$$= 90^\circ - 75.33^\circ$$

$$= \underline{14.67^\circ}$$

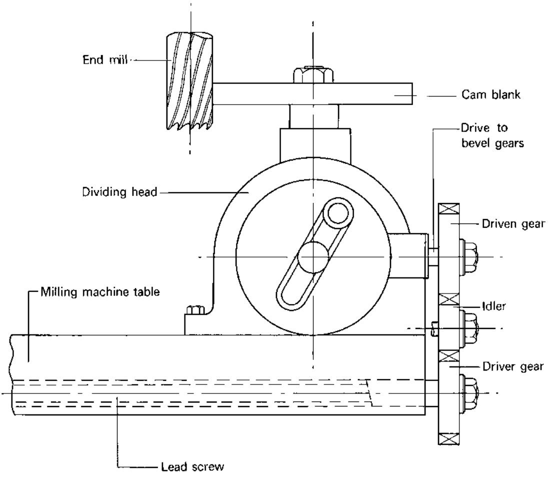
Note: For practical purposes the table would be set over by 15°.

(Courtesy of Addison Wesley Longman.)

1.23 Cam milling



(a) Snail cam



(b) Set-up for cam milling

Snail cams of the type shown in Fig. (a) above can be milled using a universal dividing head geared to the table lead screw of a vertical milling machine as shown in Fig. (b) above. As the table feeds the cam blank into the cutter the dividing head rotates the blank. The dividing head has been set with its spindle vertical in Fig. (b) above. The gear ratio to provide a given cam lift can be calculated from the expression:

$$\frac{\text{Driver}}{\text{Driven}} = \frac{\text{lead of machine}}{\text{lift per revolution of cam}}$$

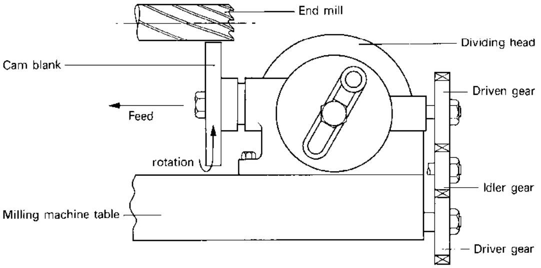
Example 1.23.1

Calculate the gear ratio to cut a cam that has a lift of 12 mm in 90° rotation if the table lead screw has a pitch (lead) of 6 mm.

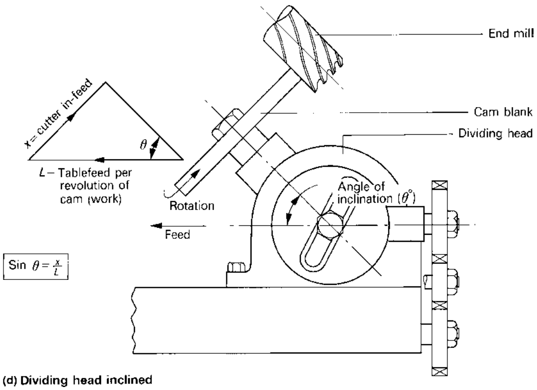
Lead of machine $= 40p = 40 \times 6\,\text{mm} = 240\,\text{mm}$

$$\text{Lift of cam per revolution} = 12\,\text{mm} \times \frac{360^\circ}{90^\circ} = 48\,\text{mm}$$

$$\frac{\text{Driver}}{\text{Driven}} = \frac{\text{lead of machine}}{\text{lift per revolution}} = \frac{240}{48} = \frac{5}{1}$$



(c) Dividing head horizontal, zero lift generated on cam



(d) Dividing head inclined

Unfortunately, the ratio of lift to lead rarely works out so conveniently in practice and some means has to be used to obtain intermediate values from the standard gears supplied. With the dividing head spindle set vertically the lift generated on the cam is a maximum for any given gear ratio. However, with the dividing head and the milling machine spindle set horizontally, as shown in Fig. (c) above, only a cylindrical surface will be generated and the lift will be zero. Thus, for some setting intermediate between these extremes will be the required lift.

To cam mill, an inclinable-head vertical milling machine is required. A gear ratio is then selected that gives a lift *larger* than that required, and the machine head and the dividing head are inclined to give the actual lift required, as shown in Fig. (d) above.

$$\text{Sin}\,\theta = \frac{\text{lift per revolution of cam produced } (x)}{\text{table movement per revolution of cam } (L)}$$

$$\text{and } L = \frac{x}{\sin\theta}$$

But L is the maximum lift per revolution for any given gear train, and:

$$\frac{\text{Driver}}{\text{Driven}} = \frac{\text{lead of machine}}{L}$$

$$= \frac{\text{lead of machine}}{x/\sin\theta}, \quad \text{when inclined at } \theta^\circ$$

$$= \frac{\text{lead of machine} \times \sin\theta}{x}$$

$$\text{Thus: } \sin\theta = \frac{x}{\text{lead of machine}} \times \frac{\text{driver}}{\text{driven}}$$

where x = the required lift per revolution of the cam.

Example 1.23.2

Calculate the gears and spindle inclination to cut a cam whose lift is 23.5 mm in 83° on a vertical milling machine whose lead is 240 mm.

$$\text{Lift per revolution of cam} = \frac{23.5 \times 360}{83^\circ}$$

$$= 101.9\,\text{mm/rev}$$

The nearest convenient gear ratio *greater* than this lift would be:

$$\frac{\text{Driver}}{\text{Driven}} = \frac{\text{lead of machine}}{\text{maximum lift per revolution}}$$

$$= \frac{240}{105}$$

$$= \frac{48}{21}$$

To find the angle of inclination (θ):

$$\text{Sin}\,\theta = \frac{x}{\text{lead of machine}} \times \frac{\text{driver}}{\text{driven}}$$

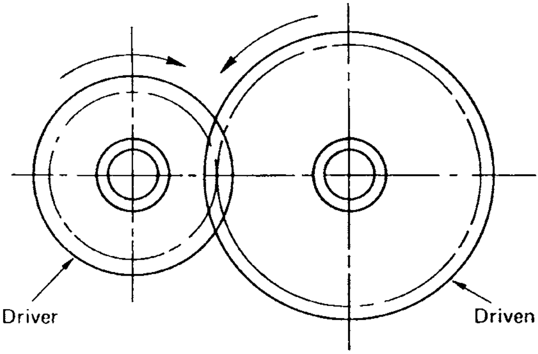
$$= \frac{101.9}{240} \times \frac{48}{21}$$

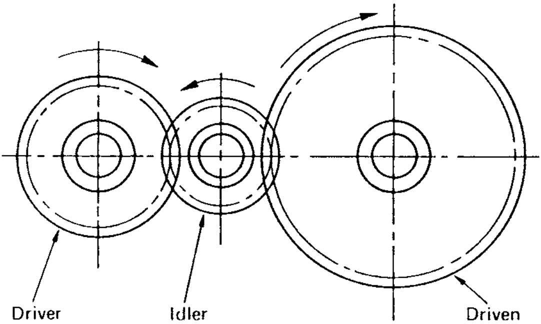
$$= \underline{0.970\,5}$$

$$\therefore \quad \theta^\circ = \underline{76^\circ 3'}$$

(Courtesy of Addison Wesley Longman.)

1.24 Gear trains (simple)





1.24.1 Simple train

(a) Driver and driven gears rotate in opposite directions.
(b) The relative speed of the gears is calculated by the expression

$$\frac{\text{rev/ min driver}}{\text{rev/ min driven}} = \frac{\text{number of teeth on driven}}{\text{number of teeth on driver}}$$

Example 1.24.1

Calculate the speed of the driven gear if the driving gear is rotating at 120 rev/min. The driven gear has 150 teeth and the driving gear has 50 teeth.

$$\frac{120}{\text{rev/ min driven}} = \frac{150}{50}$$

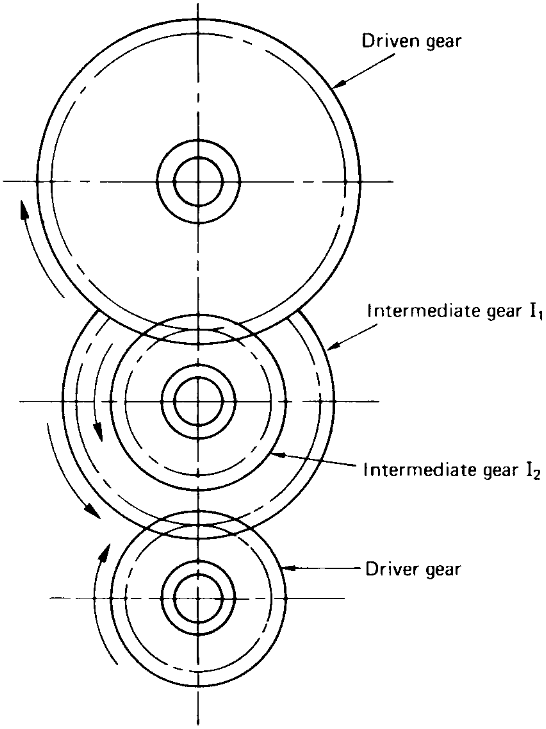
$$\text{rev/ min driven} = \frac{120 \times 50}{150} = 40\,\text{rev/ min}$$

1.24.2 Simple train with idler gear

(a) Driver and driven gears rotate in the same direction if there is an odd number of idler gears, and in the opposite direction if there is an even number of idler gears.
(b) Idler gears are used to change the direction of rotation and/or to increase the centre distance between the driver and driven gears.
(c) The number of idler gears and the number of teeth on the idler gears do not affect the overall relative speed.
(d) The overall relative speed is again calculated using the expression

$$\frac{\text{rev/ min driver}}{\text{rev/ min driven}} = \frac{\text{number of teeth on driven}}{\text{number of teeth on driver}}$$

1.25 Compound gear trains



(a) Unlike the idler gear of a simple train, the intermediate gears of a compound train do influence the overall relative speeds of the driver and driven gears.
(b) Both intermediate gears (I_1 and I_2) are keyed to the same shaft and rotate at the same speed.
(c) Driver and driven gears rotate in the same direction. To reverse the direction of rotation an idler gear has to be inserted either between the driver gear and I_1 or between I_2 and the driven gear.
(d) The overall relative speed can be calculated using the expression

$$\frac{\text{rev/min driver}}{\text{rev/min driven}} = \frac{\text{no. of teeth on } I_1}{\text{no. of teeth on driver}} \times \frac{\text{no. of teeth on driven}}{\text{no. of teeth on } I_2}$$

Example 1.25.1

Calculate the speed of the driven gear given that: the driver rotates at 600 rev/min and has 30 teeth; I_1 has 60 teeth; I_2 has 40 teeth; and the driven gear has 80 teeth.

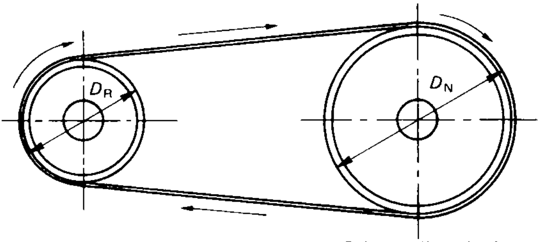
$$\frac{\text{rev/min driver}}{\text{rev/min driven}} = \frac{60 \times 80}{30 \times 40} = \frac{4}{1}$$
$$\text{but speed of driver} = 600\,\text{rev/min}$$

Therefore:

$$\frac{600\,\text{rev/min}}{\text{rev/min driven}} = \frac{4}{1}$$
$$\text{speed driven} = \frac{600 \times 1}{4}$$
$$= \underline{150\,\text{rev/min}}$$

1.26 Belt drive (simple)

1.26.1 Open belt drive



(a) Driver and driven pulley wheels rotate in the same direction.
(b) The relative speed of the pulley wheels is calculated by the expression

$$\frac{\text{rev/min driver}}{\text{rev/min driven}} = \frac{\text{diameter } D_N \text{ of driven}}{\text{diameter } D_R \text{ of driver}}$$

Example 1.26.1

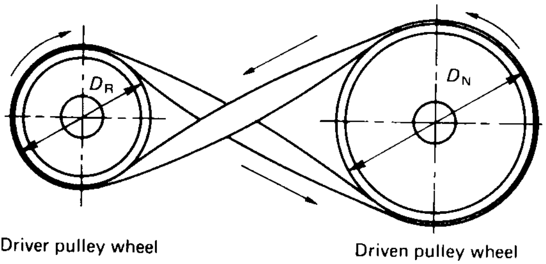
Calculate the speed in rev/min of the driven pulley if the driver rotates at 200 rev/min. Diameter D_R is

500 mm and diameter D_N is 800 mm.

$$\frac{200\,\text{rev/min}}{\text{rev/min driven}} = \frac{800\,\text{mm}}{500\,\text{mm}}$$

$$\text{rev/min driven} = \frac{200 \times 500}{800} = \underline{125\,\text{rev/min}}$$

1.26.2 Crossed belt drive



(a) Driver and driven pulley wheels rotate in opposite directions.
(b) Crossed belt drives can only be used with flat section belts (long centre distances) or circular section belts (short centre distances).
(c) The relative speed of the pulley wheels is again calculated by the expression

$$\frac{\text{rev/min driver}}{\text{rev/min driven}} = \frac{\text{diameter } D_N \text{ of driven}}{\text{diameter } D_R \text{ of driver}}$$

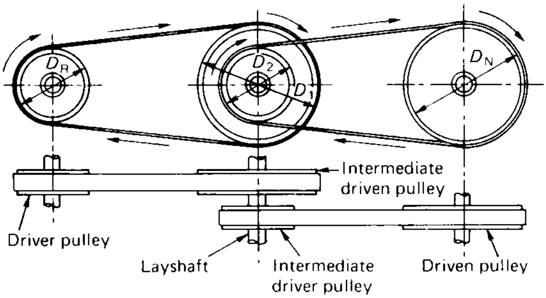
Example 1.26.2

The driver pulley rotates at 500 rev/min and is 600 mm in diameter. Calculate the diameter of the driven pulley if it is to rotate at 250 rev/min.

$$\frac{500\,\text{rev/min}}{250\,\text{rev/min}} = \frac{\text{diameter } D_N}{600\,\text{mm}}$$

$$\text{diameter } D_N = \frac{500 \times 60}{250} = 1200\,\text{mm}$$

1.27 Belt drive (compound)



(1) To identify the direction of rotation, the rules for open and crossed belt drives apply (Section 1.26).
(2) The relative speeds of the pulley wheels are calculated by the expression

$$\frac{\text{rev/ min driver}}{\text{rev/ min driven}} = \frac{\text{diameter } D_1}{\text{diameter } D_R} \times \frac{\text{diameter } D_N}{\text{diameter } D_2}$$

Example 1.27.1

Calculate the speed in rev/min of the driven pulley if the driver rotates at 600 rev/min. The diameters of the pulley wheels are: $D_R = 250$ mm. $D_1 = 750$ mm, $D_2 = 500$ mm, $D_N = 1000$ mm.

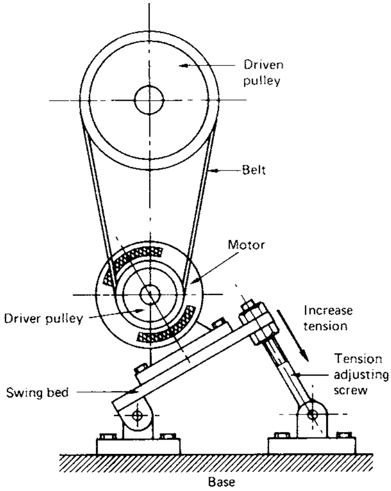
$$\frac{600 \text{ rev/ min}}{\text{rev/ min driven}} = \frac{750 \text{ mm}}{250 \text{ mm}} \times \frac{1000 \text{ mm}}{500 \text{ mm}}$$

$$\text{rev/ min driven} = \frac{600 \times 250 \times 500}{750 \times 1000}$$

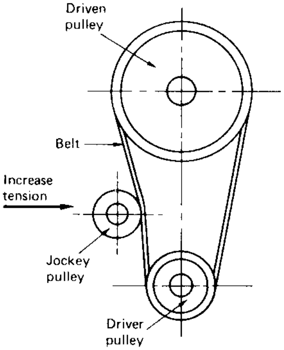
$$= \underline{100 \text{ rev/ min}}$$

1.28 Typical belt tensioning devices

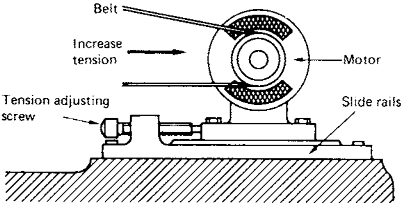
Swing bed tensioning device



Jockey pulley



Slide rail tensioning device



Part 2

Threaded Fasteners

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2.1 Introduction to threaded fasteners

Although dimensioned in 'inch' units the following screw thread tables have been retained for maintenance data and similar applications.

2.1.37 British Standard Whitworth (BSW) screw threads
2.1.38 British Standard Fine (BSF) screw threads
2.1.39 ISO Unified precision internal screw threads: coarse series
2.1.40 ISO Unified precision external screw threads: coarse series
2.1.41 ISO Unified precision internal screw threads: fine series
2.1.42 ISO Unified precision external screw threads: fine series

Although obsolescent, the following 'metric' screw thread table has been retained.

2.1.44 British Association (BA) internal and external screw threads

The tables based upon abstracts from BS 4190 and BS 3692 have become obsolescent and have been replaced by new tables based upon abstracts from the appropriate BSEN standards for screwed fasteners with metric dimension. The fasteners covered by these new standards are as follows.

2.1.12 BSEN 24014: Hexagon head bolts – product grade A and B
2.1.13 BSEN 24016: Hexagon head bolts – product grade C
2.1.14 BSEN 24017: Hexagon head screws – product grade A and B
2.1.15 BSEN 24018: Hexagon head screws – product grade C
2.1.16 BSEN 24032: Hexagon nuts style 1 – product grade A and B
2.1.17 BSEN 24033: Hexagon nuts style 2 – product grade A and B
2.1.18 BSEN 24034: Hexagon nuts style 1 – product grade C

2.1.19 BSEN 24035: Hexagon thin nuts (chamfered) – product grade A and B
2.1.20 BSEN 24036: Hexagon thin nuts (unchamfered) – product grade B

All the above standards refer to screwed fasteners with metric dimensions and have coarse pitch threads. Fine pitch threads will be referred to in due course.

Notes:

(i) BSEN 24015 refers to hexagon head bolts with their shanks reduced to effective (pitch) diameter of their threads. These are for specialised applications and have not been included in this pocket book.
(ii) The mechanical property standards contained within BS 4190 and BS 3692 can now be found in BSEN 20898 Part 1 (bolts) and Part 2 (nuts).

Interpretation of the **product grade** is as follows:

- Examine the table in Section 2.3.
- The shank diameter (d_s) has a maximum diameter which equals the normal diameter and also a minimum diameter.
- The minimum diameter can have a **product grade A** tolerance or a **product grade B** tolerance. The grade A tolerance is closer (more accurate) than the grade B tolerance.
- Product grade A tolerances apply to fasteners with a size range from M1.6 to M24 inclusive.
- Product grade B tolerances apply to fasteners with a size range from M16 to M64.
- Sizes M16 to M24 inclusive can have product grade A or product grade B tolerances.

Note that not only is the product grade defined by the diameters but by the length as well.

Example 2.1.1

An M5 hexagon head bolt will lie within product grade A tolerances and will have a shank diameter lying between 5.00 mm and 4.82 mm inclusive.

Example 2.1.2

An M36 hexagon head bolt will lie within product grade B tolerances and will have a shank diameter lying between 36 mm and 35.38 mm inclusive.

Example 2.1.3

An M16 hexagon head bolt will have a shank diameter lying between 16 mm diameter and 15.73 mm diameter inclusive if it is to product group A tolerances. If it is to product group B tolerances, it will have a shank diameter lying between 16 mm diameter and 15.57 mm inclusive.

Note: The above system of tolerancing applies to all the other dimensions for the fasteners in this table.

- Examine the table in Section 2.4. All the dimensions in this table refer to screwed fasteners with product grade C tolerances.
- Comparing this table with the previous examples shows that the fasteners made to product grade C have much coarser tolerances than those for product grade A and B.
- An M12 bolt to product grade A has a shank diameter (d_s) lying between 12 mm and 11.73 mm (a tolerance of 0.27 mm), whereas an M12 bolt to product grade C has a shank diameter (d_s) lying between 12.77 mm and 11.3 mm (a tolerance of 1.4 mm). Product grade B does not apply to this size of bolt.

Note: The old terminology of 'black' (hot forged) and 'bright/precision' (cold headed or machined from hexagon bar) bolts and nuts no longer applies. However, hot forged (black) bolts and nuts would only be made to product grade C.

All the fasteners listed so far have **coarse pitch** threads. The following tables and standards refer to a corresponding **fine pitch** series of screwed fasteners. These fine pitch series of screwed fasteners are only available in product grades A and B.

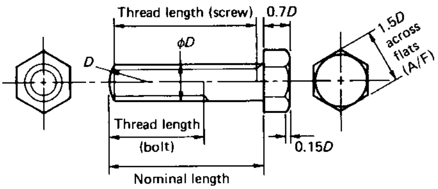
2.1.21 BSEN 28765: Hexagon head bolts with metric fine pitch threads – product grade A and B

2.1.22 BSEN 28676: Hexagon head screws with metric fine pitch threads – product grade A and B
2.1.23 BSEN 28673: Hexagon nuts (style 1) with metric fine pitch threads – product grade A and B
2.1.24 BSEN 28674: Hexagon nuts (style 2) with metric fine pitch threads – product grade A and B
2.1.25 BSEN 28675: Hexagon thin nuts with metric fine pitch threads – product grade A and B

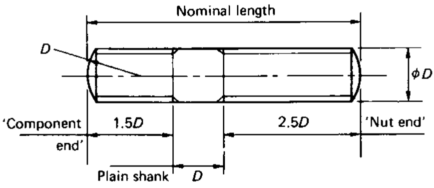
2.2 Threaded fasteners

2.2.1 Drawing proportions

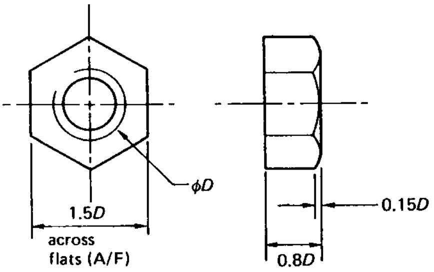
Bolts and screws



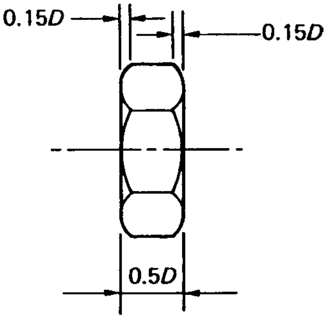
Studs



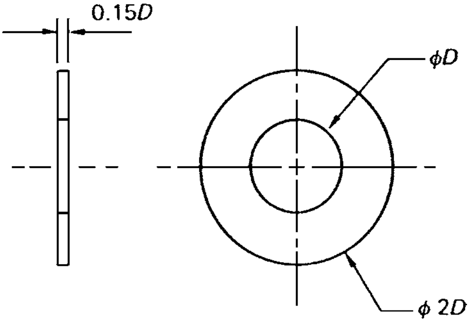
Standard nut



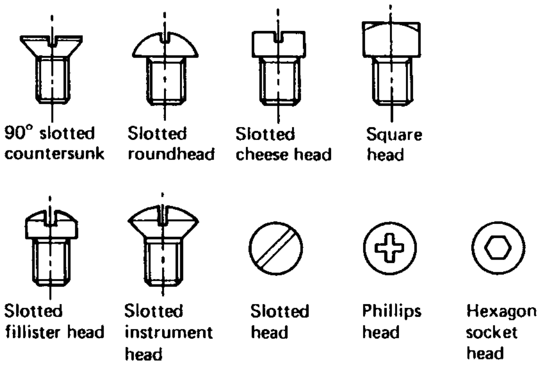
Thin (lock) nut



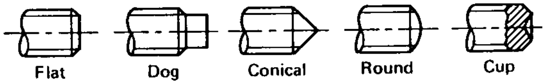
Plain washer



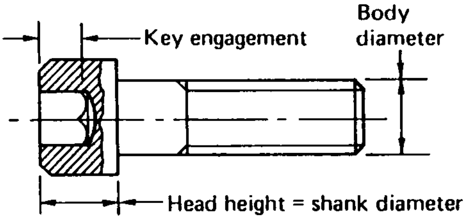
2.2.2 Alternative screw heads

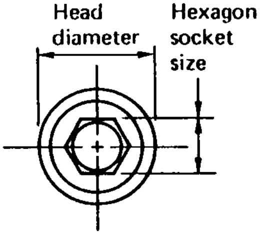


2.2.3 Alternative scew points

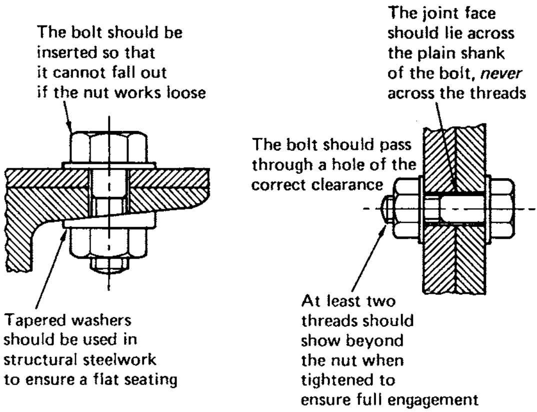


2.2.4 Hexagon socket cap head screw

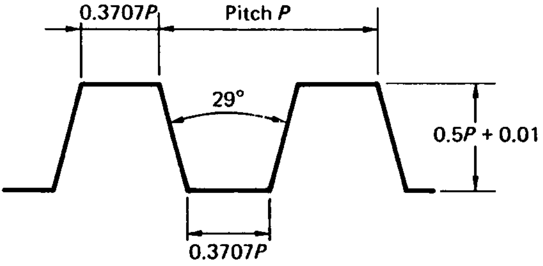




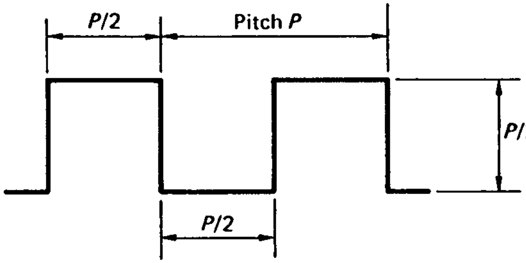
2.2.5 Applications of threaded fasteners



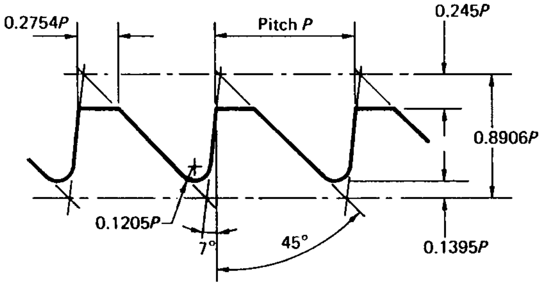
2.2.6 Acme thread form



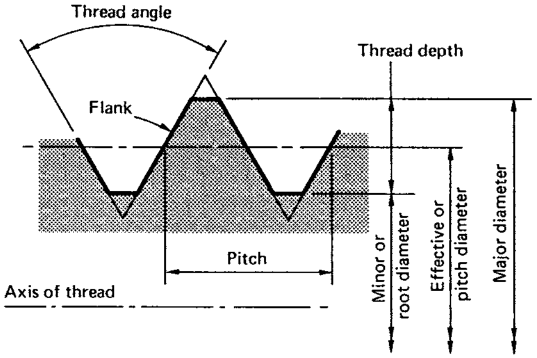
2.2.7 Square thread form



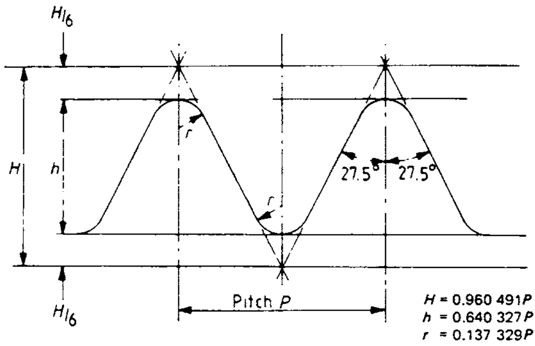
2.2.8 Buttress thread form



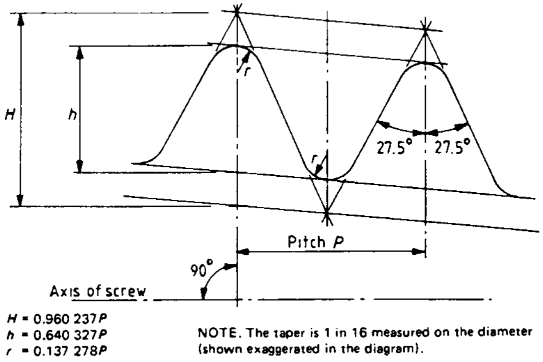
2.2.9 V-thread form



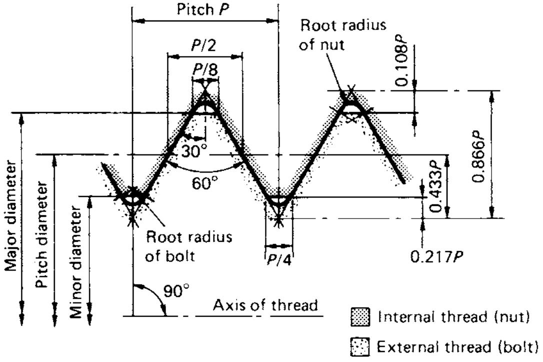
2.2.10 Basic Whitworth (55°) thread form: parallel threads



This is the basic thread form for BSW, BSF and BSP screw threads.



2.2.11 ISO metric and ISO 60° unified thread forms



2.3 ISO metric hexagon head bolts (coarse thread): preferred sizes: product grade A and B

(Dimensions in millimetres)

Designated thread size	*Product grade*	*Pitch of thread*	*Thread*			*Plain Shank*		*Hexagon*					
								Across Flats (A/F)		*Across corners*	*Thickness*		
			Major diameter	*Effective diameter*	*Minor diameter*	*Maximum diameter (nominal)*	*Minimum diameter*	*Maximum (nominal)*	*Minimum*	*(A/C) min.*	*Nominal*	*Maximum*	*Minimum*
M1.6	A	0.35	1.60	1.37	1.17	1.6	1.46	3.2	3.02	3.41	1.1	1.225	0.975
M2	A	0.40	2.00	1.74	1.50	2.0	1.86	4.0	3.82	4.32	1.4	1.525	1.275
M2.5	A	0.45	2.50	2.21	1.15	2.50	2.36	5.0	4.82	5.45	1.7	1.825	1.575
M3	A	0.50	3.00	2.68	2.39	3.00	2.86	5.5	5.32	6.01	2.0	2.125	1.875
M4	A	0.70	4.00	3.55	3.14	4.00	3.82	7.0	6.78	7.66	2.8	2.925	2.675
M5	A	0.80	5.00	4.48	4.02	5.00	4.82	8.0	7.78	8.79	3.5	3.650	3.350
M6	A	1.00	6.00	5.36	4.77	6.00	5.82	10.0	9.78	11.05	4.0	4.150	3.850
M8	A	1.25	8.00	7.19	6.47	8.00	7.78	13.0	12.73	14.38	5.3	5.450	5.150
M10	A	1.50	10.00	9.03	8.16	10.00	9.78	16.0	15.73	17.77	6.4	6.580	6.220

M12	A	1.75	12.00	10.86	9.85	12.00	11.73	18.0	17.73	20.03	7.5	7.680	7.320
M16	A	2.00	16.00	14.70	13.55	16.00	15.73	24.0	23.67	26.75	10.0	10.180	9.820
	B	2.00	16.00	14.70	13.55	16.00	15.57	24.0	23.16	26.17	10.0	10.290	9.710
M20	A	2.50	20.00	18.38	16.93	20.00	19.67	30.00	29.67	33.53	12.5	12.715	12.285
	B	2.50	20.00	18.38	16.93	20.00	19.48	30.00	29.16	32.95	12.5	12.850	12.150
M24	A	3.00	24.00	22.05	20.32	24.00	23.67	36.00	35.38	39.98	15.0	15.215	14.785
	B	3.00	24.00	22.05	20.32	24.00	23.48	36.00	35.00	39.55	15.0	15.350	14.650
M30	B	3.50	30.00	27.73	25.71	30.00	29.48	46.00	45.00	50.85	18.7	19.120	18.280
M36	B	4.00	36.00	33.40	31.09	36.00	35.38	56.00	53.80	60.79	22.5	22.920	22.06
M42	B	4.50	42.00	39.08	36.48	42.00	41.38	65.00	63.10	71.30	26	26.420	25.58
M48	B	5.00	48.00	44.75	41.87	48.00	47.38	75.00	73.10	82.60	30	30.420	29.58

For further information see BSEN 24014.

2.3 (*continued*) (Dimensions in millimetres)

Designated thread size	*Popular length combinations*						
M1.6	U/head	12	16				
	Thread	9	9				
	Shank	1.2	5.2				
M2	U/head	16	20				
	Thread	10	10				
	Shank	4	8				
M2.5	U/head	16	20	25			
	Thread	11	11	11			
	Shank	2.75	6.75	11.75			
M3	U/head	20	25	30			
	Thread	12	12	12			
	Shank	5.5	10.5	15.5			
M4	U/head	25	30	35	40		
	Thread	14	14	14	14		
	Shank	7.5	12.5	17.5	22.5		
M5	U/head	25	30	35	40	45	50
	Thread	16	16	16	16	16	16
	Shank	5	10	15	20	25	30

M6	U/head	30	35	40	45	50	55	60				
	Thread	18	18	18	18	18	18	18				
	Shank	7	12	17	22	27	33	37				
M8	U/head	40	45	50	55	60	65	70	80			
	Thread	22	22	22	22	22	22	22	22			
	Shank	11.75	16.75	21.75	26.75	31.50	36.5	41.75	51.75			
M10	U/head	45	50	55	60	65	70	80	90	100		
	Thread	26	26	26	26	26	26	26	26	26		
	Shank	11.5	16.5	21.5	26.5	31.5	36.5	46.5	56.5	66.5		
M12	U/head	50	55	60	65	70	80	90	100	110	120	
	Thread	30	30	30	30	30	30	30	30	30	30	
	Shank	11.25	16.25	21.25	26.25	31.25	41.25	51.25	61.25	71.25	81.25	
M16	U/head	65	70	80	90	100	110	120	130	140	150	160
	Thread	38	38	38	38	38	38	38	44	44	44	44
	Shank	17	22	32	42	52	62	72	76	86	96	106

(*continued*)

2.3 (*continued*) (Dimensions in millimetres)

Designated thread size	*Popular length combinations*											
M20	U/head	80	90	100	110	120	130	140	150	160	180	200
	Thread	46	46	46	46	46	52	52	52	52	52	52
	Shank	21.5	31.5	41.5	51.5	61.5	65.5	75.5	85.5	95.5	115.5	135.5
M24	U/head	90	100	110	120	130	140	150	160		180	200
	Thread	54	54	54	54	60	60	60	60		60	60
	Shank	21	31	41	51	56	65	75	85		106	125
	U/head	220	240									
	Thread	73	73									
	Shank	132	152									
M30	U/head	110	120	130	140	150	160	180	200		220	240
	Thread	66	66	72	72	72	72	72	72		85	85
	Shank	26.5	36.5	40.5	50.5	60.5	70.5	90.5	110.5		117.5	137.5
	U/head	260	280	300								
	Head	85	85	85								
	Shank	157.5	177.5	197.5								

M36	U/head	140	150	160	180	200	220	240	260	280	300	320
	Thread	84	84	84	84	84	97	97	97	97	97	97
	Shank	36	46	56	76	96	103	123	143	163	183	203
	U/head	340	360									
	Thread	97	97									
	Shank	223	243									
M42	U/head	160	180	200	220	240	260	280	300		320	340
	Thread	96	96	96	109	109	109	109	109		109	109
	Shank	41.5	61.5	81.5	88.5	108.5	128.5	148.5	168.5		188.5	208.5
	U/head	360	380	400	420	440						
	Thread	109	109	109	109	109						
	Shank	288.5	248.5	268.5	288.5	308.5						
M48	U/head	180	200	220	240	260	280	300	320		340	360
	Thread	116	116	121	121	121	121	121	121		121	121
	Shank	47	67	74	94	114	134	154	174		194	214
	U/head	380	400	420	440	460	480					
	Thread	121	121	121	121	121	121					
	Shank	234	254	274	294	314	334					

For further information see BSEN 24014.

Note: The length under the head of the bolt (U/head) is also the **nominal length**.

2.4 ISO metric hexagon head bolts (coarse thread): preferred sizes: product grade C

(Dimensions in millimetres)

Designated thread size	*Pitch of thread*	*Thread*			*Plain Shank*		*Hexagon*					
		Major diameter	*Effective diameter*	*Minor diameter*	*Maximum diameter*	*Minimum diameter*	*Across Flats (A/F)*		*Across corners (A/C) minimum*	*Thickness*		
							Maximum (nominal)	*Minimum*		*Nominal*	*Maximum*	*Minimum*
M1.6												
M2												
M2.5		Not available in product grade C										
M3												
M4												
M5	0.80	5.0	4.48	4.02	5.48	4.52	8.00	7.64	8.63	3.5	3.875	3.125
M6	1.00	6.0	5.36	4.77	6.48	5.52	10.00	9.64	10.89	4.0	4.375	3.625
M8	1.25	8.0	7.19	6.47	8.58	7.42	13.00	12.57	14.2	5.3	5.675	4.925
M10	1.50	10.0	9.03	8.16	10.58	9.42	16.00	15.57	17.59	6.4	6.850	5.950
M12	1.75	12.0	10.86	9.85	12.70	11.30	18.00	17.57	19.85	7.5	7.950	7.050
M16	2.00	16.0	14.70	13.55	16.70	15.30	24.00	23.16	26.17	10.0	10.750	9.250
M20	2.50	20.0	18.38	16.93	20.84	19.16	30.00	29.16	32.95	12.5	13.400	11.600
M24	3.00	24.0	22.05	20.32	24.84	23.16	36.00	35	39.55	15.0	15.900	14.100
M30	3.50	30.0	27.73	25.71	30.84	29.16	46.00	45	50.85	18.7	19.750	17.650
M36	4.00	36.0	33.40	31.09	37.00	35.0	55.00	53.8	60.79	22.5	23.550	22.500
M42	4.50	42.0	39.08	36.48	43.00	41.00	65.00	63.1	71.30	26.0	27.050	24.950
M48	5.00	48.0	44.75	41.87	49.00	47.00	75.00	73.1	82.60	30.0	31.050	28.950

For further information see BSEN 24016.

Note: Hot-forged (black) bolts are only available in the coarse thread: product grade C series.

Designated thread size	*Popular length combinations*											
M5	U/head	25	30	35	40	45	50					
	Thread	16	16	16	16	16	16					
	Shank	5	10	15	20	25	30					
M6	U/head	30	35	40	45	50	55	60				
	Thread	18	18	18	18	18	18	18				
	Shank	7	12	17	22	27	32	37				
M8	U/head	40	45	50	55	60	65	70	80			
	Thread	22	22	22	22	22	22	22	22			
	Shank	11.75	16.75	21.75	28.75	31.75	36.75	41.75	51.75			
M10	U/head	45	50	55	60	65	70	80	90	100		
	Thread	26	26	26	26	26	26	26	26	26		
	Shank	11.75	16.75	21.75	28.75	31.75	36.5	46.5	56.5	66.5		
M12	U/head	55	60	65	70	80	90	100	110	120		
	Thread	30	30	30	30	30	30	30	30	30		
	Shank	16.25	21.25	28.25	31.25	41.25	51.25	61.25	71.25	81.25		
M16	U/head	65	70	80	90	100	110	120	130	140	150	160
	Thread	38	38	38	38	38	38	38	44	44	44	44
	Shank	17	22	32	42	52	62	72	76	86	96	106
M20	U/head	80	90	100	110	120	130	140	150	160	180	200
	Thread	46	46	46	46	46	52	52	52	52	52	52
	Shank	21.5	31.5	41.5	51.5	61.5	65.5	75.5	85.5	95.5	115.5	135.5

(*continued*)

2.4 (*continued*)

Designated thread size	*Popular length combinations*													
M24	U/head	100	110	120	130	140	150	160	180	200	220	240		
	Thread	54	54	54	60	60	60	60	60	60	73	73		
	Shank	31	41	51	55	65	75	85	105	125	132	152		
M30	U/head	120	130	140	150	160	180	200	220	240	260	280	300	
	Thread	66	72	72	72	72	72	72	85	85	85	85	85	
	Shank	36.5	40.5	50.5	60.5	70.5	90.5	110.5	117.5	137.5	157.5	177.5	197.5	
M36	U/head	140	150	160	180	200	220	240	260	280	300	320	340	360
	Thread	84	84	84	84	84	97	97	97	97	97	97	97	97
	Shank	36	46	56	76	96	103	123	143	163	183	203	223	243
M42	U/head	180	200	220	240	260	280	300	320	340	360	380	400	420
	Thread	96	96	109	109	109	109	109	109	109	109	109	109	109
	Shank	61.5	81.5	88.5	108.5	128.5	148.5	168.5	188.5	208.5	228.5	248.5	268.5	288.5
M48	U/head	200	220	240	260	280	300	320	340	360	380	400	420	440
	Thread	108	121	121	121	121	121	121	121	121	121	121	121	121
	Shank	67	74	94	114	134	154	174	194	214	234	254	271	294
	U/head	460	480											
	Thread	121	121											
	Shank	314	334											

For further information see: BSEN 24016.
Note: This length under the bolt head (U/head) is also the **nominal length**.

2.5 ISO metric hexagon head screws (coarse thread): preferred sizes: product grade A and B

Notes:

(1) Reference back to Section 2.2.1 shows that hexagon head **bolts** have a plain shank between the head and the thread. It also shows that hexagon head **screws** have the thread running the full length up to the head of the screw. For practical tooling purposes there is a short distance $(a + c)$ immediately under the head to allow the thread to run out and also allow for a small radius. The dimensions $(a + c)$ refer to BSEN 24017.

(2) The thread and hexagon proportions are the same as those shown in Section 2.3. Therefore only the length under the head (**nominal length**) and the dimensions $(a + c)$ are listed here.

(Dimensions in millimetres)

Designated thread size	*Grade*	*Feature*	*Popular lengths*								
M1.6	A	U/head (nom)	2	3	4	5	6	8	10	12	16
		U/head (max)	2.20	3.20	4.24	5.24	6.24	8.29	10.29	12.35	16.35
		U/head (min)	1.80	2.80	3.76	4.76	5.76	7.71	9.71	11.65	15.65
		a + c (max)	1.05 + 0.25 = 1.30 mm for all screw lengths								
		a + c (min)	0.35 + 0.10 = 0.45 mm for all screw lengths								
M2	A	U/head (nom)	4	5	6	8	10	12	16	20	
		U/head (max)	4.24	5.24	6.24	8.29	10.29	12.35	16.35	20.42	
		U/head (min)	3.76	4.76	5.76	7.71	9.71	11.65	15.65	19.58	
		a + c (max)	1.20 + 0.25 = 1.45 mm for all screw lengths								
		a + c (min)	0.40 + 0.10 = 0.50 mm for all screw lengths								
M2.5	A	U/head (nom)	5	6	8	10	12	16	20	25	
		U/head (max)	5.24	6.24	8.29	10.29	12.35	16.35	20.42	25.42	
		U/head (min)	4.76	5.76	7.71	9.71	11.65	15.65	19.58	24.58	
		a + c (max)	1.35 + 0.25 = 1.60 mm for all screw lengths								
		a + c (min)	0.45 + 0.10 = 0.55 mm for all screw lengths								
M3	A	U/head (nom)	6	8	10	12	16	20	25	30	
		U/head (max)	6.24	8.29	10.29	12.35	16.35	20.42	25.42	30.42	
		U/head (min)	5.76	7.71	9.71	11.65	15.65	19.58	24.58	29.58	
		a + c (max)	1.50 + 0.40 = 1.90 mm for all screw lengths								
		a + c (min)	0.50 + 0.15 = 0.65 mm for all screw lengths								

M4	A	U/head (nom)	8	10	12	16	20	25	30	35	40				
		U/head (max)	8.29	10.29	12.35	16.35	20.42	25.42	30.42	35.5	40.5				
		U/head (min)	7.71	9.71	11.65	15.65	19.58	24.58	29.58	34.5	39.5				
		a + c (max)	2.1 + 0.4 = 2.5 mm for all screw lengths												
		a + c (min)	0.70 + 0.15 = 0.85 mm for all screw lengths												
M5	A	U/head (nom)	10	12	16	20	25	30	35	40	45	50			
		U/head (max)	10.29	12.35	16.35	20.42	25.42	30.42	35.5	40.5	45.5	50.5			
		U/head (min)	9.71	11.65	15.65	19.58	24.58	29.58	34.5	39.5	44.5	49.5			
		a + c (max)	2.4 + 0.5 = 2.9 mm for all screw lengths												
		a + c (min)	0.80 + 0.15 = 0.95 mm for all screw lengths												
M6	A	U/head (nom)	12	16	20	25	30	35	40	45	50	55	60		
		U/head (max)	12.35	16.35	20.42	25.42	30.42	35.5	40.5	45.5	50.5	55.6	60.6		
		U/head (min)	11.65	15.65	19.58	24.58	29.58	34.5	39.5	44.5	49.5	54.4	59.4		
		a + c (max)	3.0 + 0.5 = 3.5 for all screw lengths												
		a + c (min)	1.0 + 0.15 = 1.15 for all screw lengths												
M6	B	U/head (nom)	60												
		U/head (max)	61.5												
		U/head (min)	58.5												
		a + c	As for product grade A.												
M8	A	U/head (nom)	16	20	25	30	35	40	45	50	55	60	65	70	80
		U/head (max)	16.35	20.42	25.42	30.42	35.5	40.5	45.5	50.5	55.6	60.6	65.6	70.6	80.6
		U/head (min)	15.65	19.58	24.58	29.58	34.5	39.5	44.5	49.5	54.4	59.4	64.4	69.4	79.4
		a + c (max)	4.0 + 0.6 = 4.6 mm for all screw lengths												
		a + c (min)	1.25 + 0.15 = 1.40 mm for all screw lengths												

(*continued*)

2.5 (*continued*) (Dimensions in millimetres)

Designated thread size	*Grade*	*Feature*	*Popular lengths*														
M8	B	U/head (nom)	60	65	70	80											
		U/head (max)	61.5	66.5	71.5	81.5											
		U/head (min)	58.5	63.5	68.5	78.5											
		a + c	As for product grade A.														
M10	A	U/head (nom)	20	25	30	35	40	45	50	55	60	65	70	80	90	100	
		U/head (max)	20.42	25.42	30.42	35.5	40.5	45.5	50.5	55.6	60.6	65.6	70.6	80.6	90.7	100.7	
		U/head (min)	19.58	24.58	29.58	34.5	39.5	44.5	49.5	54.4	59.4	64.4	69.4	79.4	89.3	99.3	
		a + c (max)	4.5 + 0.6 = 5.1 mm for all screw lengths														
		a + c (min)	1.50 + 0.15 = 1.65 mm for all screw lengths														
M10	B	U/head (nom)	60	65	70	80	90	100									
		U/head (max)	61.5	66.5	71.5	81.5	91.75	101.75									
		U/head (min)	58.5	63.5	68.5	78.5	88.25	98.25									
		a + c	As for product grade A.														
M12	A	U/head (nom)	25	30	35	40	45	50	55	60	65	70	80	90	100	110	120
		U/head (max)	25.42	30.42	35.5	40.5	45.5	50.5	55.6	60.6	65.6	70.6	80.6	90.7	100.7	110.7	120.7
		U/head (min)	24.58	29.58	34.5	39.5	44.5	49.5	54.4	59.4	64.4	69.4	79.4	89.3	99.3	109.3	119.3
		a + c (max)	5.3 + 0.6 = 5.9 mm for all screw lengths														
		a + c (min)	1.75 + 0.15 = 1.90 mm for all screw lengths														

M12	B	U/head (nom)	60	65	70	80	90	100	110	120									
		U/head (max)	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75									
		U/head (min)	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.25									
		a + c	As for product grade A.																
M16	A	U/head (nom)	30	35	40	45	50	55	60	65	70	80	90	100	110	120	130	140	150
		U/head (max)	30.42	35.5	40.5	45.5	50.5	55.6	60.6	65.6	70.6	80.6	90.7	100.7	110.7	120.7	130.8	140.8	150.8
		U/head (min)	29.58	34.5	39.5	44.5	49.5	54.4	59.4	64.4	69.4	79.4	89.3	99.3	109.3	119.3	129.2	139.2	149.2
		a + c (max)	$6.0 + 0.8 = 6.8$ mm for all screw lengths																
		a + c (min)	$2.0 + 0.2 = 2.2$ mm for all screw lengths																
M16	B	U/head (nom)	60	65	70	80	90	100	110	120	130	140	150						
		U/head (max)	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	151						
		U/head (min)	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.25	128	138	148						
		a + c	As for product grade A.																
M20	A	U/head (nom)	40	45	50	55	60	65	70	80	90	100	110	120	130	140	150		
		U/head (max)	40.5	45.5	50.5	55.6	60.6	65.6	70.6	80.6	90.7	100.7	110.7	120.7	130.8	140.8	150.8		
		U/head (min)	39.5	44.5	49.5	54.5	59.5	64.4	69.4	79.4	89.3	99.3	109.3	119.3	129.2	139.2	149.2		
		a + c (max)	$7.5 + 0.8 = 8.3$ mm for all screw lengths																
		a + c (min)	$2.5 + 0.2 = 2.7$ mm for all screw lengths																
M20	B	U/head (nom)	60	65	70	80	90	100	110	120	130	140	150	160	180	200			
		U/head (max)	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	162	182	202.3			
		U/head (min)	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.25	128	138	148	158	178	197.7			
		a + c	As for product grade A.																

(*continued*)

2.5 (*continued*) (Dimensions in millimetres)

Designated thread size	*Grade*	*Feature*	*Popular lengths*													
M24	A	U/head (nom)	50	55	60	65	70	80	90	100	110	120	130	140	150	
		U/head (max)	50.5	55.6	60.6	65.6	70.6	80.6	90.7	100.7	110.7	120.7	130.8	140.8	150.8	
		U/head (min)	49.5	54.5	59.5	64.4	69.4	79.4	89.3	99.3	109.3	119.3	129.2	139.2	149.2	
		a + c (max)	9.0 + 0.8 = 9.8 mm for all screw lengths													
		a + c (min)	3.0 + 0.2 = 3.2 mm for all screw lengths													
M24	B	U/head (nom)	60	65	70	80	90	100	110	120	130	140	150	160	180	200
		U/head (max)	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	162	182	202.3
		U/head (min)	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.25	128	138	148	158	178	197.7
		a + c	As for product grade A.													
M30	A	U/head (nom)	60	65	70	80	90	100	110	120	130	140	150			
		U/head (max)	60.6	65.6	70.6	80.6	90.7	100.7	120.7	130.8	140.8	150.8				
		U/head (min)	59.5	64.4	69.4	79.4	89.3	99.3	109.3	119.3	129.2	139.2	149.2			
		a + c (max)	10.5 + 0.8 = 11.3 mm for all screw lengths													
		a + c (min)	3.5 + 0.2 = 3.7 mm for all screw lengths													
M30	B	U/head (nom)	60	65	70	80	90	100	110	120	130	140	150	160	180	200
		U/head (max)	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	162	182	202.3
		U/head (min)	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.25	128	138	148	158	178	197.7
		a + c	As for product grade A.													
M36	A	U/head (nom)	70	80	90	100	110	120	130	140	150					
		U/head (max)	70.6	80.6	90.7	100.7	110.7	120.7	130.8	140.8	150.8					
		U/head (min)	69.4	79.4	89.3	99.3	109.3	119.3	129.2	139.2	149.2					
		a + c (max)	12.0 + 0.8 = 12.8 mm for all screw lengths													
		a + c (min)	4.0 + 0.2 = 4.2 mm for all screw lengths													

M36	B	U/head (nom)	60	65	70	80	90	100	110	120	130	140	150	160	180	200
		U/head (max)	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	162	182	202.3
		U/head (min)	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.25	128	138	148	158	178	197.7
		a + c	As for product grade A.													
M42	A	U/head (nom)	80	90	100	110	120	130	140	150						
		U/head (max)	80.6	90.7	100.7	110.7	120.7	130.8	140.8	150.8						
		U/head (min)	79.4	89.3	99.3	109.3	119.3	129.2	139.2	149.2						
		a + c (max)	13.5 + 1.0 = 14.5 mm for all screw lengths													
		a + c (min)	4.5 + 0.3 = 4.8 mm for all screw lengths													
M42	B	U/head (nom)	60	65	70	80	90	100	110	120	130	140	150	160	180	200
		U/head (max)	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	162	182	202.3
		U/head (min)	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.25	128	138	148	158	178	197.7
		a + c	As for product grade A.													
M48	A	U/head (nom)	100	110	120	130	140	150								
		U/head (max)	100.7	110.7	120.7	130.8	140.8	150.8								
		U/head (min)	99.3	109.3	119.3	129.2	139.2	149.2								
		a + c (max)	15.0 + 1.0 = 16.0 mm for all screw lengths													
		a + c (min)	5.0 + 0.3 = 5.3 mm for all screw lengths													
M48	B	U/head (nom)	60	65	70	80	90	100	110	120	130	140	150	160	180	200
		U/head (max)	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	162	182	202.3
		U/head (min)	58.5	63.5	68.5	78.5	88.75	98.25	108.25	118.25	128	138	148	158	178	197.7
		a + c	As for product grade A.													

For further information see BSEN 24017.

2.6 ISO metric hexagon head screws (coarse thread): preferred sizes: product grade C

Notes:

(1) Reference back to Section 2.2.1 shows that hexagon head **bolts** have a plain shank between the head and the thread. It also shows that hexagon head **screws** have the thread running the full length up to the head of the screws. For practical tooling purposes there is a short distance (a + c) immediately under the head to allow for the thread to run out and also for a small radius. The dimensions (a + c) refer to BSEN 24018.

(2) The thread and hexagon proportions are the same as those shown in Section 2.4. Therefore only the length under the head (**nominal length**) and the dimensions (a + c) are listed here.

(Dimensions in millimetres)

Designated thread size	*Feature*	*Popular lengths*													
M5	U/head (nom)	10	12	16	20	25	30	35	40	45	50				
	U/head (max)	10.75	12.9	16.9	21.05	26.05	31.05	36.25	41.25	46.25	51.25				
	U/head (min)	9.25	11.1	15.1	18.95	23.95	28.95	33.75	38.75	43.75	48.75				
	a + c (max)	2.4 + 0.5 = 2.9 mm for all screw lengths													
	a + c (min)	0.8 + 0 = 0.8 mm for all screw lengths													
M6	U/head (nom)	12	16	20	25	30	35	40	45	50	55	60			
	U/head (max)	12.9	16.9	21.05	26.05	31.05	36.25	41.25	46.25	51.25	56.5	61.5			
	U/head (min)	11.1	15.1	18.95	23.95	28.95	33.75	38.75	43.75	48.75	53.5	58.5			
	a + c (max)	3.0 + 0.5 = 3.5 mm for all screw lengths													
	a + c (min)	1.0 + 0 = 1.0 mm for all screw lengths													
M8	U/head (nom)	16	20	25	30	35	40	45	50	55	60	65	70	80	
	U/head (max)	21.05	26.05	31.05	36.25	41.25	46.25	51.25	56.5	61.5	66.5	71.5	81.5	91.75	101.75
	U/head (min)	15.1	18.95	23.95	28.95	33.75	38.75	43.75	48.75	53.5	58.5	63.5	68.5	78.5	
	a + c (max)	4.0 + 0.6 = 4.6 mm for all screw lengths													
	a + c (min)	1.25 + 0 = 1.25 mm for all screw lengths													
M10	U/head (nom)	20	25	30	35	40	45	50	55	60	65	70	80	90	100
	U/head (max)	21.05	26.05	31.05	36.25	41.25	46.25	51.25	56.5	61.5	66.5	71.5	81.5	91.75	101.75
	U/head (min)	18.95	23.95	28.95	33.75	38.75	43.75	48.75	53.5	58.5	63.5	68.5	78.5	88.25	98.25
	a + c (max)	4.5 + 0.6 = 5.1 mm for all screw lengths													
	a + c (min)	1.5 + 0 = 1.5 mm for all screw lengths													

(*continued*)

2.6 (*continued*) (Dimensions in millimetres)

Designated thread size	*Feature*	*Popular lengths*																	
M12	U/head (nom)	25	30	35	40	45	50	55	60	65	70	80	90	100	110	120			
	U/head (max)	26.05	31.05	36.25	41.25	46.25	51.25	56.25	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75			
	U/head (min)	23.95	28.95	33.75	38.75	43.75	48.75	53.5	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.25			
	a + c (max)	5.3 + 0.6 = 5.9 mm for all screw lengths																	
	a + c (min)	1.75 + 0 = 1.75 mm for all screw lengths																	
M16	U/head (nom)	30	35	40	45	50	55	60	65	70	80	90	100	110	120	130	140	150	160
	U/head (max)	31.05	36.25	41.25	46.25	51.25	56.25	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	164
	U/head (min)	28.95	33.75	38.75	43.75	48.75	53.5	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.75	128	138	148	156
	a + c (max)	6.0 + 0.8 = 6.8 mm for all screw lengths																	
	a + c (min)	2.0 + 0 = 2.0 mm for all screw lengths																	
M20	U/head (nom)	40	45	50	55	60	65	70	80	90	100	110	120	130	140	150	160	180	200
	U/head (max)	41.25	46.25	51.25	56.25	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	164	184	204.6
	U/head (min)	38.75	43.75	48.75	53.5	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.75	128	138	148	156	176	195.4
	a + c (max)	7.5 + 0.8 = 8.3 mm for all screw lengths																	
	a + c (min)	2.5 + 0 = 2.5 mm for all screw lengths																	
M24	U/head (nom)	50	55	60	65	70	80	90	100	110	120	130	140	150	160	180	200	220	240
	U/head (max)	51.25	56.25	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	164	184	204.6	224.6	244.6
	U/head (min)	48.75	53.5	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.75	128	138	148	156	176	195.4	215.4	235.4
	a + c (max)	9.0 + 0.8 = 9.8 mm for all screw lengths																	
	a + c (min)	3.0 + 0 = 3.0 mm for all screw lengths																	

M30	U/head (nom)	60	65	70	80	90	100	110	120	130	140	150	160	180	200	220	240	260
	U/head (max)	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	164	184	204.6	224.6	244.6	265.2
	U/head (min)	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.75	128	138	148	156	176	195.4	215.4	235.4	254.8
	U/head (nom)	280	300															
	U/head (max)	285.2	305.2															
	U/head (min)	274.8	294.8															
	a + c (max)	10.5 + 0.8 = 11.3 mm for all screw lengths																
	a + c (min)	3.5 + 0 = 3.5 mm for all screw lengths																
M36	U/head (nom)	70	80	90	100	110	120	130	140	150	160	180	200	220	240			
	U/head (max)	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	164	184	204.6	224.6	244.6			
	U/head (min)	68.5	78.5	88.25	98.25	108.25	118.25	128	138	148	156	176	195.4	215.4	235.4			
	U/head (nom)	260	280	300	320	340	360											
	U/head (max)	265.2	285.2	305.2	325.7	345.7	365.7											
	U/head (min)	254.8	274.8	294.8	314.3	334.3	354.3											
	a + c (max)	12.0 + 0.8 = 12.8 mm for all screw lengths																
	a + c (min)	4.0 + 0 = 4 mm for all screw lengths																

(*continued*)

2.6 (*continued*) (Dimensions in millimetres)

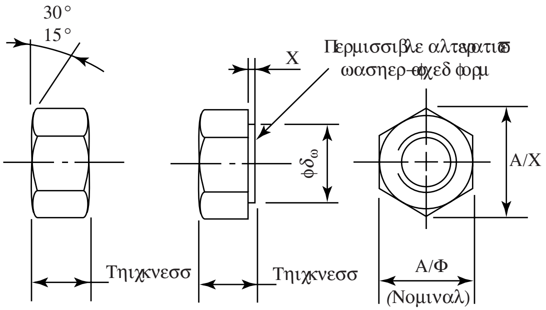
Designated thread size	*Feature*	*Popular lengths*												
M42	U/head (nom)	80	90	100	110	120	130	140	150	160	180	200	220	240
	U/head (max)	81.5	91.75	101.75	111.75	121.75	132	142	152	164	184	204.6	224.6	244.6
	U/head (min)	78.5	88.25	98.25	108.25	118.25	128	138	148	156	176	195.4	215.4	235.4
	U/head (nom)	260	280	300	320	340	360	380	400	420				
	U/head (max)	265.2	285.2	305.2	325.7	345.7	365.7	385.7	405.7	426.3				
	U/head (min)	254.8	274.8	294.8	314.3	334.3	354.3	374.3	394.3	413.7				
	a + c (max)	13.5 + 1.0 = 14.5 for all screw lengths												
	a + c (min)	4.5 + 0 = 4.5 for all screw lengths												
M48	U/head (nom)	90	100	110	120	130	140	150	160	180	200	220	240	260
	U/head (max)	91.75	101.75	111.75	121.75	132	142	152	164	184	204.6	224.6	244.6	265.2
	U/head (min)	88.25	98.25	108.25	118.25	128	138	148	156	176	195.4	215.4	235.4	254.8
	U/head (nom)	280	300	325	340	360	380	400	420	440	460	480		
	U/head (max)	285.2	305.2	325.7	345.7	365.7	385.7	405.7	426.3	446.3	466.3	486.3		
	U/head (min)	274.8	294.8	314.3	334.3	354.3	374.3	394.3	413.7	433.7	453.7	473.7		
	a + c (max)	15.0 + 1.0 = 16 mm for all screw lengths												
	a + c (min)	5.0 + 0 = 5 mm for all screw lengths												

For further information see BSEN 24018.

2.7 ISO metric tapping and clearance drills, coarse thread series

Nominal size	*Tapping drill size* (mm)		*Clearance drill size* (mm)		
	Recommended 80% *engagement*	*Alternative* 70% *engagement*	*Close fit*	*Medium fit*	*Free fit*
M1.6	1.25	1.30	1.7	1.8	2.0
M2	1.60	1.65	2.2	2.4	2.6
M2.5	2.05	2.10	2.7	2.9	3.1
M3	2.50	2.55	3.2	3.4	3.6
M4	3.30	3.40	4.3	4.5	4.8
M5	4.20	4.30	5.3	5.5	5.8
M6	5.00	5.10	6.4	6.6	7.0
M8	6.80	6.90	8.4	9.0	10.0
M10	8.50	8.60	10.5	11.0	12.0
M12	10.20	10.40	13.0	14.0	15.0
M14	12.00	12.20	15.0	16.0	17.0
M16	14.00	14.25	17.0	18.0	19.0
M18	15.50	15.75	19.0	20.0	21.0
M20	17.50	17.75	21.0	22.0	24.0
M22	19.50	19.75	23.0	24.0	26.0
M24	21.00	21.25	25.0	26.0	28.0
M27	24.00	24.25	28.0	30.0	32.0
M30	26.50	26.75	31.0	33.0	35.0
M33	29.50	29.75	34.0	36.0	38.0
M36	32.00	–	37.0	39.0	42.0
M39	35.00	–	40.0	42.0	45.0
M42	37.50	–	43.0	45.0	48.0
M45	40.50	–	46.0	48.0	52.0
M48	43.00	–	50.0	52.0	56.0
M52	47.00	–	54.0	56.0	62.0

2.8 ISO metric hexagon nuts (coarse thread) style 1: product grade A and B (preferred sizes)

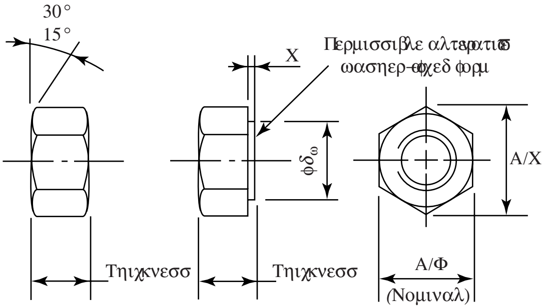


(Dimensions in millimetres)

Designated thread size	*Across corners A/C (min)*	*Across flats (A/F)*		Thickness		*Washer-faced form (C) thickness*		
		Maximum (nom)	*Minimum*	*Maximum*	*Minimum*	*Maximum*	*Minimum*	d_w*(min)*
M1.6	3.41	3.20	3.02	1.30	1.05	0.2	0.1	2.4
M2	4.32	4	3.82	1.60	1.35	0.2	0.1	3.1
M2.5	5.45	5	4.82	2.00	1.75	0.3	0.1	4.1
M3	6.01	5.5	5.32	2.40	2.15	0.4	0.15	4.6
M4	7.66	7	6.78	3.2	2.9	0.4	0.15	5.9
M5	8.79	8	7.78	4.7	4.4	0.5	0.15	6.9
M6	11.05	10	9.78	5.2	4.9	0.5	0.15	8.9
M8	14.38	13	12.73	6.8	6.44	0.6	0.15	11.6
M10	17.77	16	15.30	8.4	8.04	0.6	0.15	14.6
M12	20.03	18	17.73	10.8	10.37	0.6	0.15	16.6
M16	26.75	24	23.67	14.8	14.1	0.8	0.2	22.5
M20	32.95	30	29.16	18.0	16.9	0.8	0.2	27.7
M24	39.55	36	35.00	21.5	20.5	0.8	0.2	33.3
M30	50.85	46	45.00	25.6	24.3	0.8	0.2	42.8
M36	60.79	55	53.80	31.0	29.4	0.8	0.2	51.1
M42	71.30	65	63.10	34.0	32.4	1.0	0.3	60.0
M48	82.60	75	73.10	38.0	36.4	1.0	0.3	69.5

For further information see BSEN 24032.

2.9 ISO metric hexagon nuts (coarse thread) style 2: product grade A and B (preferred sizes)

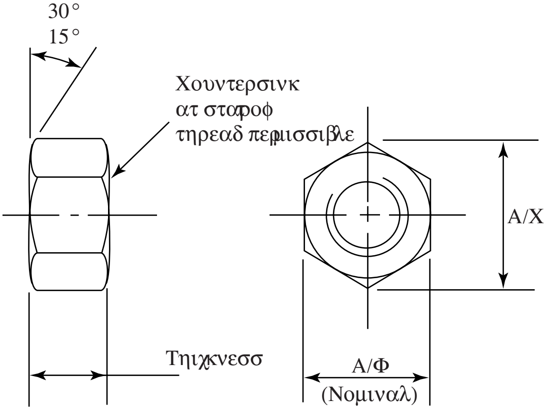


(Dimensions in millimetres)

Designated thread size	*Across corners A/C (min)*	*Across flats (A/F)*		Thickness		*Washer-faced form (C) thickness*	
		Maximum (nom)	*Minimum*	*Maximum*	*Minimum*	*Maximum*	d_w *(min)*
M5	8.79	8	7.78	5.1	4.8	0.5	6.9
M6	11.05	10	9.78	5.7	5.4	0.5	8.9
M8	14.38	13	12.73	7.5	7.14	0.6	11.6
M10	17.77	16	15.73	9.3	8.94	0.6	14.6
M12	20.03	18	17.73	12.0	11.75	0.6	16.6
(M14)	23.35	21	20.67	14.1	13.4	0.6	19.6
M16	26.75	24	23.67	16.4	15.7	0.8	22.5
M20	32.95	30	29.16	20.3	19.0	0.8	27.7
M24	39.55	36	35.0	23.9	22.6	0.8	33.2
M30	50.85	46	45.0	28.6	27.3	0.8	42.7
M36	60.79	55	53.8	34.7	33.1	0.8	51.1

M14 is not a preferred thread size and should be avoided wherever possible.
For further information see BSEN 24033.

2.10 ISO metric hexagon nuts (coarse thread) style 1: product grade C (preferred sizes)

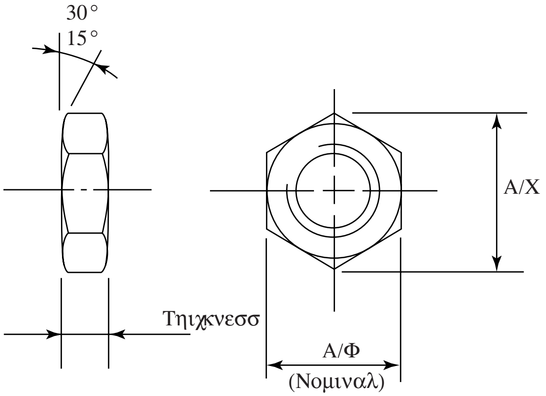


(Dimensions in millimetres)

Designated thread size	*Across corners A/C (min.)*	*Across Flats (A/F)*		*Thickness*	
		Max. (nom.)	*Min.*	*Max.*	*Min.*
M5	8.63	8	7.64	5.6	4.4
M6	10.89	10	9.64	6.1	4.6
M8	14.20	13	12.57	7.9	6.4
M10	17.59	16	15.57	9.5	8.0
M12	19.85	18	17.57	12.2	10.4
M16	26.17	24	23.16	15.9	14.1
M20	32.95	30	29.16	19.0	16.9
M24	39.55	36	35.00	22.3	20.2
M30	50.85	46	45.00	26.4	24.3
M36	60.79	55	53.80	31.5	28.0
M42	72.02	65	63.10	34.9	32.4
M48	82.60	75	73.10	38.9	36.4
M56	93.56	85	82.80	45.9	43.4
M64	104.86	95	92.80	52.4	49.4

For further information see BSEN 24034.

2.11 ISO metric hexagon thin nuts (chamfered) – coarse thread – product grade A and B (also known as lock-nuts)



Preferred sizes (Dimensions in millimetres)

Designated thread size	*Across corners A/C (min.)*	*Across flats (A/F)*		*Thickness*	
		Max. (nom.)	*Min.*	*Max.*	*Min.*
M1.6	3.41	3.2	3.02	1.0	0.75
M2	4.32	4.0	3.82	1.2	0.95
M2.5	5.45	5.0	4.82	1.6	1.35
M3	6.01	5.5	5.32	1.8	1.55
M4	7.66	7.0	6.78	2.2	1.95
M5	8.79	8.0	7.78	2.7	2.45
M6	11.05	10.0	9.78	3.2	2.90
M8	14.38	13.0	12.73	4.0	3.70
M10	17.77	16.0	15.73	5.0	4.70
M12	20.03	18.0	17.73	6.0	5.70
M16	26.75	24.0	23.67	8.0	7.42
M20	32.95	30.0	29.16	10.0	9.10
M24	39.55	36.0	35.00	12.0	10.90
M30	50.85	46.0	45.00	15.0	13.90
M36	60.79	55.0	53.80	18.0	16.90
M42	71.30	65.0	63.10	21.0	19.70
M48	82.60	75.0	73.10	24.0	22.70
M56	93.56	85.0	82.80	28.0	26.70
M64	104.86	95.0	92.80	32.0	30.40

For further information see BSEN 24035.

2.12 ISO metric hexagon head bolts (fine thread): preferred sizes: product grade A and B

(Dimensions in millimetres)

Designated thread size	*Product Grade*	*Pitch of Thread*	*Thread*			*Plain shank*		*Hexagon*					
			Major diameter	*Effective diameter*	*Minor diameter*	*Maximum diameter (nominal)*	*Minimum diameter*	*Across flats (AlF)*		*Across corners (A/C)*	*Thickness*		
								Maximum (nominal)	*Minimum*	*Minimum*	*Nominal*	*Maximum*	*Minimum*
M8 × 1	A	1.0	8.0	7.35	6.77	8.0	7.78	13	12.3	14.33	5.3	5.45	5.15
M10 × 1	A	1.0	10.0	9.19	8.47	10.0	9.78	16	15.73	17.77	6.4	6.58	6.22
M12 × 1.5	A	1.5	12.0	11.19	10.47	12.0	11.73	18	17.73	20.03	7.5	7.68	7.32
M16 × 1.5	A	1.5	16.0	15.03	14.16	16.0	15.73	24	23.67	26.75	10	10.18	9.82
M16 × 1.5	B	1.5	16.0	15.03	14.16	16.0	15.57	24	23.16	26.17	10	10.29	9.71
M20 × 1.5	A	1.5	20.0	19.03	18.16	20.0	19.67	30	29.67	33.53	12.5	12.75	12.285
M20 × 1.5	B	1.5	20.0	19.03	18.16	20.0	19.48	30	29.16	32.95	12.5	12.85	12.15
M24 × 2	A	2.0	24.0	22.70	21.55	24.0	23.67	36	35.38	39.98	15.0	15.215	14.785
M24 × 2	B	2.0	24.0	22.70	21.55	24.0	23.48	36	35.0	39.55	15.0	15.35	14.65
M30 × 2	B	2.0	30.0	28.70	27.55	30.0	29.48	46	45.0	50.85	18.7	19.12	18.28
M36 × 3	B	3.0	36.0	34.05	32.32	36.0	35.80	55	53.8	60.79	22.5	22.92	22.08
M42 × 3	B	3.0	42.0	40.05	38.32	42.0	41.38	65	63.1	71.3	26	26.42	25.58
M48 × 3	B	3.0	48.0	46.05	44.32	48.0	47.38	75	73.1	82.6	30	30.42	29.58
M56 × 4	B	4.0	56.0	53.40	51.09	56.0	55.26	85	82.8	93.56	35	35.5	34.5
M64 × 4	B	4.0	64.0	61.40	59.09	64.0	63.26	95	92.8	104.86	40	40.5	39.5

Note: There is no product grade C for the fine thread series.
For further information see BSEN 28765.

(Dimensions in millimetres)

Designed at thread size	*Feature*	*Popular length combinations*										
M6 × 1	U/head	40	45	50	55	60	65	70	80			
(Grade A)	Thread	22	22	22	22	22	22	22	22			
	Shank	11.75	16.75	21.75	26.75	31.75	36.75	41.75	51.75			
M10 × 1	U/head	45	50	55	60	65	70	80	90	100		
(Grade A)	Thread	26	26	26	26	26	26	26	26	26		
	Shank	11.5	16.5	21.5	26.5	31.5	36.5	46.5	56.5	66.5		
M12 × 1.5	U/head	50	55	60	65	70	80	90	100	110	120	
(Grade A)	Thread	30	30	30	30	30	30	30	30	30	30	
	Shank	11.25	16.25	21.25	26.25	31.25	41.25	51.25	61.25	71.25	81.25	
M16 × 1.5	U/head	65	70	80	90	100	110	120	130	140	150	160
(Grade A)	Thread	38	38	38	38	38	38	38	44	44	44	44
	Shank	17	22	32	42	52	62	72	76	86	96	106
M20 × 1.5	U/head	80	90	100	110	120	130	140	150	160	180	200
(Grade A)	Thread	46	46	46	46	46	52	52	52	52	52	52
	Shank	21.5	31.5	41.5	51.5	61.5	65.5	75.5	85.5	95.5	115.5	135.5
M24 × 2	U/head	100	110	120	130	140	150	160	180	200	220	240
(Grade A)	Thread	54	54	54	60	60	60	60	60	60	73	73
	Shank	31	41	51	55	65	75	85	105	125	132	152

Length below and to the right of the broken line - - - - refer to and are only available in product grade B.

M30 × 2	U/head	120	130	140	150	160	180	200	220	240	260	280	300			
(Grade B)	Thread	66	72	72	72	72	72	72	85	85	85	85	85			
	Shank	36.5	40.5	50.5	60.5	70.5	90.5	110.5	117.5	137.5	157.5	177.5	197.5			
M36 × 3	U/head	140	150	160	180	200	220	240	260	280	300	320	340	360		
(Grade B)	Thread	84	84	84	84	84	97	97	97	97	97	97	97	97		
	Shank	36	46	56	76	96	103	123	143	163	183	203	223	243		
M42 × 3	U/head	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440
(Grade B)	Thread	96	96	96	109	109	109	109	109	109	109	109	109	109	109	109
	Shank	41.5	61.5	81.5	88.5	108.5	128.5	148.5	168.5	188.5	208.5	228.5	248.5	268.5	288.5	308.5
M48 × 3	U/head	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480
(Grade B)	Thread	108	121	121	121	121	121	121	121	121	121	121	121	121	121	121
	Shank	67	74	94	114	134	154	174	194	214	234	254	274	294	314	334
M56 × 3	U/head	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500
(Grade B)	Thread	137	137	137	137	137	137	137	137	137	137	137	137	137	137	137
	Shank	55.5	75.5	95.5	115.5	135.5	155.5	175.5	195.5	215.5	235.5	255.5	275.5	295.5	315.5	335.5
M64 × 4	U/head	260	280	300	320	340	360	380	400	420	440	460	480	500		
(Grade B)	Thread	153	153	153	153	153	153	153	153	153	153	153	153	153		
	Shank	77	97	117	137	157	177	197	217	237	257	277	297	317		

Note: The length under the head of the bolt (U/head) is also the **nominal length.**
For further information see BSEN 28765.

2.13 ISO metric hexagon head screws (fine thread): preferred sizes: product grade A and B

Notes:

(1) There is no product grade C for the fine thread series.

(2) Reference back to Section 2.2.1 shows that hexagon head **bolts** have a plain shank between the head and the thread. It also shows that hexagon head **screws** have the thread running the full length up to the head of the screw. For practical tooling purposes there is a short distance (a + c) immediately under the head to allow the thread to run out and also allow for a small radius. The dimensions (a + c) refer to BSEN 28676

a = runout of thread
c = u/head radius

(3) The thread and hexagon proportions are the same as those shown in the table in Section 2.11. Therefore only the length under the head (**nominal length**) and the dimensions (a + c) are listed here.

(Dimensions in millimetres)

Designated thread size	*Grade*	*Feature*	*Popular lengths*														
M8 × 1	A	U'head (nom.)	16	20	25	30	35	40	45	50	55	60	65	70	80		
		U/head (max.)	16.35	20.42	25.42	30.42	35.5	40.5	45.5	50.5	55.6	60.6	65.6	70.6	80.6		
		U/head (min.)	15.65	19.58	24.58	29.58	34.5	39.5	44.5	49.5	54.4	59.4	64.4	69.4	79.4		
		a + c (max.)	3.0 + 0.6 = 3.6 mm for all screw lengths														
		a + c (min.)	1.0 + 0.15 = 1.15 mm for all screw lengths														
M10 × 1	A	U/head (nom.)	20	25	30	35	40	45	50	55	60	65	70	80	90	100	
		U/head (max.)	20.42	25.42	30.42	35.5	40.5	45.5	50.5	55.6	60.6	65.6	70.6	80.6	90.7	100.7	
		U/head (min.)	19.58	24.58	29.58	34.5	39.5	44.5	49.5	54.4	59.4	64.4	69.4	79.4	89.3	99.3	
		a + c (max.)	3.0 + 0.6 = 3.6 mm for all screw legths														
		a + c (min.)	1.0 + 0.15 = 1.15 mm for all screw lengths														
M12 × 1.5	A	U/head (nom.)	25	30	35	40	45	50	55	60	65	70	80	90	100	110	120
		U/head (max.)	25.42	30.42	35.5	40.5	45.5	50.5	55.6	60.6	65.6	70.6	80.6	90.7	100.7	110.7	120.7
		U/head (min.)	24.58	29.58	34.5	39.5	44.5	49.5	54.4	59.4	64.4	69.4	79.4	89.3	99.3	109.3	119.3
		a + c (max.)	4.5 + 0.6 = 5.1 mm for all screw lengths														
		a + c (min.)	1.5 + 0.15 = 1.20 mm for all screw lengths														

(*continued*)

2.13 (*continued*) (Dimensions in millimetres)

Designated thread size	*Grade*	*Feature*	*Popular lengths*																	
M16 × 1.5	A	U/head (nom.)	35	40	45	50	55	60	65	70	80	90	100	110	120	130	140	150	160	
		U/head (max.)	35.5	40.5	45.5	50.5	55.6	60.6	65.6	70.6	80.6	90.7	100.7	110.7	120.7	130.8	140.8	150.8	162	
		U/head (min.)	34.5	39.5	44.5	49.5	54.4	59.4	64.4	69.4	79.4	89.3	99.3	109.3	119.3	129.2	139.2	149.2	158	
		a + c (max.)	4.5 + 0.8 = 5.3 mm for all screw lengths																Grade	
		a + c (min.)	1.5 + 0.2 = 1.7 mm for all screw lengths																B	
M20 × 1.5	A	U/head (nom.)	40	45	50	55	60	65	70	80	90	100	110	120	130	140	150	160	180	200
		U/head (max.)	40.5	45.5	50.5	55.6	60.6	65.6	70.6	80.6	90.7	100.7	110.7	120.7	130.8	140.8	150.8	162	182	202.3
		U/head (nom.)	39.5	44.5	49.5	54.4	59.4	64.4	69.4	79.4	89.3	99.3	109.3	119.3	129.2	139.2	149.2	158	178	197.7
		a + c (max.)	6.0 + 0.8 = 6.8 mm for all screw lengths																Grade	
		a + c (min.)	2.0 + 0.2 = 2.2 mm for all screw lengths																B	
M24 × 2.0	A	U/head (nom.)	40	45	50	55	60	65	70	80	90	100	110	120	130	140	150	160	180	200
		U/head (max.)	40.5	45.5	50.5	55.6	60.6	65.6	70.6	80.6	90.7	100.7	110.7	120.7	130.8	140.8	150.8	162	182	202.3
		U/head (min.)	39.5	44.5	49.5	54.4	59.4	64.4	69.4	79.4	89.3	99.3	109.3	119.3	129.2	139.2	149.2	158	178	197.7
		a + c (max.)	6.0 + 0.8 = 6.8 mm for all screw lengths																Grade	
		a + c (min.)	2.0 + 0.2 = 2.2 mm for all screw lengths																B	
M30 × 2	B	U/head (nom.)	40	45	50	55	60	65	70	80	90	100	110	120	130	140	150	160	180	200
		U/head (max.)	41.25	46.25	51.25	56.5	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	162	182	202.3
		U/head (min.)	38.75	43.75	48.75	53.5	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.25	128	132	148	158	178	197.7
		a + c (max.)	6.0 + 0.8 = 6.8 mm for all screw lengths																	
		a + c (min.)	2.0 + 0.2 = 2.2 mm for all screw lengths																	

M36 × 3	B	U/head (nom.)	40	45	50	55	60	65	70	80	90	100	110	120	130	140	150	160	180	200
		U/head (max.)	41.25	46.25	51.25	56.5	61.5	66.5	71.5	81.5	91.75	101.75	111.75	121.75	132	142	152	162	182	202.3
		U/head (min.)	38.75	43.75	48.75	53.5	58.5	63.5	68.5	78.5	88.25	98.25	108.25	118.25	128	138	148	158	178	197.7
		a + c (max.)	9.0 + 0.8 = 9.8 mm for all screw lengths																	
		a + c (min.)	3.0 + 0.2 = 3.2 mm for all screw lengths																	
M42 × 3	B	U/head (nom.)	90	100	110	120	130	140	150	160	180	200	220	240	260	280	300	320		
		U/head (max.)	91.75	101.75	111.75	121.75	132	142	152	162	182	202.3	222.3	242.3	262.6	282.6	302.6	322.85		
		U/head (min.)	88.25	98.25	108.25	118.25	128	138	148	158	178	197.7	297.7	237.7	257.4	277.4	297.4	317.15		
		a + c (max.)	9.0 + 1.0 = 10 mm for all screw lengths																	
		a + c (min.)	3.0 + 0.3 = 3.3 mm for all screw lengths																	
M42 × 3 (continued)		U/head (nom.)	340	360	380	400	420													
		U/head (max.)	342.85	362.85	382.85	402.85	423.15													
		U/head (min.)	337.15	357.15	377.15	397.15	416.85													
		a + c (max.)	9.0 + 1.0 = 10 mm for all screw lengths																	
		a + c (min.)	3.0 + 0.3 = 3.3 mm for all screw lengths																	
M48 × 3	B	U/head (nom.)	100	110	120	130	140	150	160	180	200	220	240	260	280	300	320			
		U/head (max.)	101.75	111.75	121.75	132	142	152	162	182	202.3	222.3	242.3	262.6	282.6	302.6	322.58			
		U/head (min.)	98.25	108.25	118.25	128	138	148	158	178	197.7	297.7	237.7	257.4	277.4	297.4	317.15			
		a + c (max.)	9.0 + 1.0 = 10 mm for all screw lengths																	
		a + c (min.)	3.0 + 0.3 = 3.3 mm for all screw lengths																	
M48 × 3 (continued)		U/head (nom.)	340	360	380	400	420	440	460	480										
		U/head (max.)	342.85	362.85	382.85	402.85	423.15	443.15	463.15	483.15										
		U/head (min.)	337.15	357.15	377.15	397.15	416.85	436.85	456.85	476.85										
		a + c(max.)	9.0 + 1.0 = 10 mm for all screw lengths																	
		a + c(min.)	3.0 + 0.3 = 3.3 mm for all screw lengths																	

(continued)

2.13 (*continued*) (Dimensions in millimetres)

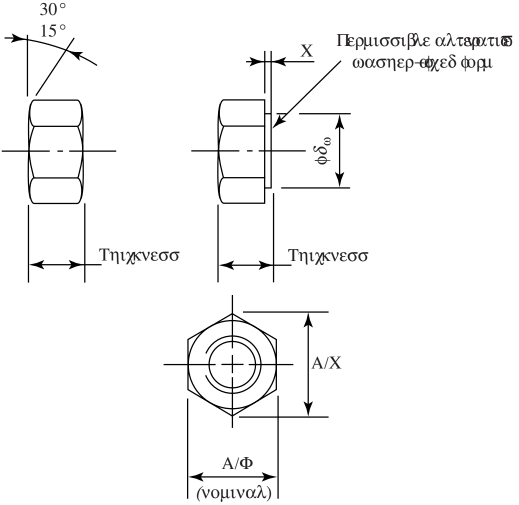
Designated thread size	*Grade*	*Feature*	*Popular lengths*												
M56 × 4	B	U/head (nom.)	120	130	140	150	160	180	200	220	240	260	280	300	320
		U/head (max.)	121.75	132	142	152	162	182	203.3	222.3	242.3	262.6	282.6	302.6	322.58
		U/head (min.)	118.25	128	138	148	158	178	197.7	297.7	237.7	257.4	277.4	297.4	317.15
		a + c (max.)	12 + 1 = 13 mm for all screw lengths												
		a + c (min.)	4.0 + 0.3 = 4.3 mm for all screw lengths												
M56 × 4 (continued)		U/head (nom.)	340	360	380	400	420	440	460	480	500				
		U/head (max.)	342.85	362.85	382.85	402.85	423.15	443.15	463.15	483.15	503.15				
		U/head (min.)	337.15	357.15	377.15	397.15	416.85	436.85	456.85	476.85	496.85				
		a + c (max.)	12 + 1 = 13 mm for all screw lengths												
		a + c (min.)	4.0 + 0.3 = 4.3 mm for all screw lengths												
M64 × 4	B	U/head (nom.)	130	140	150	160	180	200	220	240	260	280	300	320	
		U/head (max.)	132	142	152	162	182	202.3	222.3	242.3	262.6	282.6	302.6	322.58	
		U/head (min.)	128	138	148	158	178	197.7	297.7	237.7	257.4	277.4	297.4	317.15	
		a + c (max.)	12 + 1 = 13 mm for all screw lengths												
		a + c (min.)	4.0 + 0.3 = 4.3 mm for all screw lengths												
		U/head (nom.)	340	360	380	400	420	440	460	480	500				
		U/head (max.)	342.85	362.85	382.85	402.85	423.15	443.15	463.15	483.15	503.15				
		U/head (min.)	337.15	357.15	377.15	397.15	416.85	436.85	456.85	476.85	496.85				
		a + c (max.)	12 + 1 = 13 mm for all screw lengths												
		a + c (min.)	4.0 + 0.3 = 4.3 mm for all screw lengths												

For further information see BSEN 28676.

2.14 ISO metric tapping and clearance drills, fine thread series

Nominal size	*Tapping drill size* (mm)		*Clearance drill size* (mm)		
	Recommended 80% *engagement*	*Alternative* 70% *engagement*	*Close fit*	*Medium fit*	*Free fit*
M6	5.20	5.30	6.4	6.6	7.0
M8	7.00	7.10	8.4	9.0	10.0
M10	8.80	8.90	10.5	11.0	12.0
M12	10.80	10.90	13.0	14.0	15.0
M14	12.50	12.70	15.0	16.0	17.0
M16	14.50	14.75	17.0	18.0	19.0
M18	16.50	16.75	19.0	20.0	21.0
M20	18.50	18.75	21.0	22.0	24.0
M22	20.50	20.75	23.0	24.0	26.0
M24	22.00	22.25	25.0	26.0	28.0
M27	25.00	25.25	28.0	30.0	32.0
M30	28.00	28.25	31.0	33.0	35.0
M33	31.00	31.25	34.0	36.0	38.0
M36	33.00	–	37.0	39.0	42.0
M39	36.00	–	40.0	42.0	45.0
M42	39.00	–	43.0	45.0	48.0

2.15 ISO metric hexagon nuts (fine thread) style 1: product grade A and B (preferred sizes)

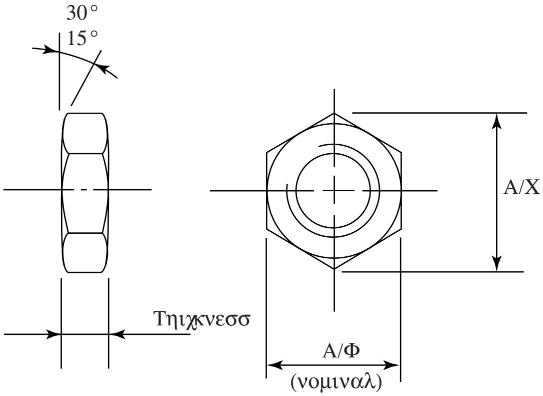


(Dimensions in millimetres)

Designated thread size	*Across corners A/C (min.)*	*Across flats (A/F)*		*Thickness*		*Washer-faced form (C) thickness*		
		Maximum (nom.)	*Minimum*	*Maximum*	*Minimum*	*Maximum*	*Minimum*	d_w *(min.)*
M8 × 1	14.38	13	12.73	7.5	7.14	0.6	0.15	11.63
M10 × 1	17.77	16	15.73	9.3	8.94	0.6	0.15	14.63
M12 × 1.5	20.03	18	17.73	12.0	11.57	0.6	0.15	16.63
M16 × 1.5	26.75	24	23.67	16.4	15.7	0.8	0.2	22.49
M20 × 1.5	32.95	30	29.16	20.3	19.0	0.8	0.2	27.70
M24 × 2.0	39.55	36	35	23.9	22.6	0.8	0.2	33.25
M30 × 2.0	50.85	46	45	28.6	27.3	0.8	0.2	42.75
M36 × 3.0	60.79	55	53.8	34.7	33.1	0.8	0.2	51.11

For further information see BSEN 28673.

2.16 ISO metric hexagon thin nuts (chamfered) – fine thread – product grade A and B (also known as lock-nuts)

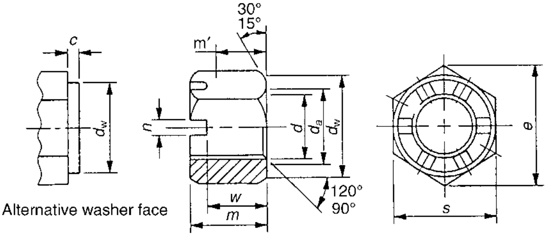


Preferred sizes (Dimensions in millimetres)

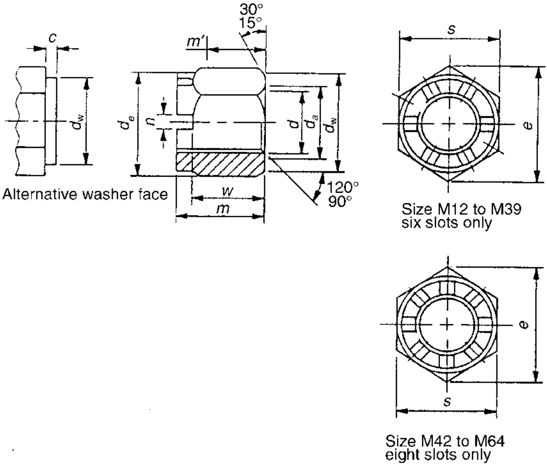
Designated thread size	*Across corners A/C (min.)*	*Across flats (A/F)*		*Thickness*	
		max. (nom.)	*min.*	*max.*	*min.*
M8 × 1	14.38	13	12.73	4.0	3.7
M10 × 1	17.77	16	15.73	5.0	4.7
M12 × 1.5	20.03	18	17.73	6.0	5.7
M16 × 1.5	26.75	24	23.67	8.0	7.42
M20 × 1.5	32.95	30	29.16	10.0	9.1
M24 × 2	39.55	36	35.00	12.0	10.9
M30 × 2	50.85	46	45.00	15.0	13.9
M36 × 3	60.79	55	53.80	18.0	16.9
M42 × 3	71.30	65	63.10	21.0	19.7
M48 × 3	82.60	75	73.10	24.0	22.7
M56 × 4	93.56	85	82.80	28.0	26.7
M64 × 4	104.86	95	92.80	32.0	30.4

For further information see BSEN 28675.

2.17 ISO metric hexagon slotted nuts and castle nuts



(a) Dimensions of slotted nuts



(b) Dimensions of castle nuts

Dimensions of hexagon slotted nuts and castle nuts (Dimensions in millimetres)

d		M4	M5	M6	M8	M10	M12	(M14)	M16	(M18)	M20	(M22)	M24	(M27)	M30	(M33)	M36	(M39)	M42	(M45)	M48	(M52)	M56	(M60)	M64
p		0.7	0.8	1	1.25	1.5	1.75	2	2	2.5	2.5	2.5	3	3	3.5	3.5	4	4	4.5	4.5	5	5	5.5	5.5	6
c	max.	0.4	0.5	0.5	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1	1	1	1	1	1	1	1
d_a	min.	4	5	6	8	10	12	14	16	18	20	22	24	27	30	33	36	39	42	45	48	52	56	60	64
	max.	4.6	5.75	6.75	8.75	10.8	13	15.1	17.3	19.5	21.6	23.7	25.9	29.1	32.4	35.6	38.9	42.1	45.4	48.6	51.8	56.2	60.5	64.8	69.1
d_e	max.	–	–	–	–	–	16	19	22	25	28	30	34	38	42	46	50	55	58	62	65	70	75	80	85
	min.	–	–	–	–	–	15.57	18.48	21.48	24.16	27.16	29.16	33	37	41	45	49	53.8	56.8	60.8	63.8	68.8	73.8	78.8	83.8
d_w	min.	5.9	6.9	8.9	11.6	14.6	16.6	19.6	22.5	24.8	27.7	31.4	33.2	38	42.7	46.6	51.1	55.9	59.9	64.7	69.4	74.2	78.7	83.4	88.2
e	min.	7.66	8.79	11.05	14.38	17.77	20.03	23.36	26.75	29.58	32.95	37.29	39.55	45.2	50.85	55.37	60.79	66.44	71.3	76.95	82.6	88.25	93.56	99.21	104.86
m	max.	5	6	7.5	9.5	12	15	16	19	21	22	26	27	30	33	35	38	40	46	48	50	54	57	63	66
	min.	4.7	5.7	7.14	9.14	11.57	14.57	15.57	18.48	21.48	21.48	25.48	25.48	29.48	32.38	34.38	37.38	39.38	45.38	47.38	49.38	53.26	56.26	62.26	65.26
m'	min.	2.32	3.52	3.92	5.15	6.43	8.3	9.68	11.28	12.08	13.52	14.48	16.16	18	19.44	21.92	23.52	25.44	25.92	27.52	29.12	32.32	34.72	37.12	39.3
n	min.	1.2	1.4	2	2.5	2.8	3.5	3.5	4.5	4.5	4.5	5.5	5.5	5.5	7	7	7	7	9	9	9	9	9	11	11
	max.	1.45	1.65	2.25	2.75	3.05	3.8	3.8	4.8	4.8	4.8	5.8	5.8	5.8	7.36	7.36	7.36	7.36	9.36	9.36	9.36	9.36	9.36	11.43	11.43
s	max.	7	8	10	13	16	18	21	24	27	30	34	36	41	46	50	55	60	65	70	75	80	85	90	95
	min.	6.78	7.78	9.78	12.73	15.73	17.73	20.67	23.67	26.16	29.16	33	35	40	45	49	53.8	58.8	63.1	68.1	73.1	78.1	82.8	87.8	92.8
w	max.	2.9	4	5	6.5	8	10	11	13	15	16	18	19	22	24	26	29	31	34	36	38	42	45	48	51
	min.	3.2	3.7	4.7	6.14	7.64	9.64	10.57	12.59	14.57	15.57	17.57	18.48	21.48	23.48	25.48	28.48	30.38	33.38	35.38	37.38	41.38	44.38	47.38	50.26

Note 1. Non-preferred sizes are shown in brackets.
Note 2. Castle nuts shall not be specified below M12.
Note 3. Castle nuts above M39 shall have eight slots.

For further information see BS 7764.

2.18 Marking threaded fasteners

2.18.1 Symbols

Marking symbols are shown in Table (a) below.

2.18.2 Identification

(a) Hexagon bolts and screws
Hexagon bolts and screws shall be marked with the designation symbol of the property class described in clause 3 of BSEN 20898-1.

The marking is obligatory for all property classes, preferably on the top of the head by indenting or embossing or on the side of the head by indenting (see Fig. (a) below).

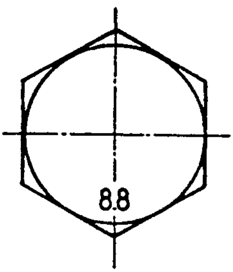
Marking is required for hexagon bolts and screws with nominal diameters $d \geq 5$ mm where the shape of the product allows it, preferably on the head.

(b) Hexagon socket head cap screws
Hexagon socket head cap screws shall be marked with the designation symbol of the property class described in clause 3 of BSEN 20898-1

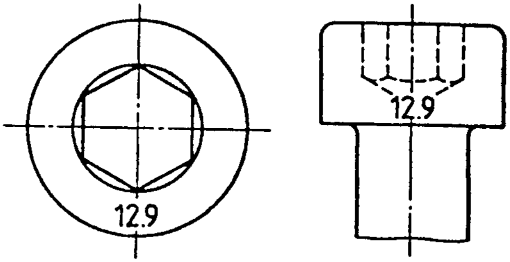
The marking is obligatory for property classes equal to or higher than 8.8, preferably on the side of the head by indenting or on the top of the head by indenting or embossing (see Fig. (b) below).

Marking is required for hexagon socket head cap screws with nominal diameters $d \geq 5$ mm where the shape of the product allows it, preferably on the head.

The clock-face marking system as given for nuts in ISO 898-2 may be used as an alternative method on small hexagon socket head cap screws.



(a) Examples of marking on hexagon bolts and screws



(b) Examples of marking on hexagon socket head cap screws

Table (a) Marking symbols

Property class	*3.6*	*4.6*	*4.8*	*5.6*	*5.8*	*6.8*	*8.8*	*9.8*	*10.9*	*12.9*
Marking symbol	3.6	4.6	4.8	5.6	5.8	6.8	8.8	9.8	10.9	12.9

The full-stop in the marking symbol may be omitted.

Table (b) Identification marks for studs

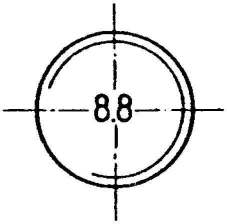
Property class	*8.8*	*9.8*	*10.9*	*12.9*
Identification mark	○	+		△

(c) Studs

Studs shall be marked with the designation symbol of the property class described in clause 3 of BSEN 20898-1.

The marking is obligatory for property classes equal to or higher than 8.8, preferably on the extreme end of the threaded portion by indenting (see Fig. (c) below). For studs with interference fit, the marking shall be at the nut end.

Marking is required for studs with nominal diameters equal to or greater than 5 mm.



(c) Marking of stud

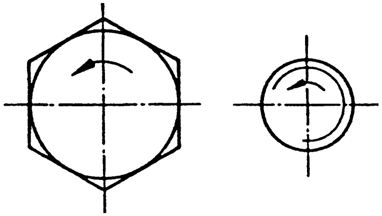
The symbols in Table (b) above are permissible as an alternative identification method.

(d) Other types of bolts and screws

The same marking system as described in Sections 2.18.2 (a) and (b) shall be used for other types of bolts and screws of property classes 4.6, 5.6 and all classes equal to or higher than 8.8, as described in the appropriate International Standards or, for special components, as agreed between the interested parties.

2.18.3 Marking of left-hand thread

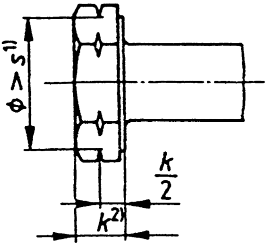
Bolts and screws with left-hand thread shall be marked with the symbol shown in Fig. (d) below either on the top of the head or the point.



(d) Left-hand thread marking

Marking is required for bolts and screws with nominal thread diameters $d \geq 5\,\text{mm}$.

Alternative marking for left-hand thread may be used for hexagon bolts and screws as shown in Fig. (e) below.



1) *s* is the width across flats.
2) *k* is the height of the head.

(e) Alternative left-hand thread marking

2.18.4 Alternative marking

Alternative or optional permitted marking as stated in Sections 2.18.1 to 2.18.3 should be left to the choice of the manufacturer.

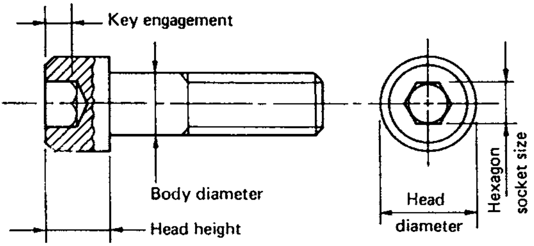
2.18.5 Trade (identification) marking

The trade (identification) marking of the manufacturer is mandatory on all products which are marked with property classes.

For full information on the marking of threaded fasteners see BSEN 20898-1.

2.19 ISO metric hexagon socket head screws

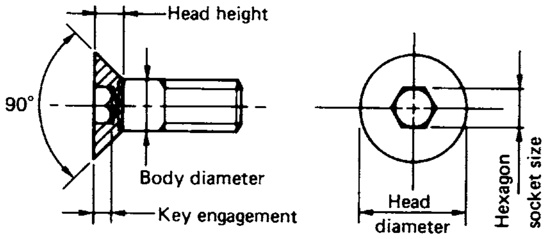
Cap head screws



(Dimensions in millimetres)

Nominal size 1st choice	*Body diameter and head height*		*Head diameter*		*Hexagon socket size*	*Key engagement*
	max	*min*	*max*	*min*		*min*
M3	3.00	2.86	5.50	5.20	2.50	1.30
M4	4.00	3.82	7.00	6.64	3.00	2.00
M5	5.00	4.82	8.50	8.14	4.00	2.70
M6	6.00	5.82	10.00	9.64	5.00	3.30
M8	8.00	7.78	13.00	12.57	6.00	4.30
M10	10.00	9.78	16.00	15.57	8.00	5.50
M12	12.00	11.73	18.00	17.57	10.00	6.60
M16	16.00	15.73	24.00	23.48	14.00	8.80
M20	20.00	19.67	30.00	29.48	17.00	10.70
M24	24.00	23.67	36.00	35.38	19.00	12.90

90° countersunk head screws

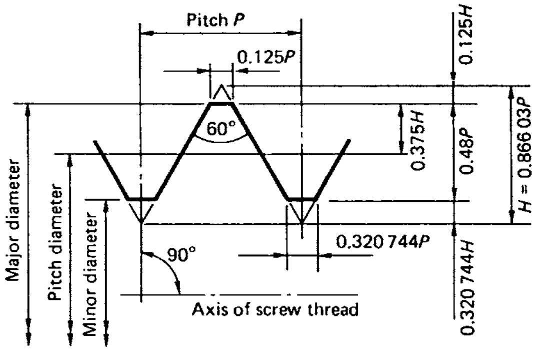


(Dimensions in millimetres)

Nominal size	*Body diameter*		*Head diameter*		*Head height*	*Hexagon socket*	*Key engagement*
1st choice	*max*	*min*	*max*	*min*		*size*	*min*
M3	3.00	2.86	6.00	5.82	1.86	2.00	1.05
M4	4.00	3.82	8.00	7.78	2.48	2.50	1.49
M5	5.00	4.82	10.00	9.78	3.10	3.00	1.86
M6	6.00	5.82	12.00	11.73	3.72	4.00	2.16
M8	8.00	7.78	16.00	15.73	4.96	5.00	2.85
M10	10.00	9.78	20.00	19.67	6.20	6.00	3.60
M12	12.00	11.73	24.00	23.67	7.44	8.00	4.35
M16	16.00	15.73	32.00	29.67	8.80	10.00	4.89
M20	20.00	19.67	40.00	35.61	10.16	12.00	5.45

For full range and further information see BS 4168 (metric) and BS 2470 (inch).

2.20 ISO metric screw threads, miniature series



(Dimensions in millimetres)

Nominal size		*Pitch of thread P*	*Major diameter*	*Pitch (effective) diameter*	*Minor diameter*
1st choice	*2nd choice*				
S-0.3		0.080	0.300 000	0.248 038	0.223 200
	S-0.35	0.090	0.350 000	0.291 543	0.263 600
S-0.4		0.100	0.400 000	0.335 048	0.304 000
	S-0.45	0.100	0.450 000	0.385 048	0.354 000
S-0.5		0.125	0.500 000	0.418 810	0.380 000
	S-0.55	0.125	0.550 000	0.468 810	0.430 000
S-0.6		0.150	0.600 000	0.502 572	0.456 000
	S-0.7	0.175	0.700 000	0.586 334	0.532 000
S-0.8		0.200	0.800 000	0.670 096	0.608 000
	S-0.9	0.225	0.900 000	0.753 858	0.684 000
	S-1	0.250	1.000 000	0.837 620	0.760 000
	S-1.1	0.250	1.100 000	0.937 620	0.860 000
	S-1.2	0.250	1.200 000	1.037 620	0.960 000
	S-1.4	0.300	1.400 000	1.205 144	1.112 000

For full range and further information see BS 4827.

2.21 ISO metric tapping and clearance drills, miniature series

Nominal size		*Pitch*		*Tapping drill size*		*Clearance drill size*	
ISO mm	*ASA B1.10* mm	mm	*Threads per inch*	mm	*Number or fraction*	mm	*Number or fraction*
S-0.3	0.30 unm	0.080	318	0.25	—	0.32	—
(S-0.35)	(0.35 unm)	0.090	282	0.28	—	0.38	79
S-0.4	0.40 unm	0.100	254	0.35	80	0.45	77
(S-0.45)	(0.45 unm)	0.100	254	0.38	79	0.50	76
S-0.5	0.50 unm	0.125	203	0.42	78	0.55	75.74
(S-0.55)	(0.55 unm)	0.125	203	0.45	77	0.60	73
S-0.6	0.60 unm	0.150	169	0.50	76	0.65	72
(S-0.7)	(0.70 unm)	0.175	145	0.58	74	0.78	1/32 in
S-0.8	0.80 unm	0.200	127	0.65	72	0.88	66, 65
(S-0.9)	(0.90 unm)	0.225	113	0.72	70	0.98	62
S-1.0	1.00 unm	0.250	102	0.80	1/32 in	1.10	57
(S-1.1)	(1.10 unm)	0.250	102	0.90	65	1.20	3/64 in
S-1.2	1.20 unm	0.250	102	1.00	61	1.30	55
(S-1.4)	(1.40 unm)	0.300	85	1.15	3/64 in	1.50	53

2.22 ISO metric screw threads: constant pitch series

(Dimensions in millimetres)

Pitch of thread	*Basic major diameter*			*Pitch (effective) diameter*	*Basic minor diameter*	
	1st choice	*2nd choice*	*3rd choice*		*External*	*Internal*
0.25	2.0	—	—	1.84	1.69	1.73
0.25	—	2.2	—	2.04	1.89	1.93
0.35	2.5	—	—	2.27	2.07	2.12
0.35	3.0	—	—	2.77	2.57	2.62
0.35	—	3.5	—	3.27	3.07	3.12
0.50	4.0	—	—	3.68	3.39	3.46
0.50	—	4.5	—	4.18	3.86	3.96
0.50	5.0	—	—	4.68	4.39	4.46
0.50	—	—	5.5	5.18	4.86	4.96
0.75	6.0	—	—	5.51	5.08	5.19
0.75	—	—	7.0	6.51	6.08	6.19
0.75	8.0	—	—	7.51	7.08	7.19
0.75	—	—	9.0	8.51	8.08	8.19
0.75	10.0	—	—	9.51	9.08	9.19
0.75	—	—	11.0	10.51	10.08	10.19
1.0	8.0	—	—	7.35	6.77	6.92
1.0	—	—	9.0	8.35	7.77	7.92
1.0	10.0	—	—	9.35	8.77	8.92
1.0	—	—	11.0	10.35	9.77	9.92
1.0	12.0	—	—	11.35	10.77	10.92
1.0	—	14.0	—	13.35	12.77	12.92

1.0	—	—	15.0	14.35	13.77	13.92
1.0	16.0	—	—	15.35	14.77	14.92
1.0	—	—	17.0	16.35	15.77	15.92
1.0	—	18.0	—	17.35	16.77	16.92
1.0	20.0	—	—	19.35	18.77	18.92
1.0	—	22.0	—	21.35	21.77	21.92
1.0	24.0	—	—	23.35	22.77	22.92
1.0	—	—	25.0	24.35	23.77	23.92
1.0	—	27.0	—	26.35	25.77	25.92
1.0	—	—	28.0	27.35	26.77	26.92
1.0	30.0	—	—	29.35	28.77	28.92
1.25	10.0	—	—	9.19	8.47	8.65
1.25	12.0	—	—	11.19	10.47	10.65
1.25*	—	14.0*	—	13.19	12.47	12.65
1.5	12.0	—	—	11.03	10.16	10.38
1.5	—	14.0	—	13.03	12.16	12.38
1.5	—	—	15.0	14.03	13.16	13.38
1.5	16.0	—	—	15.03	14.16	14.38
1.5	—	—	17.0	16.03	15.16	15.38
1.5	—	18.0	—	17.03	16.16	16.38
1.5	20.0	—	—	19.03	18.16	18.38
1.5	—	22.0	—	21.03	20.16	20.38
1.5	24.0	—	—	23.03	22.16	22.38
1.5	—	—	25.0	24.03	23.16	23.38
1.5	—	—	26.0	25.03	24.16	24.38
1.5	—	27.0	—	26.03	25.16	25.38
1.5	—	—	28.0	27.03	26.16	26.38
1.5	30.0	—	—	29.03	28.16	28.38
1.5	—	—	32.0	31.03	30.16	30.38
1.5	—	33.0	—	32.03	31.16	31.38
1.5	—	—	35.0	34.03	33.16	33.38

The 1.5 mm pitch series continues to a maximum diameter of 80 mm.

2.0	—	18.0	—	16.70	15.55	15.84
2.0	20.0	—	—	18.70	17.55	17.84
2.0	—	22.0	—	20.70	19.55	19.84
2.0	24.0	—	—	22.70	21.55	21.84
2.0	—	—	25.0	23.70	22.55	22.84
2.0	—	—	26.0	24.70	23.55	23.84
2.0	—	27.0	—	25.70	24.55	24.84
2.0	—	—	28.0	26.70	25.55	25.84
2.0	30.0	—	—	28.70	27.55	27.84
2.0	—	—	32.0	30.70	29.55	29.84
2.0	—	33.0	—	31.70	30.55	30.84
2.0	—	—	35.0	33.70	32.55	32.84

The 2.0 mm pitch series continues to a maximum diameter of 150 mm.

3.0	30.0	—	—	28.05	26.32	26.75
3.0	—	33.0	—	31.05	29.32	29.75
3.0	36.0	—	—	34.05	32.32	32.75
3.0	—	—	38.0	36.05	34.32	34.75
3.0	—	39.0	—	37.05	35.32	35.75
3.0	—	—	40.0	38.05	36.32	36.75
3.0	42.0	—	—	40.05	38.32	38.75
3.0	—	45.0	—	43.05	41.32	41.75
3.0	48.0	—	—	46.05	44.32	44.75
3.0	—	—	50.0	48.05	46.32	46.75
3.0	—	52.0	—	50.05	48.32	48.75
3.0	—	—	55.0	53.05	51.32	51.75

The 3.0 mm pitch series continues to a maximum diameter of 250 mm.

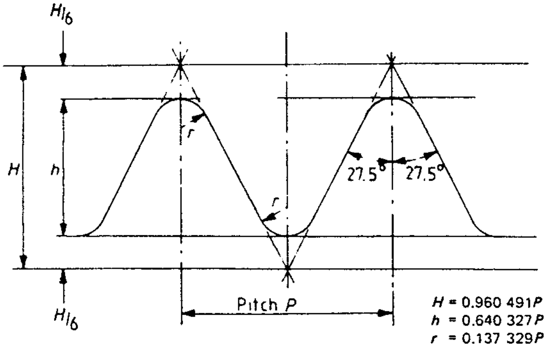
(*continued*)

Pitch of thread	*Basic major diameter*			*Pitch (effective) diameter*	*Basic minor diameter*	
	1st choice	*2nd choice*	*3rd choice*		*External*	*Internal*
4.0	42.0	–	–	39.40	37.09	37.67
4.0	–	45.0	–	42.40	40.09	40.67
4.0	48.0	–	–	45.40	43.09	43.67
4.0	–	–	50.0	47.40	45.09	45.67
4.0	–	52.0	–	49.40	47.09	47.67
4.0	–	–	55.0	52.40	50.09	50.67
4.0	56.0	–	–	53.40	51.09	51.67
4.0	–	–	58.0	55.40	53.09	53.67
4.0	–	60.0	–	57.40	55.09	55.67
4.0	–	–	62.0	59.40	57.09	57.67
4.0	64.0	–	–	61.40	59.09	59.67
4.0	–	–	65.0	62.40	60.09	60.67
The 4.0 mm pitch series continues to a maximum diameter of 300 mm.						
6.0	–	–	70.0	66.10	62.64	63.50
6.0	72.0	–	–	68.10	64.64	65.50
6.0	–	76.0	–	72.10	68.64	69.50
6.0	80.0	–	–	76.10	72.64	73.50
6.0	–	85.0	–	81.10	77.64	78.50
6.0	90.0	–	–	86.10	82.64	83.50
6.0	–	95.0	–	91.10	87.64	88.50
6.0	100.0	–	–	96.10	92.64	93.50
6.0	–	105.0	–	101.10	97.64	98.50
6.0	110.0	–	–	106.10	102.64	103.50
6.0	–	115.0	–	111.10	107.64	108.50
6.0	–	120.0	–	116.10	112.64	113.50
6.0	125.0	–	–	121.10	117.64	118.50
The 6.0 mm pitch series continues to a maximum diameter of 300 mm.						

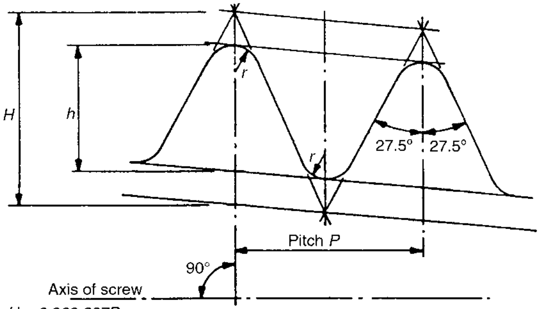
* This size sparking plugs only.
For further information see BS 3643.

2.23 ISO pipe thread forms

2.23.1 Basic Whitworth thread form: parallel threads



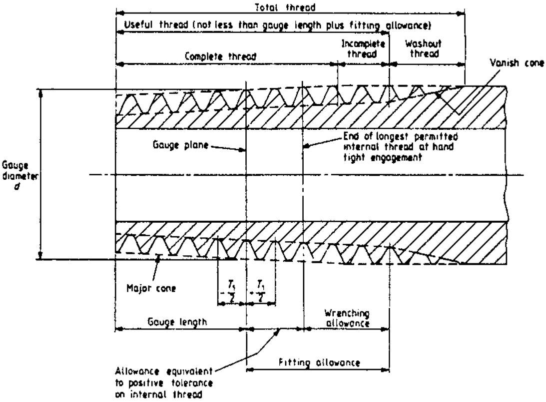
2.23.2 Basic Whitworth thread form: taper threads



$H = 0.960\,237P$
$h = 0.640\,327P$
$r = 0.137\,278P$

Note. The taper is 1 in 16 measured on the diameter (shown exaggerated in the diagram).

2.23.3 Terms relating to taper pipe threads



2.23.4 ISO pipe threads, parallel: basic sizes

*Nominal (bore) size of pipe**		*Number of threads*	*Pitch of thread*	*Depth of thread*		*Major diameter*		*Pitch (effective) diameter*	*Minor diameter*	*Minimum length of thread on pipe end*
in	mm	per inch	mm	in	mm	in	mm	mm	mm	mm
1/16†	3	28	0.907	0.0230	0.581	0.304	7.723	7.142	6.561	4.9
1/8†	6	28	0.907	0.0230	0.581	0.383	9.728	9.147	8.566	6.5
1/4	8	19	1.337	0.0335	0.856	0.518	13.157	12.301	11.445	9.7
3/8	10	19	1.337	0.0335	0.856	0.656	16.662	15.806	14.950	10.1
1/2	15	14	1.814	0.0455	1.162	0.805	20.455	19.793	18.631	13.2
5/8	–	14	1.814	0.0455	1.162	0.902	22.911	21.749	20.587	13.9
3/4	20	14	1.814	0.0455	1.162	1.041	26.441	25.279	24.117	14.5
7/8	–	14	1.814	0.0455	1.162	1.189	30.201	29.039	27.877	15.7
1	25	11	2.309	0.0580	1.479	1.309	33.249	31.770	30.291	16.8
1 1/8	–	11	2.309	0.0580	1.479	1.492	37.897	36.418	34.939	18.0
1 1/4	32	11	2.309	0.0580	1.479	1.650	41.910	40.431	38.952	19.1

1 1/2	40	11	2.309	0.0580	1.479	1.882	47.803	46.324	44.845	19.1
1 3/4	–	11	2.309	0.0580	1.479	2.116	53.746	52.267	50.788	21.3
2	50	11	2.309	0.0580	1.479	2.347	59.614	58.135	56.656	23.4
2 1/4	–	11	2.309	0.0580	1.479	2.587	65.710	64.231	62.752	25.0
2 1/2	65	11	2.309	0.0580	1.479	2.960	75.184	73.705	72.226	26.7
2 3/4	–	11	2.309	0.0580	1.479	3.210	81.534	80.055	78.576	28.3
3	80	11	2.309	0.0580	1.479	3.460	87.884	84.405	84.926	29.8
3 1/2	90	11	2.309	0.0580	1.479	3.950	100.330	98.851	97.372	31.4
4	100	11	2.309	0.0580	1.479	4.450	113.030	141.551	110.072	35.8
4 1/2	–	11	2.309	0.0580	1.479	4.950	125.730	124.251	122.772	35.8
5	125	11	2.309	0.0580	1.479	5.450	138.430	136.951	135.472	40.1
5 1/2	–	11	2.309	0.0580	1.479	5.950	151.130	149.651	148.172	40.1
6	150	11	2.309	0.0580	1.479	6.450	163.830	162.351	160.872	40.1

*These are nominal pipe size equivalents and are *not* inch/metric conversions. For example, for all practical purposes a pipe of 8 mm nominal bore is the same size as 1/4 in nominal bore. The actual bore will lie between these nominal sizes and the O/D of this nominal size of pipe will be approximately 14 mm.

†These sizes are no longer recommended.

ISO pipe threads (parallel and tapered) are based upon the previous British Standard pipe (BSP) threads and retain the Whitworth (55°) thread form. For further information see BS 2779.

2.23.5 ISO pipe threads, tapered: basic sizes

*Nominal (bore) Size of pipe**		*Number of threads*	*Pitch of thread*	*Depth of thread*	*Basic diameters at gauge plane*		
					Major (gauge) diameter	*Pitch (effective) diameter*	*Minor diameter*
in	mm	per inch	mm	mm	mm	mm	mm
1/8	6	28	0.907	0.581	9.728	9.147	8.566
1/4	8	19	1.337	0.856	13.157	12.301	11.445
3/8	10	19	1.337	0.856	16.662	15.806	14.950
1/2	15	14	1.814	1.162	20.955	19.793	18.631
3/4	20	14	1.814	1.162	26.441	25.279	24.117
1	25	11	2.309	1.479	33.249	31.770	30.291
1 1/4	32	11	2.309	1.479	41.910	40.431	38.952
1 1/2	40	11	2.309	1.479	47.803	46.324	44.845
2	50	11	2.309	1.479	59.614	58.135	56.656
2 1/2	65	11	2.309	1.479	75.184	73.705	72.226
3	80	11	2.309	1.479	87.884	86.405	84.926
4	100	11	2.309	1.479	113.030	111.551	110.072
5	125	11	2.309	1.479	138.430	136.951	135.472
6	150	11	2.309	1.479	163.830	162.351	160.872

2.23.5 (*continued*)

*Nominal (bore) size of pipe**		*Gauge length†*				*Useful thread (min.)*			*Fitting allowance*	*Wrenching allowance*	*Position of gauge plane tolerance‡*	*Diametral tolerance§*
			Tolerance									
in	mm	*Basic*	±	*max.*	*min.*	*Basic*	*max.*	*min.*			±	±
1/8	6	4 3/8 (4.0)	1 (0.9)	5 3/8 (4.9)	3 3/8 (3.1)	7 1/8 (6.5)	8 1/8 (7.4)	6 1/8 (5.6)	2 3/4 (2.5)	1 1/2 (1.4)	1 1/4 (1.1)	0.071
1/4	8	4 1/2 (5.0)	1 (1.3)	5 1/2 (7.3)	3 1/2 (4.7)	7 1/4 (9.7)	8 1/4 (11.0)	6 1/4 (8.4)	2 3/4 (3.7)	1 1/2 (2.0)	1 1/4 (1.7)	0.104
3/8	10	4 3/4 (6.4)	1 (1.3)	5 3/4 (7.7)	3 3/4 (5.1)	7 1/2 (10.1)	8 1/2 (11.4)	6 1/2 (8.8)	2 3/4 (3.7)	1 1/2 (2.0)	1 1/4 (1.7)	0.104
1/2	15	4 1/2 (8.2)	1 (1.8)	5 1/2 (10.0)	3 1/2 (6.4)	7 1/4 (13.2)	8 1/4 (15.0)	6 1/4 (11.4)	2 3/4 (5.0)	1 1/2 (2.7)	1 1/4 (2.3)	0.142
3/4	20	5 1/4 (9.5)	1 (1.8)	6 1/4 (11.3)	4 1/4 (7.7)	8 (14.5)	9 (16.3)	7 (12.7)	2 3/4 (5.0)	1 1/2 (2.7)	1 1/4 (2.3)	0.142
1	25	4 1/2 (10.4)	1 (2.3)	5 1/2 (12.7)	3 1/2 (8.1)	7 1/4 (16.8)	8 3/4 (19.1)	6 1/4 (14.5)	2 3/4 (6.4)	1 1/2 (3.5)	1 1/4 (2.9)	0.180
1 1/4	32	5 1/2 (12.7)	1 (2.3)	6 1/2 (15.0)	4 1/2 (10.4)	8 1/4 (19.1)	9 1/4 (21.4)	7 1/4 (16.8)	2 3/4 (6.4)	1 1/2 (3.5)	1 1/4 (2.9)	0.180
1 1/2	40	5 1/2 (12.7)	1 (2.3)	6 1/2 (15.0)	4 1/2 (10.4)	8 1/4 (19.1)	9 1/4 (21.4)	7 1/4 (16.8)	2 3/4 (6.4)	1 1/2 (3.5)	1 1/4 (2.9)	0.180

(*continued*)

2.23.5 (*continued*)

*Nominal (bore) size of pipe**		*Gauge length†*				*Useful thread (min.)*			*Fitting allowance*	*Wrenching allowance*	*Position of gauge plane tolerance‡*	*Diametral tolerance§*
in	mm	*Basic*	*Tolerance* ±	*max.*	*min.*	*Basic*	*max.*	*min.*			±	±
2	50	6 7/8 (15.9)	1 (2.3)	7 7/8 (18.2)	5 7/8 (15.6)	10 1/8 (23.4)	11 1/8 (25.7)	9 1/8 (21.1)	3 1/4 (7.5)	2 (4.6)	1 1/4 (2.9)	0.180
2 1/2	65	7 9/16 (17.5)	1 1/2 (3.5)	9 1/16 (21.0)	6 1/16 (14.0)	11 9/16 (26.7)	13 1/16 (30.2)	10 1/16 (23.2)	4 (9.2)	2 1/2 (5.8)	1 1/2 (3.5)	0.216
3	80	8 15/16 (20.6)	1 1/2 (3.5)	10 7/16 (24.1)	7 7/16 (17.1)	12 15/16 (29.8)	14 7/16 (33.3)	11 7/16 (26.3)	4 (9.2)	2 1/2 (5.8)	1 1/2 (3.5)	0.216
4	100	11 (25.4)	1 1/2 (3.5)	12 1/2 (28.9)	9 1/2 (21.9)	15 1/2 (35.8)	17 (19.3)	14 (32.3)	4 1/2 (10.4)	3 (6.9)	1 1/2 (3.5)	0.216
5	125	12 3/8 (28.6)	1 1/2 (3.5)	13 7/8 (32.1)	10 7/8 (25.1)	17 3/8 (40.1)	18 7/8 (43.6)	15 7/8 (36.6)	5 (11.5)	3 1/2 (8.1)	1 1/2 (3.5)	0.216
6	150	12 3/8 (28.6)	1 1/2 (3.5)	13 7/8 (32.1)	10 7/8 (25.1)	17 7/8 (40.1)	18 7/8 (43.6)	15 7/8 (36.6)	5 (11.5)	3 1/2 (8.1)	1 1/2 (3.5)	0.216

*Nominal pipe size equivalents, *not* conversions.

†Gauge length in number of turns of thread {(   ) = linear equivalent to nearest 0.1 mm}.

‡Tolerance on position of gauge plane relative to face of internally taper threaded parts.

§Diametral tolerance on parallel internal threads (millimetres).

For further information see BS 2779.

Note: The threaded fasteners to be described in the following tables (Sections 2.24 to 2.34) are now obsolete or obsolescent. Therefore they are not recommended for use in new product design or manufacture. However, they are still manufactured and still in widespread use. For this reason they have been included in this book.

2.24 British Standard Whitworth (BSW) bolts and nuts

Nominal size (in)	Threads per inch (TPI)	Pitch (in)	Depth (in)	*Diameters*			*Hexagon (bolt heads)*					*Hexagon (nuts)*				
				Major (in)	Effective (in)	Minor (in)	Across flats (A/F)		Across corners	Head thickness		Across flats (A/F)		Across corners	Nut thickness	
							Max. (in)	Min. (in)	Max. (in)	Max. (in)	Min. (in)	Max. (in)	Min. (in)	Max. (in)	Max. (in)	Min. (in)
1/4	20	0.05000	0.0320	0.2500	0.2180	0.1860	0.455	0.438	0.51	0.19	0.18	0.455	0.438	0.51	0.200	0.190
5/16	18	0.05536	0.0356	0.3125	0.2769	0.2413	0.525	0.518	0.61	0.22	0.21	0.525	0.518	0.61	0.250	0.240
3/8	16	0.06250	0.0400	0.3750	0.3350	0.2950	0.600	0.592	0.69	0.27	0.26	0.600	0.592	0.69	0.312	0.302
7/16	14	0.07141	0.0457	0.4375	0.3981	0.3461	0.710	0.702	0.82	0.33	0.32	0.710	0.702	0.82	0.375	0.365
1/2	12	0.08333	0.0534	0.5000	0.4466	0.3932	0.820	0.812	0.95	0.38	0.37	0.820	0.812	0.95	0.437	0.427
9/16	12	0.08333	0.0534	0.5625	0.5091	0.4557	0.920	0.912	1.06	0.44	0.43	0.920	0.912	1.06	0.500	0.490
5/8	11	0.09091	0.0542	0.6250	0.5668	0.5086	1.010	1.000	1.17	0.49	0.48	0.010	1.000	1.17	0.562	0.552
3/4	10	0.10000	0.0640	0.7500	0.6860	0.3039	1.200	1.190	1.39	0.60	0.59	1.200	1.190	1.39	0.687	0.677
7/8	8	0.11111	0.0711	0.8750	0.8039	0.7328	1.300	1.288	1.50	0.66	0.65	1.300	1.288	1.50	0.750	0.740

1	8	0.12500	0.0800	1.0000	0.9200	0.8400	1.480	1.468	1.71	0.77	0.76	1.480	1.468	1.71	0.875	0.865
1 1/8	7	0.14286	0.0915	1.1250	1.0335	0.9402	1.670	1.658	1.93	0.88	0.87	1.670	1.658	1.93	1.000	0.990
1 1/4	7	0.14286	0.0915	1.2500	1.1585	1.0670	1.860	1.845	2.15	0.98	0.96	1.860	1.845	2.15	1.125	1.105
1 1/2	6	0.16667	0.1067	1.5000	1.3933	1.2866	2.220	2.200	2.56	1.20	1.18	2.220	2.200	2.56	1.375	1.355
1 3/4	5	0.20000	0.1281	1.7500	1.6219	1.4938	2.580	2.555	2.98	1.42	1.40	2.580	2.555	2.98	1.625	1.605
2	4.5	0.20222	0.1423	2.0000	1.8577	1.7154	2.760	2.735	3.19	1.53	1.51	2.760	2.735	3.19	1.750	1.730
2 1/4	4	0.25000	0.1601	2.2500	2.0899	1.9298	–	–	–	–	–	–	–	–	–	–
2 1/2	4	0.25000	0.1601	2.5000	2.3399	2.1798	–	–	–	–	–	–	–	–	–	–
2 3/4	3.5	0.28571	0.1830	2.7500	2.5670	2.3840	–	–	–	–	–	–	–	–	–	–
3	3.5	0.28571	0.1830	3.0000	2.8170	2.6340	–	–	–	–	–	–	–	–	–	–
3 1/2	3.25	0.30769	0.1970	3.5000	3.3030	3.1060	–	–	–	–	–	–	–	–	–	–
4	3	0.33333	0.2134	4.0000	3.7866	3.5732	–	–	–	–	–	–	–	–	–	–
4 1/2	2.875	0.34783	0.2227	4.5000	4.2773	4.0546	–	–	–	–	–	–	–	–	–	–
5	2.75	0.36364	0.2328	5.0000	4.7672	4.5344	–	–	–	–	–	–	–	–	–	–

2.25 British Standard Whitworth (BSW) tapping and clearance drill sizes

Size	*TPI*	*Tapping*	*Clearing*
1/16	60	58	49
3/32	48	49	36
1/8	40	38	29
5/32	32	31	19
3/16	24	26	9
7/32	24	15	1
1/4	20	7	G
5/16	18	F	P
3/8	16	O	W
7/16	14	U	29/64
1/2	12	27/64	33/64

Note: if number, letter and fractional size drills are not available, see Table 1.5 for nearest metric alternative.

2.26 British Standard Fine (BSF) bolts and nuts

Nominal size (in)	Threads per inch (TPI)	Pitch (in)	Depth (in)	*Diameters* Major (in)	Effective (in)	Minor (in)	*Hexagon (bolt heads)* Across flats (A/F) Max. (in)	Across flats (A/F) Min. (in)	Across corners Max. (in)	Head thickness Max. (in)	Head thickness Min. (in)	*Hexagon (nuts)* Across flats (A/F) Max. (in)	Across flats (A/F) Min. (in)	Across corners Max. (in)	Nut thickness Max. (in)	Nut thickness Min. (in)
1/4	26	0.03846	0.0246	0.2500	0.2254	0.2008	0.455	0.438	0.51	0.19	0.18	0.455	0.438	0.51	0.200	0.190
5/16	22	0.04545	0.0291	0.3125	0.2834	0.2543	0.525	0.518	0.61	0.22	0.21	0.525	0.518	0.61	0.250	0.240
3/8	20	0.05000	0.0320	0.3750	0.3430	0.3110	0.600	0.592	0.69	0.27	0.26	0.600	0.592	0.69	0.312	0.302
7/16	18	0.05556	0.0356	0.4375	0.4019	0.3663	0.710	0.708	0.82	0.33	0.32	0.710	0.706	0.82	0.375	0.365
1/2	16	0.06250	0.0400	0.5000	0.4600	0.4200	0.820	0.812	0.95	0.38	0.37	0.820	0.812	0.95	0.437	0.427
9/16	16	0.06250	0.0400	0.5625	0.5225	0.4825	0.920	0.912	1.06	0.44	0.43	0.920	0.912	1.06	0.500	0.490
5/8	14	0.07143	0.0457	0.6250	0.5793	0.5335	1.010	1.000	1.17	0.49	0.48	1.010	1.000	1.17	0.562	0.552
3/4	12	0.08333	0.0534	0.7500	0.6966	0.6432	1.200	1.190	1.39	0.60	0.59	1.200	1.190	1.39	0.687	0.677
7/8	11	0.09091	0.0582	0.8750	0.8168	0.7586	1.300	1.288	1.50	0.66	0.65	1.300	1.288	1.50	0.750	0.740

(*continued*)

2.26 (*continued*)

Nominal size (in)	*Threads per inch (TPI)*	*Pitch (in)*	*Depth (in)*	*Diameters*			*Hexagon (bolt heads)*					*Hexagon (nuts)*				
				Major (in)	*Effective (in)*	*Minor (in)*	*Across flats (A/F)*		*Across corners*	*Head thickness*		*Across flats (A/F)*		*Across corners*	*Nut thickness*	
							Max. (in)	*Min. (in)*	*Max. (in)*	*Max. (in)*	*Min. (in)*	*Max. (in)*	*Min. (in)*	*Max. (in)*	*Max. (in)*	*Min. (in)*
1	10	0.10000	0.0640	1.0000	0.9360	0.8720	1.480	1.468	1.71	0.77	0.76	1.480	1.468	1.71	0.875	0.865
1 1/8	9	0.11111	0.0711	1.1250	1.0539	0.9828	1.670	1.658	1.93	0.88	0.87	1.670	1.658	1.93	1.000	0.990
1 1/4	9	0.11111	0.0711	1.2500	1.1789	1.1078	1.860	1.845	2.15	0.98	0.96	1.860	1.845	2.15	1.125	1.105
1 3/8	8	0.12500	0.0800	1.1370	1.2950	1.2150	2.050	2.035	2.37	1.09	1.07	2.050	2.035	2.37	1.250	1.230
1 1/2	8	0.12500	0.0800	1.5000	1.4200	1.3400	2.220	2.200	2.56	1.20	1.18	2.220	2.200	2.56	1.375	1.355
1 5/8	8	0.12500	0.0800	1.6250	1.5450	1.4650	—	—	—	—	—	—	—	—	—	—
1 3/4	7	0.14826	0.0915	1.7500	1.6585	1.5670	2.580	2.555	2.98	1.42	1.40	2.580	2.555	2.98	1.625	1.605
2	7	0.14826	0.0915	2.0000	1.9085	1.8170	2.760	2.735	3.19	1.53	1.51	2.760	2.735	3.19	1.750	1.730
2 1/4	6	0.16667	0.1067	2.2500	2.1433	2.0366	—	—	—	—	—	—	—	—	—	—

2.27 British Standard Fine (BSF) tapping and clearance drill sizes

Size	*TPI*	*Tapping*	*Clearing*
7/32	28	14	1
1/4	26	3	G
9/32	26	C	M
5/16	22	H	P
3/8	20	21/64	W
7/16	18	W	29/64
1/2	16	7/16	33/64

Note: if number, letter and fractional size drills are not available, see Table 1.5 for nearest metric alternative.

2.28 ISO unified precision internal screw threads, coarse series (UNC)

(Dimensions in inches)

	Major diameter	Pitch (effective) diameter		Minor diameter		Hexagon (nut)				
						Max width across flats	Max width across corners	Nut thickness		
Designation	*min*	*max*	*min*	*max*	*min*	*(A/F)*	*(A/C)*	*Thick*	*Normal*	*Thin*
$\frac{1}{4}$-20 UNC-2B	0.2500	0.2223	0.2175	0.2074	0.1959	0.4375	0.505	0.286	0.224	0.161
$\frac{5}{16}$-18 UNC-2B	0.3125	0.2817	0.2764	0.2651	0.2524	0.5000	0.577	0.333	0.271	0.192
$\frac{3}{8}$-16 UNC-2B	0.3750	0.3401	0.3344	0.3214	0.3073	0.5625	0.650	0.411	0.333	0.224
$\frac{7}{16}$-14 UNC-2B	0.4375	0.3972	0.3911	0.3760	0.3602	0.6875	0.794	0.458	0.380	0.255
$\frac{1}{2}$-13 UNC-2B	0.5000	0.4565	0.4500	0.4336	0.4167	0.7500	0.866	0.567	0.442	0.317
$\frac{9}{16}$-12 UNC-2B*	0.5625	0.5152	0.5084	0.4904	0.4723	0.8750	1.010	0.614	0.489	0.349
$\frac{5}{8}$-11 UNC-2B	0.6250	0.5732	0.5660	0.5460	0.5266	0.9375	1.083	0.724	0.552	0.380
$\frac{3}{4}$-10 UNC-2B	0.7500	0.6927	0.6850	0.6627	0.6417	1.1250	1.300	0.822	0.651	0.432
$\frac{7}{8}$-9 UNC-2B	0.8750	0.8110	0.8028	0.7775	0.7547	1.3125	1.515	0.916	0.760	0.494
1-8 UNC-2B	1.0000	0.9276	0.9188	0.8897	0.8647	1.5000	1.732	1.015	0.874	0.562

$1\frac{1}{8}$-7 UNC-2B	1.1250	1.0416	1.0322	0.9980	0.9704	1.6875	1.948	1.176	0.989	0.629
$1\frac{1}{4}$-7 UNC-2B	1.2500	1.1668	1.1572	1.1230	1.0954	1.8750	2.165	1.275	1.087	0.744
$1\frac{3}{8}$-6 UNC-2B*	1.3750	1.2771	1.2667	1.2252	1.1946	2.0625	2.382	1.400	1.197	0.806
$1\frac{1}{2}$-6 UNC-2B	1.5000	1.4022	1.3917	1.3502	1.3196	2.2500	2.598	1.530	1.311	0.874
$1\frac{3}{4}$-5 UNC-2B	1.7500	1.6317	1.6201	1.5675	1.5335	2.6250	3.031	–	1.530	0.999
2-$4\frac{1}{2}$ UNC-2B	2.0000	1.8681	1.8557	1.7952	1.7594	3.0000	3.464	–	1.754	1.129
$2\frac{1}{4}$-$4\frac{1}{2}$ UNC-2B	2.2500	2.1183	2.1057	2.0452	2.0094					
$2\frac{1}{2}$-4 UNC-2B	2.5000	2.3511	2.3376	2.2669	2.2294					
$2\frac{3}{4}$-4 UNC-2B	2.7500	2.6013	2.5876	2.5169	2.4794					
3-4 UNC-2B	3.0000	2.8515	2.8376	2.7669	2.7294					
$3\frac{1}{4}$-4 UNC-2B	3.2500	3.1017	3.0876	3.0169	2.9794					
$3\frac{1}{2}$-4 UNC-2B	3.5000	3.3519	3.3376	3.2669	3.2294					
$3\frac{3}{4}$-4 UNC-2B	3.7500	3.6021	3.5876	3.5169	3.4794					
4-4 UNC-2B	4.0000	3.8523	3.8376	3.7669	3.7294					

*To be dispensed with wherever possible.
For full range and further information see BS 1768.

Example

The interpretation of designation $\frac{1}{2}$-13 UNC-2B is as follows: nominal diameter $\frac{1}{2}$ inch; threads per inch 13; ISO unified thread, coarse series; thread tolerance classification 2B.

2.29 ISO unified precision external screw threads, coarse series (UNC)

(Dimensions in inches)

	Major diameter		*Pitch (effective) diameter*		*Minor diameter*		*Shank diameter*		*Hexagon head (bolt)*		
Designation	*max*	*min*	*max*	*min*	*max*	*min*	*max*	*min*	*Max width across flats (A/F)*	*Max width across corners (A/C)*	*Max height*
$\frac{1}{4}$-20 UNC-2A	0.2489	0.2408	0.2164	0.2127	0.1876	0.1803	0.2500	0.2465	0.4375	0.505	0.163
$\frac{5}{16}$-18 UNC-2A	0.3113	0.3026	0.2752	0.2712	0.2431	0.2351	0.3125	0.3090	0.5000	0.577	0.211
$\frac{3}{8}$-16 UNC-2A	0.3737	0.3643	0.3331	0.3287	0.2970	0.2881	0.3750	0.3715	0.5625	0.650	0.243
$\frac{7}{16}$-14 UNC-2A	0.4361	0.4258	0.3897	0.3850	0.3485	0.3387	0.4375	0.4335	0.6250	0.722	0.291
$\frac{1}{2}$-13 UNC-2A	0.4985	0.4876	0.4485	0.4435	0.4041	0.3936	0.5000	0.4960	0.7500	0.866	0.323
$\frac{9}{16}$-12 UNC-2A*	0.5609	0.5495	0.5068	0.5016	0.4587	0.4475	0.5625	0.5585	0.8125	0.938	0.371
$\frac{5}{8}$-11 UNC-2A	0.6234	0.6113	0.5644	0.5589	0.5119	0.4999	0.6250	0.6190	0.9375	1.083	0.403
$\frac{3}{4}$-10 UNC-2A	0.7482	0.7353	0.6832	0.6773	0.6255	0.6124	0.7500	0.7440	1.1250	1.300	0.483
$\frac{7}{8}$-9 UNC-2A	0.8731	0.8592	0.8009	0.7946	0.7368	0.7225	0.8750	0.8670	1.3125	1.515	0.563
1-8 UNC-2A	0.9980	0.9830	0.9168	0.9100	0.8446	0.8288	1.0000	0.9920	1.5000	1.732	0.627

(*continued*)

2.29 (*continued*) (Dimensions in inches)

Designation	*Major diameter*		*Pitch (effective) diameter*		*Minor diameter*		*Shank diameter*		*Hexagon head (bolt)*		
	max	*min*	*max*	*min*	*max*	*min*	*max*	*min*	*Max width across flats (A/F)*	*Max width across corners (A/C)*	*Max height*
$1\frac{1}{8}$-7 UNC-2A	1.1228	1.1064	1.0300	1.0228	0.9475	0.9300	1.1250	1.1170	1.6875	1.948	0.718
$1\frac{1}{4}$-7 UNC-2A	1.2478	1.2314	1.1550	1.1476	1.0725	1.0548	1.2500	1.2420	1.8750	2.165	0.813
$1\frac{3}{8}$-6 UNC-2A*	1.3726	1.3544	1.2643	1.2563	1.1681	1.1481	1.3750	1.3650	2.0625	2.382	0.878
$1\frac{1}{2}$-6 UNC-2A	1.4976	1.4794	1.3893	1.3812	1.2931	1.2730	1.5000	1.4900	2.2500	2.598	0.974
$1\frac{3}{4}$-5 UNC-2A	1.7473	1.7268	1.6174	1.6085	1.5019	1.4786	1.7500	1.7400	2.6250	3.031	1.134
2-$4\frac{1}{2}$ UNC-2A	1.9971	1.9751	1.8528	1.8433	1.7245	1.6990	2.000	1.9900	3.000	3.464	1.263
$2\frac{1}{4}$-$4\frac{1}{2}$ UNC-2A	2.2471	2.2251	2.1028	2.0931	1.9745	1.9488					
$2\frac{1}{2}$-4 UNC-2A	2.4969	2.4731	2.3345	2.3241	2.1902	2.1618					
$2\frac{3}{4}$-4 UNC-2A	2.7468	2.7230	2.5844	2.5739	2.4401	2.4116					
3-4 UNC-2A	2.9968	2.9730	2.8344	2.8237	2.6901	2.6614					
$3\frac{1}{4}$-4 UNC-2A	3.2467	3.2229	3.0843	3.0734	2.9400	2.9111					
$3\frac{1}{2}$-4 UNC-2A	3.4967	3.4729	3.3343	3.3233	3.1900	3.1610					
$3\frac{3}{4}$-4 UNC-2A	3.7466	3.7228	3.5842	3.5730	3.4399	3.4107					
4-4 UNC-2A	3.9966	3.9728	3.8342	3.8229	3.6899	3.6606					

*To be dispensed with wherever possible.
For full range and further information see BS 1768.

Example

The interpretation of designation $^1/_2$-13 UNC-2A is as follows: nominal diameter ½ inch; threads per inch 13; ISO unified thread, coarse series, thread tolerance classification 2A.

2.30 ISO unified tapping and clearance drills, coarse thread series

Nominal size	*Tapping drill size*		*Clearance drill size*	
in	mm	in	mm	Letter or in
$\frac{1}{4} \times 20$	5.20	$\frac{13}{64}$	6.50	$\frac{17}{64}$ or F
$\frac{5}{16} \times 18$	6.60	$\frac{17}{64}$	8.00	$\frac{21}{64}$ or O
$\frac{3}{8} \times 16$	8.00	$\frac{5}{16}$	9.80	$\frac{25}{64}$ or W
$\frac{7}{16} \times 14$	9.40	$\frac{3}{8}$	11.30	$\frac{29}{64}$
$\frac{1}{2} \times 13$	10.80	$\frac{27}{64}$	13.00	$\frac{33}{64}$
$\frac{9}{16} \times 12$	12.20	$\frac{31}{64}$	14.75	$\frac{37}{64}$
$\frac{5}{8} \times 11$	13.50	$\frac{17}{32}$	16.25	$\frac{41}{64}$
$\frac{3}{4} \times 10$	16.50	$\frac{21}{32}$	19.50	$\frac{47}{64}$
$\frac{7}{8} \times 9$	19.25	$\frac{49}{64}$	20.25	$\frac{51}{64}$
1×8	22.25	$\frac{7}{8}$	25.75	$1\frac{1}{64}$
$1\frac{1}{8} \times 7$	25.00	$\frac{63}{64}$	26.00	$1\frac{9}{64}$
$1\frac{1}{4} \times 7$	28.25*	$1\frac{7}{64}$	28.25	$1\frac{17}{64}$
$1\frac{3}{8} \times 6$	30.50*	$1\frac{13}{64}$	30.75	$1\frac{25}{64}$
$1\frac{1}{2} \times 6$	34.00*	$1\frac{21}{64}$	34.00	$1\frac{33}{64}$
$1\frac{3}{4} \times 5$	39.50*	$1\frac{35}{64}$	45.00	$1\frac{49}{64}$
$2 \times 4\frac{1}{2}$	45.50*	$1\frac{25}{32}$	52.00	$2\frac{1}{64}$

* Nearest standard metric size: approx. 0.25 mm over recommended inch size.

2.31 ISO unified precision internal screw threads, fine series (UNF)

(Dimensions in inches)

Designation	Major diameter min	Pitch (effective) diameter		Minor diameter		Hexagon (nut)				
						Max width across flats (A/F)	Max width across corners (A/C)	Nut thickness		
		max	min	max	min			Thick	Normal	Thin
$\frac{1}{4}$-28 UNF-2B	0.2500	0.2311	0.2268	0.2197	0.2113	0.4375	0.505	0.286	0.224	0.161
$\frac{5}{16}$-24 UNF-2B	0.3125	0.2902	0.2854	0.2771	0.2674	0.5000	0.577	0.333	0.271	0.192
$\frac{3}{8}$-24 UNF-2B	0.3750	0.3528	0.3479	0.3396	0.3299	0.5625	0.650	0.411	0.333	0.224
$\frac{7}{16}$-20 UNF-2B	0.4375	0.4104	0.4050	0.3949	0.3834	0.6875	0.794	0.458	0.380	0.255
$\frac{1}{2}$-20 UNF-2B	0.5000	0.4731	0.4675	0.4574	0.4459	0.7500	0.866	0.567	0.442	0.317
$\frac{9}{16}$-18 UNF-2B*	0.5625	0.5323	0.5264	0.5151	0.5024	0.8750	1.010	0.614	0.489	0.349
$\frac{5}{8}$-18 UNF-2B	0.6250	0.5949	0.5889	0.5776	0.5649	0.9375	1.083	0.724	0.552	0.380

$\frac{3}{4}$-14 UNF-2B	0.7500	0.7159	0.7094	0.6964	0.6823	1.1250	1.300	0.822	0.651	0.432
$\frac{7}{8}$-14 UNF-2B	0.8750	0.8356	0.8286	0.8135	0.7977	1.3125	1.515	0.916	0.760	0.494
1-12 UNF-2B	1.0000	0.9535	0.9459	0.9279	0.9098	1.5000	1.732	1.015	0.874	0.562
$1\frac{1}{8}$-12 UNF-2B	1.1250	1.0787	1.0709	1.0529	1.0348	1.6875	1.948	1.176	0.984	0.629
$1\frac{1}{4}$-12 UNF-2B	1.2500	1.2039	1.1959	1.1779	1.1598	1.8750	2.165	1.275	1.087	0.744
$1\frac{3}{8}$-12 UNF-2B*	1.3750	1.3291	1.3209	1.3029	1.2848	2.0625	2.382	1.400	1.197	0.806
$1\frac{1}{2}$-12 UNF-2B	1.5000	1.4542	1.4459	1.4279	1.4098	2.2500	2.598	1.530	1.311	0.874

*To be dispensed with wherever possible.
For full range and further information see BS 1768.

Example

The interpretation of designation $\frac{1}{2}$-20 UNF-2B is as follows: nominal diameter $\frac{1}{2}$ inch; threads per inch 20; ISO unified thread, fine series; thread tolerance classification 2B.

2.32 ISO unified precision external screw threads, fine series (UNF)

(Dimensions in inches)

Designation	*Major diameter*		*Pitch (effective) diameter*		*Minor diameter*		*Shank diameter*		*Hexagon head (bolt)*		
	max	*min*	*max*	*min*	*max*	*min*	*max*	*min*	*Max width across flats (A/F)*	*Max width across corners (A/C)*	*Max height*
$\frac{1}{4}$-28 UNF-2A	0.2490	0.2425	0.2258	0.2225	0.2052	0.1993	0.2500	0.2465	0.4375	0.505	0.163
$\frac{5}{16}$-24 UNF-2A	0.3114	0.3042	0.2843	0.2806	0.2603	0.2536	0.3125	0.3090	0.5000	0.577	0.211
$\frac{3}{8}$-24 UNF-2A	0.3739	0.3667	0.3468	0.3430	0.3228	0.3160	0.3750	0.3715	0.5625	0.650	0.243
$\frac{7}{16}$-20 UNF-2A	0.4362	0.4281	0.4037	0.3995	0.3749	0.3671	0.4375	0.4335	0.6250	0.722	0.291
$\frac{1}{2}$-20 UNF-2A	0.4987	0.4906	0.4662	0.4615	0.4374	0.4295	0.5000	0.4960	0.7500	0.866	0.323
$\frac{9}{16}$-18 UNF-2A*	0.5611	0.5524	0.5250	0.5205	0.4929	0.4844	0.5625	0.5585	0.8125	0.938	0.371
$\frac{5}{8}$-18 UNF-2A	0.6236	0.6149	0.5875	0.5828	0.5554	0.5467	0.6250	0.6190	0.9375	1.083	0.403
$\frac{3}{4}$-16 UNF-2A	0.7485	0.7391	0.7079	0.7029	0.6718	0.6623	0.7500	0.7440	1.1250	1.300	0.483

(*continued*)

2.32 (*continued*) (Dimensions in inches)

Designation	*Major diameter*		*Pitch (effective) diameter*		*Minor diameter*		*Shank diameter*		*Hexagon head (bolt)*		
	max	*min*	*max*	*min*	*max*	*min*	*max*	*min*	*Max width across flats (A/F)*	*Max width across corners (A/C)*	*Max height*
$\frac{7}{8}$-14 UNF-2A	0.8734	0.8631	0.8270	0.8216	0.7858	0.7753	0.8750	0.8670	1.3125	1.515	0.563
1-12 UNF-2A	0.9982	0.9868	0.9441	0.9382	0.8960	0.8841	1.0000	0.9920	1.5000	1.732	0.627
$1\frac{1}{8}$-12 UNF-2A	1.1232	1.1118	1.0691	1.0631	0.0210	1.0090	1.1250	1.1170	1.6875	1.948	0.718
$1\frac{1}{4}$-12 UNF-2A	1.2482	1.2368	1.1941	1.1879	1.1460	1.1338	1.2500	1.2420	1.8750	2.165	0.813
$1\frac{3}{8}$-12 UNF-2A*	1.3731	1.3617	1.3190	1.3127	1.2709	1.2586	1.3750	1.3650	2.0625	2.382	0.878
$1\frac{1}{2}$-12 UNF-2A	1.4981	1.4867	1.4440	1.4376	1.3959	1.3835	1.5000	1.4900	2.2500	2.598	0.974

*To be dispensed with wherever possible.
For full range and further information see BS 1768.

Example

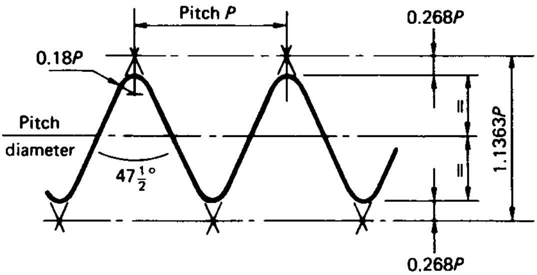
The interpretation of designation $\frac{1}{2}$-20 UNF-2A is as follows: nominal diameter $\frac{1}{2}$ inch: threads per inch 20; ISO unified thread, fine series: thread tolerance classification 2A.

2.33 ISO unified tapping and clearance drills, fine thread series

Nominal	*Tapping drill size*		*Clearance drill size*	
size in	mm	Letter or in	mm	Letter or in
$\frac{1}{4} \times 28$	5.50	$\frac{7}{32}$	6.50	F
$\frac{5}{16} \times 24$	6.90	I	8.00	O
$\frac{3}{8} \times 24$	8.50	R	9.80	W
$\frac{7}{16} \times 20$	9.90	$\frac{25}{64}$	11.30	$\frac{29}{64}$
$\frac{1}{2} \times 20$	11.50	$\frac{29}{64}$	13.00	$\frac{33}{64}$
$\frac{9}{16} \times 18$	12.90	$\frac{33}{64}$	14.75	$\frac{37}{64}$
$\frac{5}{8} \times 18$	14.50	$\frac{37}{64}$	16.50	$\frac{41}{64}$
$\frac{3}{4} \times 16$	17.50	$\frac{11}{16}$	19.50	$\frac{49}{64}$
$\frac{7}{8} \times 14$	20.50	$\frac{13}{16}$	22.75	$\frac{57}{64}$
1×12	23.25	$\frac{59}{64}$	25.80	$1\frac{1}{64}$
$1\frac{1}{8} \times 12$	26.50	$1\frac{3}{64}$	29.00	$1\frac{9}{64}$
$1\frac{1}{4} \times 12$	29.50	$1\frac{11}{64}$	32.50	$1\frac{17}{64}$
$1\frac{3}{8} \times 12$	33.00	$1\frac{19}{64}$	35.50	$1\frac{25}{64}$
$1\frac{1}{2} \times 12$	36.00	$1\frac{27}{64}$	38.50	$1\frac{33}{64}$

Note: if number, letter and fractional size drills are not available, see Table 1.5 for nearest metric alternative.

2.34 British Association (BA) thread form



British Association (BA) thread forms are obsolete but are still used in repairs, maintenance and model making.

BA internal and external screw threads

(Dimensions in millimetres)

Designation number	*Pitch*	*Depth of thread*	*Major diameter*	*Pitch (effective) diameter*	*Minor diameter*	*Crest radius*	*Root radius*
0	1.0000	0.600	6.00	5.400	4.80	0.1808	0.1808
1	0.9000	0.540	5.30	4.760	4.22	0.1627	0.1627
2	0.8100	0.485	4.70	4.215	3.73	0.1465	0.1465
3	0.7300	0.440	4.10	3.660	3.22	0.1320	0.1320
4	0.6600	0.395	3.60	3.205	2.81	0.1193	0.1193
5	0.5900	0.355	3.20	2.845	2.49	0.1067	0.1067
6	0.5300	0.320	2.80	2.480	2.16	0.0958	0.0958
7	0.4800	0.290	2.50	2.210	1.92	0.0868	0.0868
8	0.4300	0.260	2.20	1.940	1.68	0.0778	0.0778
9	0.3900	0.235	1.90	1.665	1.43	0.0705	0.0705
10	0.3500	0.210	1.70	1.490	1.28	0.0633	0.0633
11	0.3100	0.185	1.50	1.315	1.13	0.0561	0.0561
12	0.2800	0.170	1.30	1.130	0.96	0.0506	0.0506
13	0.2500	0.150	1.20	1.050	0.90	0.0452	0.0452

(*continued*)

(Dimensions in millimetres)

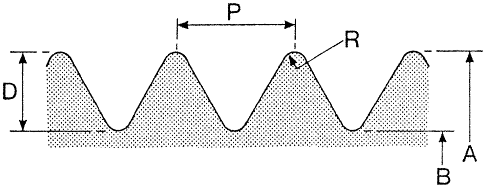
Designation number	*Pitch*	*Depth of thread*	*Major diameter*	*Pitch (effective) diameter*	*Minor diameter*	*Crest radius*	*Root radius*
14	0.2300	0.140	1.00	0.860	0.72	0.0416	0.0416
15	0.2100	0.125	0.90	0.775	0.65	0.0380	0.0380
16	0.1900	0.115	0.79	0.675	0.56	0.0344	0.0344
17	0.1700	0.100	0.70	0.600	0.50	0.0307	0.0307
18	0.1500	0.090	0.62	0.530	0.44	0.0271	0.0271
19	0.1400	0.085	0.54	0.455	0.37	0.0253	0.0253
20	0.1200	0.070	0.48	0.410	0.34	0.0217	0.0217
21	0.1100	0.065	0.42	0.355	0.29	0.0199	0.0199
22	0.1000	0.060	0.37	0.310	0.25	0.0181	0.0181
23	0.0900	0.055	0.33	0.275	0.22	0.0163	0.0163
24	0.0800	0.050	0.29	0.240	0.19	0.0145	0.0145
25	0.0700	0.040	0.25	0.210	0.17	0.0127	0.0127

For further information see BS 57 and BS 93.

2.35 BA threads: tapping and clearance drills

	Tapping size drill		*Clearance size drill*	
BA no.	mm	Number or fraction size	mm	Number or letter
0	5.10	8	6.10	D
1	4.50	16	5.50	2
2	4.00	22	4.85	10
3	3.40	29	4.25	18
4	3.00	32	3.75	24
5	2.65	37	3.30	29
6	2.30	43	2.90	32
7	2.05	45/46	2.60	36
8	1.80	50	2.25	41
9	1.55	53	1.95	45
10	1.40	54	1.75	49
11	1.20	56	1.60	52
12	1.05	59	1.40	54
13	0.98	62	1.30	55
14	0.78	68	1.10	57
15	0.70	70	0.98	60
16	0.60	73	0.88	65

2.36 Model engineering threads (55° ME)



Dia.	Thread per inch	Out-side dia. A	Core dia. B	Pitch P	Depth D	Radius R
1/8	40	0.1250	0.093	0.025	0.016	0.003
5/32	40	0.1562	0.124	0.025	0.016	0.003
3/16	40	0.1875	0.156	0.025	0.016	0.003
7/32	40	0.2187	0.187	0.025	0.016	0.003
1/4	40	0.2500	0.218	0.025	0.016	0.003
9/32	40	0.2812	0.249	0.025	0.016	0.003
5/16	40	0.3125	0.281	0.025	0.016	0.003
5/16	32	0.3125	0.273	0.031	0.020	0.004
5/16	26	0.3125	0.263	0.038	0.025	0.005
3/8	40	0.3750	0.343	0.025	0.016	0.003
3/8	32	0.3750	0.335	0.031	0.020	0.004
3/8	26	0.3750	0.325	0.038	0.025	0.005
7/16	40	0.4375	0.406	0.025	0.016	0.003
7/16	32	0.4375	0.398	0.031	0.020	0.004
7/16	26	0.4375	0.388	0.038	0.025	0.005
1/2	40	0.5000	0.468	0.025	0.016	0.003
1/2	32	0.5000	0.460	0.031	0.020	0.004
1/2	26	0.5000	0.451	0.038	0.025	0.005

2.37 Model engineer clearance and trapping drills

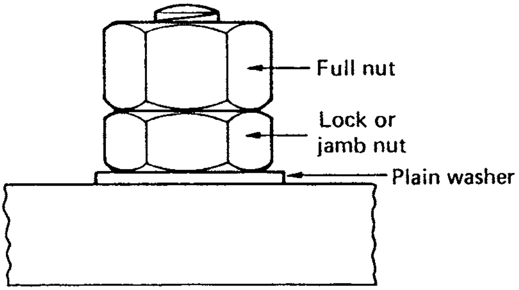
Dia.	Threads per inch	Tapping drill		Clearance drill	
		Imp.	Metric	Imp.	Metric
1/8	40	3/32	2.60	30	3.30
5/32	40	1/8	3.40	22	4.10
3/16	40	5/32	4.20	12	5.00
7/32	40	3/16	5.00	2	5.70
1/4	40	7/32	5.80	F	6.50
9/32	40	1/4	6.50	L	7.30
5/16	40	9/32	7.30	O	8.00
5/16	32	J	7.20	O	8.00
5/16	26	17/64	6.70	O	8.00
3/8	40	11/32	8.80	V	9.80
3/8	32	R	8.70	V	9.80
3/8	26	21/64	8.40	V	9.80
7/16	40	13/32	10.50	29/64	11.50
7/16	32	Y	10.40	29/64	11.50

7/16	26	25/64	10.00	29/64	11.50
1/2	40	15/32	12.10	33/64	13.00
1/2	32	15/32	11.90	33/64	13.00
1/2	26	29/64	11.70	33/64	13.00

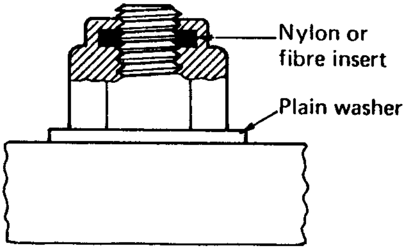
Note: All tapping drill sizes quoted in these charts are based on the British Standards Institute recomendations and sizes published in the Model Engineering Press.

2.38 Friction locking devices

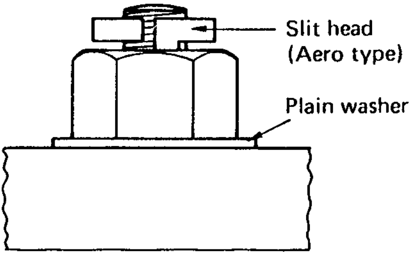
Lock nut



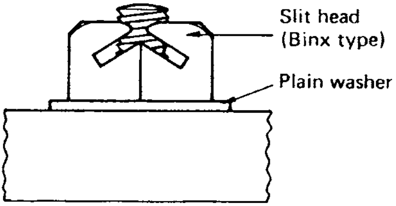
Stiff nut (insert)



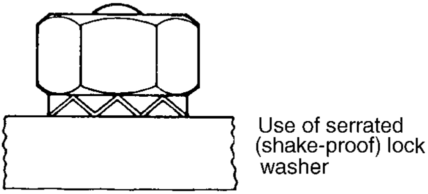
Stiff nut (slit head)



Stiff nut (slit head)



Serrated (toothed) lock washers

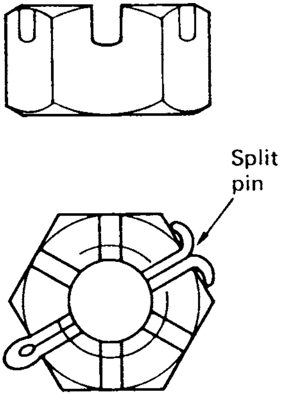


Note:

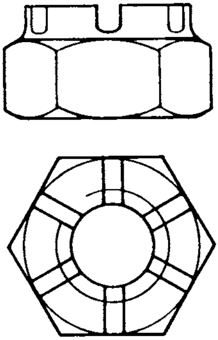
Lock washers, see:
Spring washers, Sections 4.1.3–5.
Toothed lock washers, Section 4.1.6.
Serrated lock washers, Section 4.1.7.
Crinkle washers, Section 4.1.8.

2.39 Positive locking devices

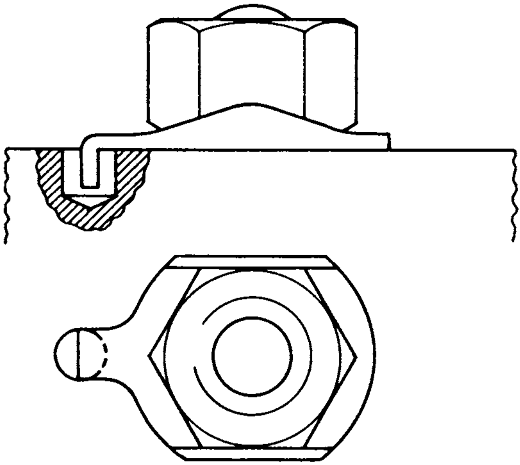
Slotted nut



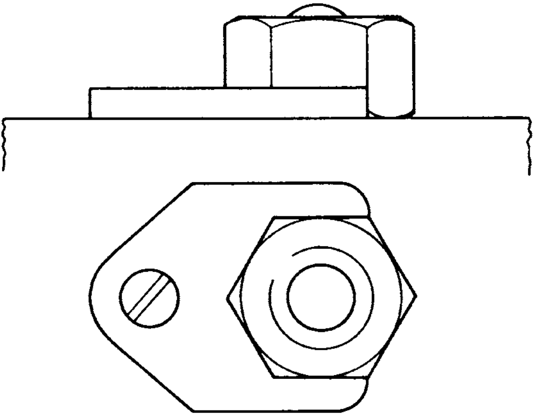
Castle nut



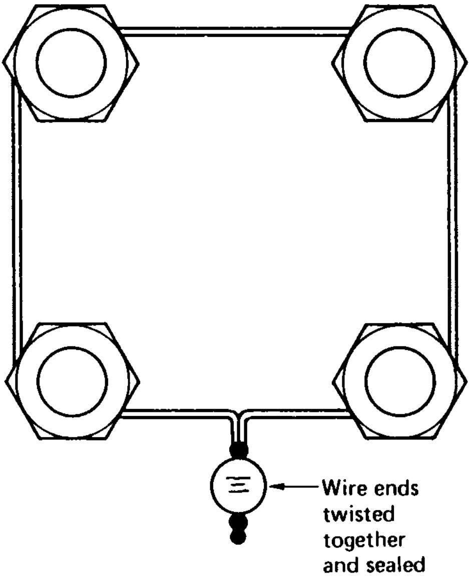
Tab washer



Lock plate



Wiring



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Part 3

Cutting Tools (HSS) and Abrasive Wheels

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3.1 Twist drill sizes, metric

Nominal diameter	Parallel shank jobber series		Parallel shank stub drills		Parallel shank long series		Morse taper (MT) shank two-flute twist and multiflute core drills			Oversize Morse taper shank	
	Flute length	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*MT no.*	*Overall length*	*MT no.*
0.20	2.5	19									
0.22	2.5	19									
0.25	3	19									
0.28	3	19									
0.30	4	19									
0.32	4	19									
0.35	4	19									
0.38	4	19									
0.40	5	20									
0.42	5	20									
0.45	5	20									
0.48	5	20									
0.50	6	22	3	20							
0.52	6	22									

(*continued*)

3.1 (*continued*) (Dimensions in millimetres)

Nominal diameter	*Parallel shank jobber series*		*Parallel shank stub drills*		*Parallel shank long series*		*Morse taper (MT) shank two-flute twist and multiflute core drills*			*Oversize Morse taper shank*	
	Flute length	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*MT no.*	*Overall length*	*MT no.*
0.55	7	24									
0.58	7	24									
0.60	7	24									
0.62	8	26									
0.65	8	26									
0.68	9	28									
0.70	9	28									
0.72	9	28									
0.75	9	28									
0.78	10	30									
0.80	10	30	5	24							
0.82	10	30									
0.85	10	30									
0.88	11	32									
0.90	11	32									
0.92	11	32									
0.95	11	32									
0.98	12	34									

1.00	12	34	6	26	33	56
1.05	12	34				
1.10	14	36			37	60
1.15	14	36				
1.20	16	38	8	30	41	65
1.25	16	38				
1.30	16	38			41	65
1.35	18	40				
1.40	18	40			45	70
1.45	18	40				
1.50	18	40	9	32	45	70
1.55	20	43				
1.60	20	43			50	76
1.65	20	43				
1.70	20	43			50	76
1.75	22	46				
1.80	22	46	11	36	53	80
1.85	22	46				
1.90	22	46			53	80
1.95	24	49				
2.00	24	49	12	38	56	85

(*continued*)

3.1 (*continued*) (Dimensions in millimetres)

Nominal diameter	*Parallel shank jobber series*		*Parallel shank stub drills*		*Parallel shank long series*		*Morse taper (MT) shank two-flute twist and multiflute core drills*			*Oversize Morse taper shank*	
	Flute length	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*MT no.*	*Overall length*	*MT no.*
2.05	24	49									
2.10	24	49			56	85					
2.15	27	53									
2.20	27	53	13	40	59	90					
2.25	27	53									
2.30	27	53			59	90					
2.35	27	53									
2.40	30	57			62	95					
2.45	30	57									
2.50	30	57	14	43	62	95					
2.55	30	57									
2.60	30	57			62	95					
2.65	30	57									
2.70	33	61			66	100					

2.75	33	61							
2.80	33	61	16	46	66	100			
2.85	33	61							
2.90	33	61			66	100			
2.95	33	61							
3.00	33	61	16	46	66	100	33	114	1
3.10	36	65			69	106			
3.20	36	65	18	49	69	106	36	117	1
3.30	36	65			69	106			
3.40	39	70			73	112			
3.50	39	70	20	52	73	112	39	120	1
3.60	39	70			73	112			
3.70	39	70			73	112			
3.80	43	75	22	55	78	119	43	123	1
3.90	43	75			78	119			
4.00	43	75	22	55	78	119	43	123	1
4.10	43	75			78	119			
4.20	43	75	22	55	78	119	43	123	1
4.30	47	80			82	126			
4.40	47	80			82	126			
4.50	47	80	24	58	82	126	47	128	1
4.60	47	80			82	126			

(*continued*)

3.1 (*continued*) (Dimensions in millimetres)

Nominal diameter	*Parallel shank jobber series*		*Parallel shank stub drills*		*Parallel shank long series*		*Morse taper (MT) shank two-flute twist and multiflute core drills*			*Oversize Morse taper shank*	
	Flute length	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*MT no.*	*Overall length*	*MT no.*
4.70	47	80			82	126					
4.80	52	86	26	62	87	132	52	133	1		
4.90	52	86			87	132					
5.00	52	86	26	62	87	132	52	133	1		
5.10	52	86			87	132					
5.20	52	86	26	62	87	132	52	133	1		
5.30	52	86			87	132					
5.40	57	93			91	139					
5.50	57	93	28	66	91	139	57	138	1		
5.60	57	93			91	139					
5.70	57	93			91	139					
5.80	57	93	28	66	91	139	57	138	1		
5.90	57	93			91	139					
6.00	57	93	28	66	91	139	57	138	1		
6.10	63	101			97	148					

6.20	63	101	31	70	97	148	63	144	1
6.30	63	101			97	148			
6.40	63	101			97	148			
6.50	63	101	31	70	97	148	63	144	1
6.60	63	101			97	148			
6.70	63	101			97	148			
6.80	69	109	34	74	102	156	69	150	1
6.90	69	109			102	156			
7.00	69	109	34	74	102	156	69	150	1
7.10	69	109			102	156			
7.20	69	109	34	74	102	156	69	150	1
7.30	69	109			102	156			
7.40	69	109			102	156			
7.50	69	109	34	74	102	156	69	150	1
7.60	75	117			109	165			
7.70	75	117			109	165			
7.80	75	117	37	79	109	165	75	156	1
7.90	75	117			109	165			

(*continued*)

3.1 (*continued*) (Dimensions in millimetres)

Nominal diameter	*Parallel shank jobber series*		*Parallel shank stub drills*		*Parallel shank long series*		*Morse taper (MT) shank two-flute twist and multiflute core drills*			*Oversize Morse taper shank*	
	Flute length	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*MT no.*	*Overall length*	*MT no.*
8.00	75	117	37	79	109	165	75	156	1		
8.10	75	117			109	165					
8.20	75	117	37	79	109	165	75	156	1		
8.30	75	117			109	165					
8.40	75	117			109	165					
8.50	75	117	37	79	109	165	75	156	1		
8.60	81	125			115	175					
8.70	81	125			115	175					
8.80	81	125	40	84	115	175	81	162	1		
8.90	81	125			115	175					
9.00	81	125	40	84	115	175	81	162	1		
9.10	81	125			115	175					
9.20	81	125	40	84	115	175	81	162	1		
9.30	81	125			115	175					
9.40	81	125			115	175					

9.50	81	125	40	84	115	175	81	162	1
9.60	87	133			121	184			
9.70	87	133			121	184			
9.80	87	133	43	89	121	184	87	168	1
9.90	87	133			121	184			
10.00	87	133	43	89	121	184	87	168	1
10.10	87	133			121	184			
10.20	87	133	43	89	121	184	87	168	1
10.30	87	133			121	184			
10.40	87	133			121	184			
10.50	87	133	43	89	121	184	87	168	1
10.60	87	133			121	184			
10.70	94	142			128	195			
10.80	94	142	47	95	128	195	94	175	1
10.90	94	142			128	195			
11.00	94	142	47	95	128	195	94	175	1
11.10	94	142			128	195			
11.20	94	142	47	95	128	195	94	175	1
11.30	94	142			128	195			
11.40	94	142			128	195			
11.50	94	142	47	95	128	195	94	175	1
11.60	94	142			128	195			
11.70	94	142			128	195			
11.80	94	142	47	95	128	195	94	175	1
11.90	101	151			134	205			

(*continued*)

3.1 (*continued*) (Dimensions in millimetres)

Nominal diameter	*Parallel shank jobber series*		*Parallel shank stub drills*		*Parallel shank long series*		*Morse taper (MT) shank two-flute twist and multiflute core drills*			*Oversize Morse taper shank*	
	Flute length	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*Flute length*	*Overall length*	*MT no.*	*Overall length*	*MT no.*
12.00	101	151	51	102	134	205	101	182	1	199	2
12.10	101	151			134	205					
12.20	101	151	51	102	134	205	101	182	1	199	2
12.30	101	151			134	205					
12.40	101	151			134	205					
12.50	101	151	51	102	134	205	101	182	1	199	2
12.60	101	151			134	205					
12.70	101	151			134	205					
12.80	101	151	51	102	134	205	101	182	1	199	2
12.90	101	151			134	205					
13.00	101	151	51	102	134	205	101	182	1	199	2
13.10	101	151			134	205					
13.20	101	151	51	102	134	205	101	182	1	199	2
13.30	108	160			140	214					
13.40	108	160			140	214					
13.50	108	160	54	107	140	214	108	189	1	206	2
13.60	108	160			140	214					
13.70	108	160			140	214					
13.80	108	160	54	107	140	214	108	189	1	206	2
13.90	108	160			140	214					

14.00	108	160	54	107	140	214	108	189	1	206	2
14.25	114	169			144	220	114	212	2	206	2
14.50	114	169	56	111	144	220	114	212	2	206	2
14.75	114	169			144	220	114	212	2	206	2
15.00	114	169	56	111	144	220	114	212	2	206	2
15.25	120	178			149	227	120	218	2	206	2
15.50	120	178	58	115	149	227	120	218	2	206	2
15.75	120	178			149	227	120	218	2	206	2
16.00	120	178	58	115	149	227	120	218	2	206	2
16.25					154	235	125	223	2	206	2
16.50			60	119	154	235	125	223	2	206	2
16.75					154	235	125	223	2	206	2
17.00					154	235	125	223	2	206	2
17.25					158	241	130	228	2	206	2
17.50					158	241	130	228	2	206	2
17.75					158	241	130	228	2	206	2
18.00					158	241	130	228	2	206	2
18.25					162	247	135	233	2	256	3
18.50					162	247	135	283	2	256	3
18.75					162	247	135	283	2	256	3
19.00					162	247	135	233	2	256	3
19.25					166	254	140	238	2	261	3

(*continued*)

3.1 (*continued*) (Dimensions in millimetres)

Nominal diameter	*Parallel shank long series*		*Morse taper (MT) shank two-flute twist and multiflute core drills*			*Oversize Morse taper shank*	
	Flute length	*Overall length*	*Flute length*	*Overall length*	*MT no.*	*Overall length*	*MT no.*
19.50	166	254	140	238	2	261	3
19.75	166	254	140	238	2	261	3
20.00	166	254	140	238	2	261	3
20.25	171	261	145	243	2	266	3
20.50	171	261	145	243	2	266	3
20.75	171	261	145	243	2	266	3
21.00	171	261	145	243	2	266	3
21.25	176	268	150	248	2	271	3
21.50	176	268	150	248	2	271	3
21.75	176	268	150	248	2	271	3
22.00	176	268	150	248	2	271	3
22.25	176	268	150	248	2	271	3
22.50	180	275	155	253	2	276	3
22.75	180	275	155	253	2	276	3
23.00	180	275	155	253	2	276	3
23.25	180	275	155	276	3	—	—
23.50	180	275	155	276	3	—	—
23.75	185	282	160	281	3	—	—
24.00	185	282	160	281	3	—	—
24.25	185	282	160	281	3	—	—
24.50	185	282	160	281	3	—	—
24.75	185	282	160	281	3	—	—
25.00	185	282	160	281	3	—	—
25.25			165	286	3	—	—
25.50			165	286	3	—	—
25.75			165	286	3	—	—
26.00			165	286	3	—	—
26.25			165	286	3	—	—
26.50			165	286	3	—	—
26.75			170	291	3	319	4
27.00			170	291	3	319	4
27.25			170	291	3	319	4
27.50			170	291	3	319	4
27.75			170	291	3	319	4
28.00			170	291	3	319	4
28.25			175	296	3	324	4
28.50			175	296	3	324	4
28.75			175	296	3	324	4
29.00			175	296	3	324	4
29.25			175	296	3	324	4
29.50			175	296	3	324	4
29.75			175	296	3	324	4
30.00			175	296	3	324	4
30.25			180	301	3	329	4
30.50			180	301	3	329	4

Nominal diameter	*Morse taper (MT) shank two-flute twist and multiflute core drills*			*Oversize Morse taper shank*	
	Flute length	*Overall length*	*MT no.*	*Overall length*	*MT no.*
30.75	180	301	3	329	4
31.00	180	301	3	329	4
31.25	180	301	3	329	4
31.50	180	301	3	329	4
31.75	185	306	3	334	4
32.00	185	334	4	—	—
32.50	185	334	4	—	—
33.00	185	334	4	—	—
33.50	185	334	4	—	—
34.00	190	339	4	—	—
34.50	190	339	4	—	—
35.00	190	339	4	—	—
35.50	190	339	4	—	—
36.00	195	344	4	—	—
36.50	195	344	4	—	—
37.00	195	344	4	—	—
37.50	195	344	4	—	—
38.00	200	349	4	—	—
38.50	200	349	4	—	—
39.00	200	349	4	—	—
39.50	200	349	4	—	—
40.00	200	349	4	—	—
40.50	205	354	4	392	5
41.00	205	354	4	392	5
41.50	205	354	4	392	5
42.00	205	354	4	392	5
42.50	205	354	4	392	5
43.00	210	359	4	397	5
43.50	210	359	4	397	5
44.00	210	359	4	397	5
44.50	210	359	4	397	5
45.00	210	359	4	397	5
45.50	215	364	4	402	5
46.00	215	364	4	402	5
46.50	215	364	4	402	5
47.00	215	364	4	402	5
47.50	215	364	4	402	5
48.00	220	369	4	407	5
48.50	220	369	4	407	5
49.00	220	369	4	407	5
49.50	220	369	4	407	5
50.00	220	369	4	407	5
50.50	225	374	4	412	5
51.00	225	412	5	—	—
52.00	225	412	5	—	—
53.00	225	412	5	—	—
54.00	230	417	5	—	—
55.00	230	417	5	—	—
56.00	230	417	5	—	—

(*continued*)

3.1 (*continued*) (Dimensions in millimetres)

Nominal diameter	*Morse taper (MT) shank two-flute twist and multiflute core drills*			*Oversize Morse taper shank*	
	Flute length	*Overall length*	*MT no.*	*Overall length*	*MT no.*
57.00	235	422	5	—	—
58.00	235	422	5	—	—
59.00	235	422	5	—	—
60.00	235	422	5	—	—
61.00	240	427	5	—	—
62.00	240	427	5	—	—
63.00	240	427	5	—	—
64.00	245	432	5	499	6
65.00	245	432	5	499	6
66.00	245	432	5	499	6
67.00	245	432	5	499	6
68.00	250	437	5	504	6
69.00	250	437	5	504	6
70.00	250	437	5	504	6
71.00	250	437	5	504	6
72.00	255	442	5	509	6
73.00	255	442	5	509	6
74.00	255	442	5	509	6
75.00	255	442	5	509	6
76.00	260	447	5	514	6
77.00	260	514	6	—	—
78.00	260	514	6	—	—
79.00	260	514	6	—	—
80.00	260	514	6	—	—
81.00	265	519	6	—	—
82.00	265	519	6	—	—
83.00	265	519	6	—	—
84.00	265	519	6	—	—
85.00	265	519	6	—	—
86.00	270	524	6	—	—
87.00	270	524	6	—	—
88.00	270	524	6	—	—
89.00	270	524	6	—	—
90.00	270	524	6	—	—
91.00	275	529	6	—	—
92.00	275	529	6	—	—
93.00	275	529	6	—	—
94.00	275	529	6	—	—
95.00	275	529	6	—	—
96.00	280	534	6	—	—
97.00	280	534	6	—	—
98.00	280	534	6	—	—
99.00	280	534	6	—	—
100.00	280	534	6	—	—

For further information see BS 328.

3.2 Gauge and letter size twist drills

(and alternative New Standard International Series)

OLD		NEW	
Drill No.	*Decimal inch*	*Drill mm*	*Decimal inch*
80	0.0135	0.35	0.0138
79	0.0145	0.38	0.0150
78	0.0160	0.40	0.0157
77	0.0180	0.45	0.0177
76	0.0200	0.50	0.0197
75	0.0210	0.52	0.0205
74	0.0225	0.58	0.0228
73	0.0240	0.60	0.0236
72	0.0250	0.65	0.0256
71	0.0260	0.65	0.0256
70	0.0280	0.70	0.0276
69	0.0292	0.75	0.0295
68	0.0310	1/32″	0.0312
67	0.0320	0.82	0.0323
66	0.0330	0.85	0.0335
65	0.0350	0.90	0.0354
64	0.0360	0.92	0.0362
63	0.0370	0.95	0.0374
62	0.0380	0.98	0.0386
61	0.0390	1.00	0.0394
60	0.0400	1.00	0.0394
59	0.0410	1.05	0.0413
58	0.0420	1.05	0.0413
57	0.0430	1.10	0.0433
56	0.0465	3/64″	0.0469
55	0.0520	1.30	0.0512
54	0.0550	1.40	0.0551
53	0.0595	1.50	0.0591
52	0.0635	1.60	0.0630
51	0.0670	1.70	0.0669
50	0.0700	1.80	0.0709
49	0.0730	1.85	0.0728
48	0.0760	1.95	0.0768
47	0.0785	2.00	0.0787
46	0.0810	2.05	0.0807

(*continued*)

3.2 (*continued*)

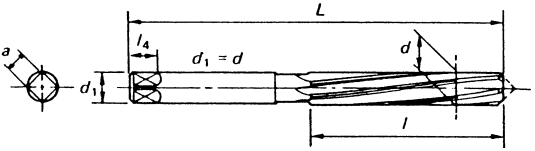
OLD		NEW	
Drill No.	*Decimal inch*	*Drill mm*	*Decimal inch*
45	0.0820	2.10	0.0827
44	0.0860	2.20	0.0866
43	0.0890	2.25	0.0886
42	0.0935	3⁄32″	0.0938
41	0.0960	2.45	0.0965
40	0.0980	2.50	0.0984
39	0.0995	2.55	0.1004
38	0.1015	2.60	0.1024
37	0.1040	2.65	0.1043
36	0.1065	2.70	0.1063
35	0.1100	2.80	0.1102
34	0.1110	2.80	0.1102
33	0.1130	2.85	0.1122
32	0.1160	2.95	0.1161
31	0.1200	3.00	0.1181
30	0.1285	3.30	0.1299
29	0.1360	3.50	0.1378
28	0.1405	9⁄64″	0.1406
27	0.1440	3.70	0.1457
26	0.1470	3.70	0.1457
25	0.1495	3.80	0.1496
24	0.1520	3.90	0.1535
23	0.1540	3.90	0.1535
22	0.1570	4.00	0.1575
21	0.1590	4.00	0.1575
20	0.1610	4.10	0.1614
19	0.1660	4.20	0.1654
18	0.1695	4.30	0.1693
17	0.1730	4.40	0.1732
16	0.1770	4.50	0.1772
15	0.1800	4.60	0.1811
14	0.1820	4.60	0.1811
13	0.1850	4.70	0.1850
12	0.1890	4.80	0.1890
11	0.1910	4.90	0.1929
10	0.1935	4.90	0.1929
9	0.1960	5.00	0.1968
8	0.1990	5.10	0.2008
7	0.2010	5.10	0.2008
6	0.2040	5.20	0.2047

5	0.2055	5.20	0.2047
4	0.2090	5.30	0.2087
3	0.2130	5.40	0.2126
2	0.2210	5.60	0.2205
1	0.2280	5.80	0.2283
A	0.2340	15/64″	0.2344
B	0.2380	6.00	0.2362
C	0.2420	6.10	0.2402
D	0.2460	6.20	0.2441
E	0.2500	1/4″	0.2500
F	0.2570	6.50	0.2559
G	0.2610	6.60	0.2598
H	0.2660	17/64″	0.2656
I	0.2720	6.90	0.2717
J	0.2770	7.00	0.2756
K	0.2810	9/32″	0.2812
L	0.2900	7.40	0.2913
M	0.2950	7.50	0.2953
N	0.3020	7.70	0.3031
O	0.3160	8.00	0.3150
P	0.3230	8.20	0.3228
Q	0.3320	8.40	0.3307
R	0.3390	8.60	0.3386
S	0.3480	8.80	0.3465
T	0.3580	9.10	0.3583
U	0.3680	9.30	0.3661
V	0.3770	3/8″	0.3750
W	0.3860	9.80	0.3858
X	0.3970	10.10	0.3976
Y	0.4040	10.30	0.4055
Z	0.4130	10.50	0.4134

Drill gauge and letters sizes are now obsolete and should not be used in new designs – ref. BS 328.

3.3 Hand reamer (normal lead)

Taper lead (1°) = $1\frac{1}{2}\times$ diameter or 20 mm whichever is the smaller



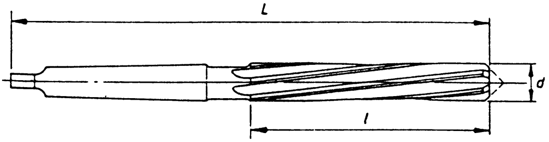
(Dimensions in millimetres)

*Preferred cutting diameters** d	*Cutting edge length* l	*Overall length* L	*Driving square* a(h12)	l_4
1.5	20	41	1.12	
1.6	21	44	1.25	
1.8	23	47	1.40	
2.0	25	50	1.60	4
2.2	27	54	1.80	
2.5	29	58	2.00	
2.8 / **3.0**	31	62	2.24	5
3.5	35	71	2.80	
4.0	38	76	3.15	6
4.5	41	81	3.55	
5.0	44	87	4.00	
5.5 / **6.0**	47	93	4.50	7
7.0	54	107	5.60	8
8.0	58	115	6.30	9
9.0	62	124	7.10	10
10.0	66	133	8.00	11
11.0	71	142	9.00	12
12.0 / 13.0	76	152	10.00	13
14.0 / 15.0	81	163	11.20	14
16.0 / 17.0	87	175	12.50	16

18.0, 19.0	93	188	14.00	18
20.0, 21.0	100	201	16.00	20
22, 23	107	215	18.00	22
24				
25	115	231	20.00	24
26				
27				
28	124	247	22.40	26
30				
32	133	265	25.00	28
34				
35	142	284	28.00	31
36				
38				
40	152	305	31.50	34
42				
44				
45	163	326	35.50	38
46				
48				
50	174	347	40.00	42
52				
55				
56	184	367	45.00	46
58				
60				
62				
63	194	387	50.00	51
67				
71	203	406	56.00	56

*The diameters in bold type should be used whenever possible.
This table is based on a table from ISO 236/1, except that the latter uses the symbols l for L and l_1 for l. For full range and further information see BS 328: Pt 4: 1983.

3.4 Long flute machine reamers



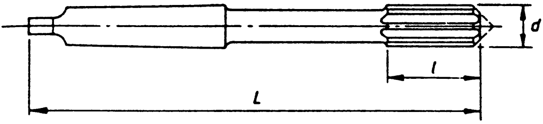
(Dimensions in millimetres)

Preferred cutting diameters d*	*Cutting edge length l*	*Overall length L*	*Morse taper shank*
7	54	134	
8	58	138	
9	62	142	
10	66	146	no. 1
11	71	151	
12 }	76	156	
13 }			
14 }	81	161	
15 }		181	
16 }	87	187	
17 }			
18 }	93	193	
19 }			no. 2
20 }	100	200	
21 }			
22 }	207	207	
23 }			
24			
25	115	242	
26			
27			no. 3
28	124	251	
30			

32	133	293	
34			
35	142	302	
36			
38			
40	152	312	no. 4
42			
44			
45	163	323	
46			
48		334	
50	174		
52		371	
55			
56	184	381	
58			
60			no. 5
62			
63	194	391	
67			
71	203	400	

*The diameters in bold type should be used whenever possible.
This table is based on a table from ISO 236/II, except that the latter uses the symbols l for L and l_1 for l.
For tool definitions, full range and further information see BS 328: 4: 1983.

3.5 Machine chucking reamers with Morse taper shanks



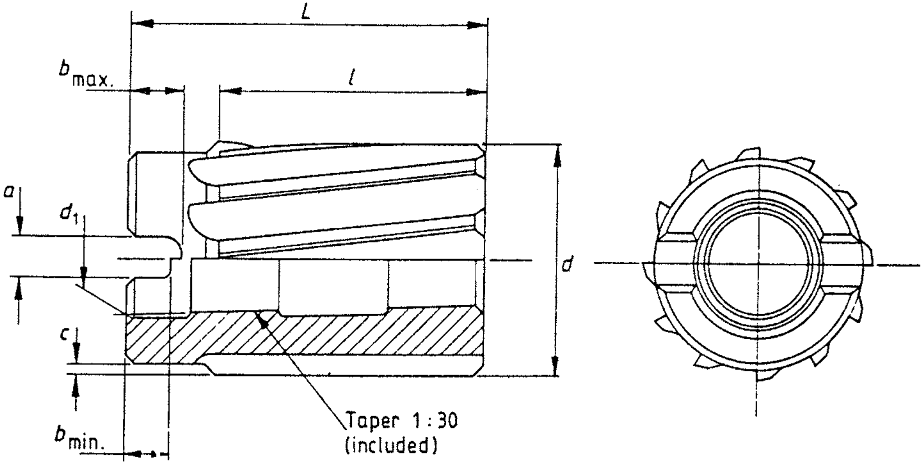
Machine chucking reamers with Morse taper shanks, dimensions

(Dimensions in millimetres)

*Preferred cutting diameters** *d*	*Cutting edge length* *l*	*Overall length* *L*	*Morse taper shank*
5.5 **6**	26	138	
7	31	150	
8	33	156	
9	36	162	no. 1
10	38	168	
11	41	175	
12 13	44	182	
14	47	189	
15	50	204	
16	52	210	
17	54	214	
18	56	219	no. 2
19	58	223	
20	60	228	
22	64	237	
24 **25**	68	268	
26	70	273	no. 3
28	71	277	
30	73	281	
32	77	317	
34 35	78	321	
36	79	325	
38 **40**	81	329	
42	82	333	no. 4
44 **45**	83	336	
46	84	340	
48 **50**	86	344	

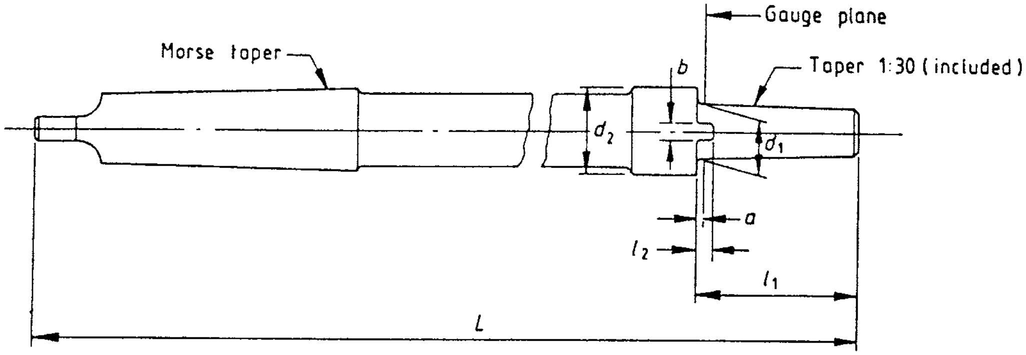
*The diameters in bold type should be used whenever possible. This table is based on a table from ISO 521. For tool definitions, full range and further information see BS 328: Pt 4: 1983.

3.6 Shell reamers with taper bore



(*continued*)

Arbor for shell reamer with taper bore



3.6 (*continued*) (Dimensions in millimetres)

Reamer diameter d			*Diameter of large end of taper bore*	*Width of driving slot a* (H13)*	*Depth of driving slot b*		*Relief depth*	*Cutting edge length*	*Overall length*
Over	*Up to and including*	*Preferred sizes*	d_1		*min.*	*max.*	*C max.*	*l*	*L*
19.9	23.6	–	10	4.3	5.4	7.0	1.0	28	40
23.6	30.0	25 26 27 28 30	13	4.3	5.4	7.0	1.0	32	45
30.0	35.5	32 34 35	16	5.4	6.2	8.3	1.5	36	50
35.5	42.5	36 38 40 42	19	6.4	7.8	10.2	1.5	40	56
42.5	50.8	45 47 48 50	22	7.4	8.6	11.3	1.5	45	63

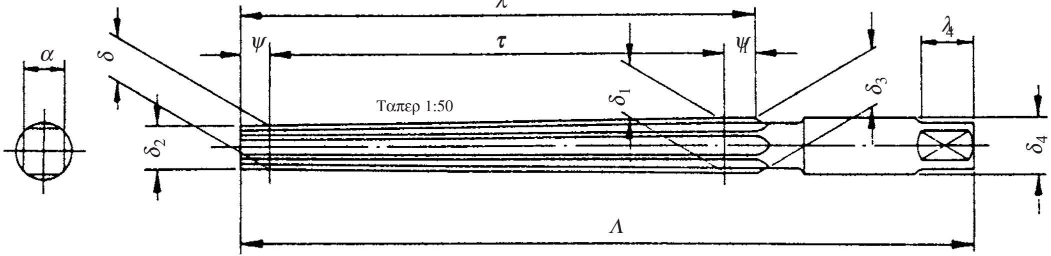
(*continued*)

3.6 (*continued*) (Dimensions in millimetres)

Reamer diameter d			*Diameter of large end of taper bore*	*Width of driving slot a*	*Depth of driving slot b*		*Relief depth*	*Cutting edge length*	*Overall length*
Over	*Up to and including*	*Preferred sizes*	d_1	(H13)*	*min.*	*max.*	*C* *max.*	*l*	*L*
50.8	60.0	52 55 58 60	27	8.4	9.3	12.5	2.0	50	71
60.0	71.0	62 65 70	32	10.4	10.5	14.5	2.0	56	80
71.0	85.0	72 75 80 85	40	12.4	11.2	16.2	2.5	63	90
85.0	101.6	90 95 100	50	14.4	13.1	18.7	2.5	71	100

*For values of the tolerance H13, see BS 328: Pt 4 Appendix B.
The dimensions shown in this table are in accordance with ISO 2402, except that the latter does not include preferred diameters.
For further information see BS 328: Pt 4: 1983.

3.7 Hand taper pin reamer



(*continued*)

3.7 (*continued*) (Dimensions in millimetres)

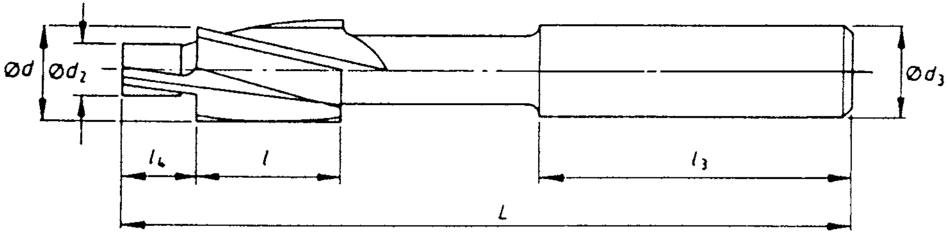
d nom.	d_1	t	y	y_1	d_2	d_3	l	d_4 (h11)*	L	a (h12)*	l_4
0.6	0.76	8	5	7	0.5	0.90	20		38	†	†
0.8	1.04	12	5	7	0.7	1.18	24		42	0.90	4
1.0	1.32	16	5	7	0.9	1.46	28		46	1.12	4
1.2	1.60	20	5	7	1.1	1.74	32		50	1.40	4
1.5	2.00	25	5	7	1.4	2.14	37	$d_4 = d_3$	57	1.80	4
2.0	2.70	35	5	8	1.9	2.86	48		68	2.24	5
2.5	3.20	35	5	8	2.4	3.36	48		68	2.80	5
3.0	3.90	45	5	8	2.9	4.06	58	4.0	80	3.15	6
4.0	5.10	55	5	8	3.9	5.26	68	5.0	93	4.00	7
5.0	6.20	60	5	8	4.9	6.36	73	6.3	100	5.00	8
6.0	7.80	90	5	10	5.9	8.00	105	8.0	135	6.30	9
8.0	10.60	130	5	10	7.9	10.80	145	10.0	180	8.00	11
10.0	13.20	160	5	10	9.9	13.40	175	12.5	215	10.00	13
12.0	15.60	180	10	20	11.8	16.00	210	14.0	255	11.20	14
16.0	20.00	200	10	20	15.8	20.40	230	18.0	280	14.00	18
20.0	24.40	220	10	20	19.8	24.80	250	22.4	310	18.00	22
25.0	29.80	240	15	45	24.7	30.70	300	28.0	370	22.40	26
30.0	35.20	260	15	45	29.7	36.10	320	31.5	400	25.00	28
40.0	45.60	280	15	45	39.7	46.50	340	40.0	430	31.50	34
50.0	56.00	300	15	45	49.7	56.90	360	50.0	460	40.00	42

*For the values of the tolerances h11 and h12 see BS 328: Pt 4: 1983 Appendix B.

†This shank size is smaller than the size range for which a size of driving square is specified in ISO 237. A parallel shank should be used without a square.

This table is in accordance with ISO 3465, except that in the latter, for values of d equal to or less than 2.5 mm, d_4 has a constant value equal to 3.15 mm. The values of a and l_4 are in accordance with ISO 237. For further information see BS 328: Pt 4: 1983.

3.8 Counterbores with parallel shanks and integral pilots



General dimensions (Dimensions in millimetres)

*Cutting diameter d (z9)**		*Pilot diameter d_2*	*Shank diameter d_3 (h9)**	*Overall length L*	*Cutting length l*	*Shank length l_3*	*Pilot length (approx.) l_4*
over	*to*						
2.00†	3.15	For all cutting diameters: $d/3$ min.	$d_3 = d$	45	7		d_2
3.15	5.00	Limits of tolerance on selected pilot diameter: e8*	$d_3 = d$	56	10		d_2
5.00	8.00	The selected pilot diameter is to be specified, when	5.0	71	14	31.5	d_2
8.00	12.50	ordering, to suit the pilot hole diameter	8.0	80	18	35.5	d_2
12.50	20.00		12.5	100	22	40.0	d_2

*For values of the tolerances z9, e8 and h9 see Tables 11, 8 and 10 in BS 328: Pt 5: 1983 Appendix A.

†Includes 2 mm.

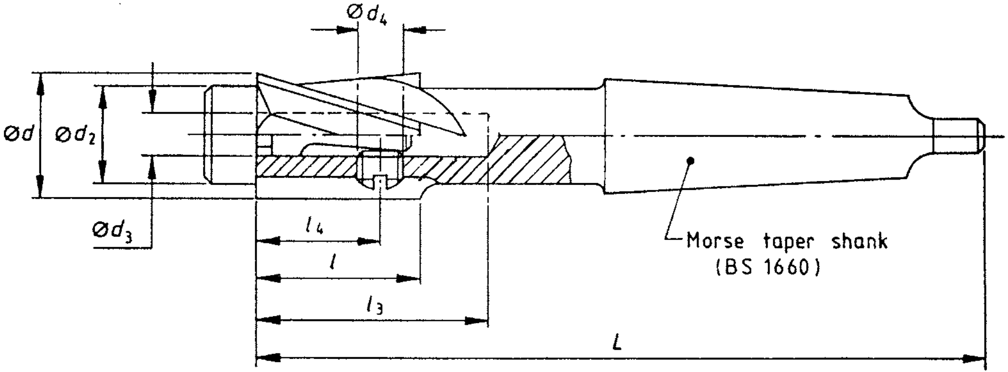
This table is in accordance with ISO 4206 except that the latter uses l_1 for L, l_2 for l and d_1 for d.

Diameters (Dimensions in millimetres)

Preferred cutting diameters d (z9)	*Pilot diameter* d_2 (38)	*Cap screw size*	*Cap screw head diameter*
6.0	2.5 3.2 3.4*	M3	5.5
8.0	3.3 4.3 4.5*	M4	7.0
10.0	4.2 5.3 5.5*	M5	8.5
11.0	5.0 6.4 6.6*	M6	10.0
15.0	6.8 8.4 9.0*	M8	13.0
18.0	8.5 10.5 11.0*	M10	16.0
20.0	10.2 13.0 14.0*	M12	18.0

*These are the preferred pilot diameters, being the diameters of clearance holes for the sizes of cap screw indicated. For further information see BS 328: Pt 5: 1983.

3.9 Counterbores with Morse taper shanks and detachable pilots



General dimensions (Dimensions in millimetres)

Cutting diameter d (z9)*		*Pilot diameter* d_2 (e8)*		*Diameter of hole for pilot* d_3 (H8)	*Set screw size* d_4	*Overall length* L	*Cutting length* l	*Pilot shank* L_3	*Set screw position* l_4	*Morse taper shank no.*
over	to	over	to							
12.5	16.0	5.0	14.0	4	M3	132	22	30	16	2
16.0	20.0	6.3	18.0	5	M4	140	25	38	19	2
20.0	25.0	8.0	22.4	6	M5	150	30	46	23	2
25.0	31.5	10.0	28.0	8	M6	180	35	54	27	3
31.5	40.0	12.5	35.5	10	M8	190	40	64	32	3
40.0	50.0	16.0	45.0	12	M8	236	50	76	42	4
50.0	63.0	20.0	56.0	16	M10	250	63	88	53	4

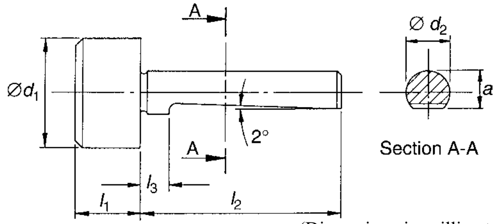
*For values of the tolerances z9, e8 and H8 see Tables 11, 8 and 12 in BS 328: Pt 5: 1983 Appendix A.
This table is in accordance with ISO 4207 except that the latter uses l_1 for L, l_2 for l and d_1 for d.

Diameters (Dimensions in millimetres)

Preferred cutting diameters d (z9)	*Pilot diameter* d_2 (e8)	*Pilot shank diameter* d_3 (f7)	*Cap screw size*	*Cap screw head diameter*
15.0	6.8 8.4 9.0*	4.0	M8	13.0
18.0	8.5 10.2 10.5	5.0	M10	16.0
20.0	11.0* 13.0 14.0*		M12	18.0
24.0	12.0 15.0 16.0*	6.0	M14	21.0
26.0	14.0 15.5 17.0	8.0	M16	24.0
30.0	18.0 19.0 20.0*		M18	27.0
33.0	17.5 19.5	10.0	M20	30.0
36.0	21.0 22.0* 23.0		M22	33.0
40.0	24.0* 25.0 26.0*		M24	36.0

*These are the preferred pilot diameters, being the diameters of clearance holes for the sizes of cap screw indicated.
For further information see BS 328: Pt 5.

3.10 Detachable pilots for counterbores

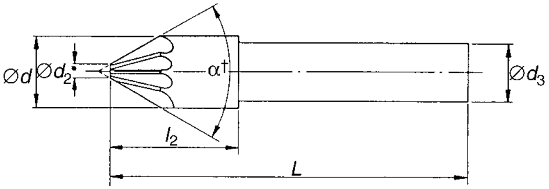


(Dimensions in millimetres)

Pilot shank diameter d_2 (f7)*	*Pilot diameter* d_1 (e8)* *over*	*to*	$a_{-0.1}^{0}$	*Pilot length* l_1	*Pilot shank length* l_2	l_3
4	5.0	6.3	3.6	5	20	3
4	6.3	8.0	3.6	6	20	3
4	8.0	10.0	3.6	7	20	3
4	10.0	12.5	3.6	8	20	4
4	12.5	14.0	3.6	10	20	4
5	6.3	8.0	4.6	6	23	3
5	8.0	10.0	4.6	7	23	3
5	10.0	12.5	4.6	8	23	4
5	12.5	16.0	4.6	10	23	4
5	16.0	18.0	4.6	12	23	4
6	8.0	10.0	5.5	7	28	4
6	10.0	12.5	5.5	8	28	4
6	12.5	16.0	5.5	10	28	4
6	16.0	20.0	5.5	12	28	5
6	20.0	22.4	5.5	15	28	5
8	10.0	12.5	7.5	8	32	4
8	12.5	16.0	7.5	10	32	4
8	16.0	20.0	7.5	12	32	5
8	20.0	25.0	7.5	15	32	5
8	25.0	28.0	7.5	18	32	5
10	12.5	16.0	9.1	10	40	5
10	16.0	20.0	9.1	12	40	5
10	20.0	25.0	9.1	15	40	5
10	25.0	31.5	9.1	18	40	6
10	31.5	35.5	9.1	22	40	6
12	16.0	20.0	11.3	12	50	5
12	20.0	25.0	11.3	15	50	5
12	25.0	31.5	11.3	18	50	6
12	31.5	40.0	11.3	22	50	6
12	40.0	45.0	11.3	27	50	6
16	20.0	25.0	15.2	15	60	6
16	25.0	31.5	15.2	18	60	6
16	31.5	40.0	15.2	22	60	6
16	40.0	50.0	15.2	27	60	6
16	50.0	56.0	15.2	30	60	6

*For values of the tolerances f7 and e8 see Tables 8 and 9 in BS 328: Pt 5: 1983 Appendix A.
This table is in accordance with ISO 4208. For further information see BS 328: Pt 5: 1983.

3.11 Countersinks with parallel shanks

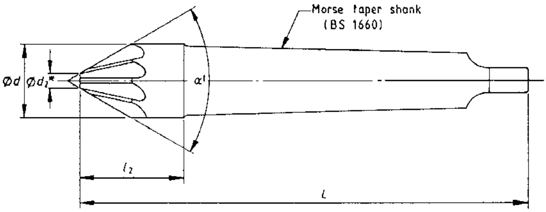


(Dimensions in millimetres)

Nominal size d	*Small diameter** d_2	*Overall length* $L^{\dagger}$ $\alpha = 60°$	$\alpha = 90°$ and 120°	*Body length* $l_2^{\dagger}$ $\alpha = 60°$	$\alpha = 90°$ and 120°	*Shank diameter* d_3(h9)‡
8.0	1.6	48	44	16	12	8
10.0	2.0	50	46	18	14	8
12.5	2.5	52	48	20	16	8
16.0	3.2	60	56	24	20	10
20.0	4.0	64	60	28	24	10
25.0	7.0	69	65	33	29	10

*Front end design optional.
†Tolerance on α is $^{0}_{-1}$ degrees.
‡For values of the tolerance h9 see Table 10 in BS 328 : Pt 5 : 1983 Appendix A.
This table is in accordance with ISO 3294, except that the latter uses l_1 for L and d_1 for d.
For further information see BS 328: Pt 5: 1983.

3.12 Countersinks with Morse taper shanks



(Dimensions in millimetres)

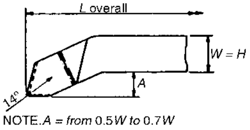
Nominal size d	*Small diameter** d_2	*Overall length L*† α = 60°	*Overall length L*† α = 90° and 120°	*Body length* l_2† α = 60°	*Body length* l_2† α = 90° and 120°	*Morse taper shank no.*
16.0	3.2	97	93	24	20	1
20.0	4.0	120	116	28	24	2
25.0	7.0	125	121	33	29	2
31.5	9.0	132	124	40	32	2
40.0	12.5	160	150	45	35	3
50.0	16.0	165	153	50	38	3
63.0	20.0	200	185	58	43	4
80.0	25.0	215	196	73	54	4

*Front end design optional.
†Tolerance on α is $^{\ 0}_{-1}$ degrees.
This table is in accordance with ISO 3293, except that the latter uses l_1 for L and d_1 for d.
For further information see BS 328: Pt 5: 1983.

3.13 Single point cutting tools: butt welded high-speed steel

Light turning and facing tool

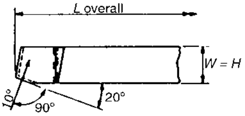
No. 1 Right hand as drawn
No. 2 Left hand opposite to drawing



Preferred sizes (mm)		
H	*W*	*L*
12	12	100
16	16	110
20	20	125
25	16	200
32	20	250
40	25	315
(20	16)	140
(25	20)	200

Straight nosed roughing tool

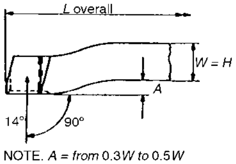
No. 3 Right hand as drawn
No. 4 Left hand opposite to drawing



Preferred sizes (mm)		
H	*W*	*L*
12	12	100
16	16	110
20	20	125
25	16	200
32	20	250
40	25	315
(20	16)	200
(25	20)	200

Knife tool or side-cutting tool

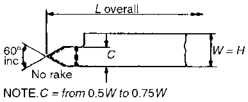
No. 7 Right hand as drawn
No. 8 Left hand opposite to drawing



Preferred sizes (mm)		
H	*W*	*L*
12	12	100
16	16	110
20	20	125
25	16	200
32	20	250
40	25	315
(20	16)	140
(25	20)	200

External screw-cutting tool

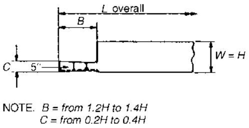
No. 13 As drawn



Preferred sizes (mm)		
H	*W*	*L*
12	12	100
16	16	110
20	20	125
25	16	200
32	20	250
40	25	315
(20	16)	140
(25	20)	200

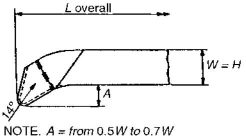
Parting-off tool

No. 16RH Right hand as drawn
No. 16LH Left hand opposite to drawing



Facing tool

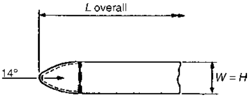
No. 19 Right hand as drawn
No. 20 Left hand opposite to drawing



Preferred sizes (mm)		
H	*W*	*L*
12	12	100
16	16	110
20	20	125
25	16	200
32	20	250
40	25	315
(20	16)	140
(25	20)	200

Round nosed planing or shaping tool

No. 17 Cuts either right hand or left hand



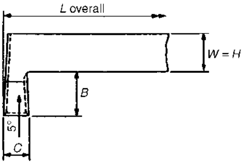
Preferred sizes (mm)		
H	*W*	*L*
12	12	100
16	16	110
20	20	125
25	25	200
32	32	315
40	40	315
25	16	200
32	20	250
40	25	315
(20	16)	140
(25	20)	200
(50	40)	400

Preferred sizes (mm)		
H	*W*	*L*
12	12	100
16	16	110
20	20	125
25	16	200
32	20	250
40	25	315
(20	16)	140
(25	20)	200

Right-angle recessing tool

No. 25 Right hand as drawn

No. 26 Left hand opposite to drawing

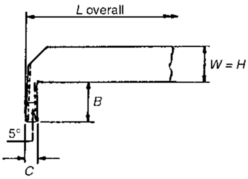


NOTE. B = from W to $1.3W$
$C = 0.5W$ to $0.6W$

Preferred sizes (mm)		
H	*W*	*L*
12	12	100
16	16	110
(20	16)	140
(25	20)	200

Right-angle parting-off tool

No. 27 Right hand as drawn
No. 28 Left hand opposite to drawing

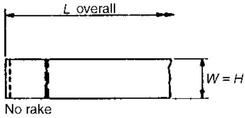


NOTE. *B* = *from 1.0H to 1.2H*
C = *from 0.2H to 0.4H*

Preferred sizes (mm)		
H	*W*	*L*
12	12	100
16	16	110
(20	16)	140
(25	20)	200

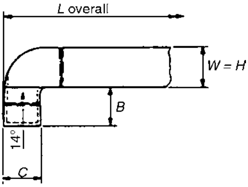
Hardened blank

No. 47



Cranked turning or recessing tool

No. 39 Right hand as drawn
No. 40 Left hand opposite to drawing

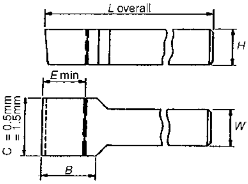


NOTE. *B* = from 0.9*W* to 1.2*W*
C = *W*

Preferred sizes (mm)		
H	*W*	*L*
12	12	100
16	16	110
20	20	125
(20	16)	140
(25	20)	200

Hardened blank

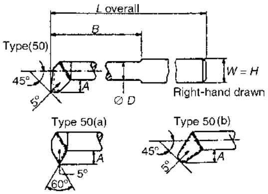
No. 62



Preferred sizes (mm)		
H	*W*	*L*
12	12	100
16	16	110
20	20	125
25	25	200
32	32	315
40	40	315
25	16	200
32	20	250
40	25	315
(20	16)	140
(25	20)	200
(50	40)	400

Boring tool

No. 50 Square nose
No. 50A V-nose for internal screw cutting
No. 50B Round nose



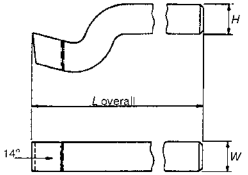
NOTE. *A = from 0.4W to 0.6W*
B = from 0.4W to 0.6W of the overall length of tool
D = from 0.6W to 1.0W

Preferred sizes (mm)		
H	*W*	*L*
12	12	160
16	16	200
(20	16)	200
(25	20)	250

Preferred sizes (mm)					
H	*W*	*C*	*B*	*E*	*L*
16	16	20	25	16	140
16	16	25	25	16	140
20	20	25	25	18	140
20	20	32	32	25	200
25	25	40	36	28	200

Swan-necked finishing tool

No. 52 Cuts either right hand or left hand



NOTE. *The cutting edge is on or below the level of the base of the tool.*

Preferred sizes (mm)		
H	*W*	*L*
40	25	355
(20	16)	200
(25	20)	250

For further details, including non-preferred sizes, nomenclature and shank sections, see BS 1296: Pts 1 to 4 inclusive.

3.14 Tool bits: ground high-speed steel

Round section tool bits

(Dimensions in millimetres)

diameter (h12)*	L^{+0}_{-3} 63	80	100	160	180
4	×	×	×	–	–
5	×	×	×	–	–
6	×	×	×	×	–
8	–	×	×	×	–
10	–	×	×	×	×
12	–	–	×	×	×
16	–	–	×	×	×
18	–	–	–	–	×

*For tolerance sizes see BS 4500.
For further information see BS 1296.

Square section tool bits

(Dimensions in millimetres)

breadth (h13)*	*height* (h13)*	L^{+0}_{-3} 63	80	100	160	180
4	4	×	–	–	–	–
5	5	×	–	–	–	–
6	6	×	×	×	×	×
8	8	×	×	×	×	×
10	10	×	×	×	×	×
12	12	×	×	×	×	×
16	16	–	–	×	×	×
20	20	–	–	–	×	×
25	25	–	–	–	–	×

*For tolerance sizes see BS 4500.
For further information see BS 1296.

Rectangular section tool bits

(Dimensions in millimetres)

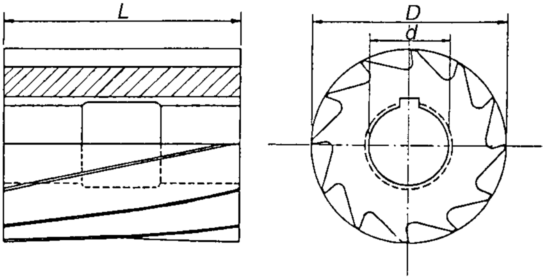
breadth (h13)*	*height* (h13)*	L^{+0}_{-3} 100	160	200
4	6	×	–	–
	8	×	–	–
5	8	×	–	–
	10	×	–	–
6	10	–	×	×
	12	–	×	×
8	12	–	×	×
	16	–	×	×
10	16	–	×	×
	20	–	×	×
12	20	–	×	×
	25	–	–	×
16	25	–	–	×
	–	–	–	–

*For tolerance sizes see BS 4500.
For further information see BS 1296.

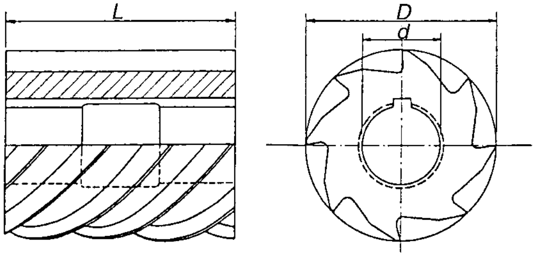
3.15 Milling cutters

3.15.1 Cylindrical cutters

Light duty cylindrical cutter



High power cylindrical cutter



The dimensions of light duty or high power cylindrical cutters are as given in the table. These cutters are normally supplied with left-hand helix as shown in the figures. The cutters have keyways in accordance with BS 122: Pt 3 Clause 3.2.

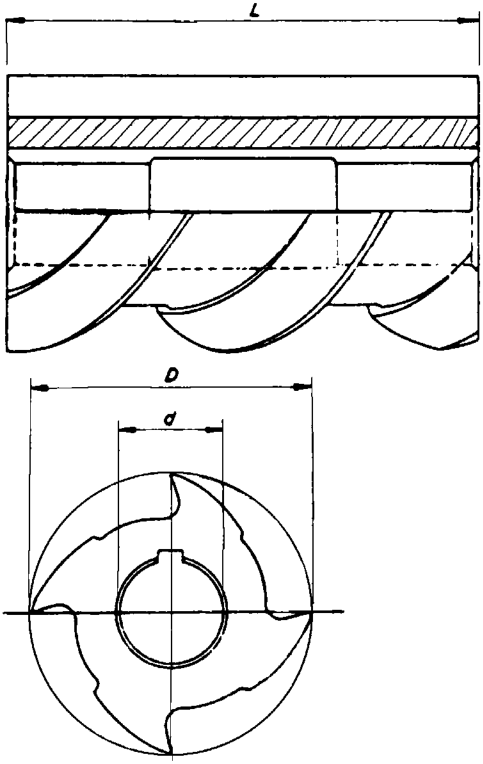
For further information, see BS 122: Pt 3: 1987.

(Dimensions in millimetres)

Diameter of cutter D (js16)*	*Diameter of bore* d (H7)*	*Lengths* L (js15)*
50	22	40, 63, 80
63	27	50, 70
80	32	63, 80, 100, 125
100	40	70, 100, 125, 160
125	50	125, 200

*For tolerances see BS 4500: Pt 1.

3.15.2 High helix cylindrical cutters



The dimensions of high helix cylindrical cutters are as given in the table. These cutters are normally supplied with left-hand helix as shown in the figure. The cutters have keyways in accordance with BS 122: Pt 3 Clause 3.2.

For further information see BS 122: Pt 3: 1987.

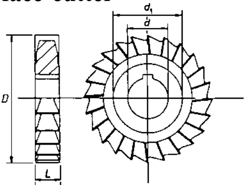
(Dimensions in millimetres)

Diameter of cutter D (js16)*	*Diameter of bore* d (H7)*	*Lengths* L (js15)*
80	32	70, 100, 160
100	40	70, 100, 160
125	50	70, 100, 160

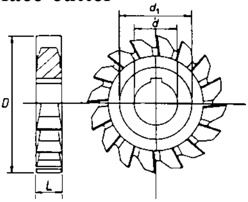
*For tolerances see BS 4500: Pt 1.

3.15.3 Side and face cutters

Light duty side and face cutter



High power side and face cutter



(Dimensions in millimetres)

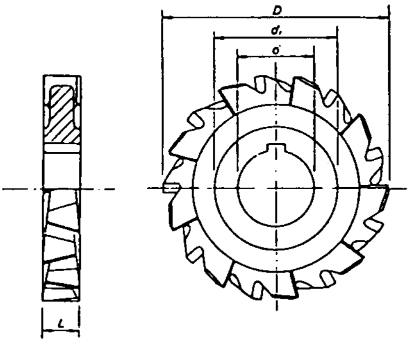
Diameter of cutter *D* (js16)*	*Diameter of boss* d_1 (min.)	*Diameter of bore* *d* (H7)*	*Width of cutting edges and boss*† *L* (k11)*
50	27	16	6, 8, 10
63	34	22	6, 8, 10, 12, (14), 16
80	41	27	6, 8, 10, 12, (14), 16, (18), 20
100	47	32	6, 8, 10, 12, (14), 16, (18), 20, (22), 25
125	47	32	8, 10, 12, (14), 16, (18), 20, (22), 25, (28)
160	55	40	10, 12, (14), 16, (18), 20, (22), 25, (28), 32
200	55	40	12, (14), 16, (18), 20, (22), 25, (28), 32, (36), 40

*For tolerances see BS 4500: Pt 1.

†Dimensions in parentheses are least preferred.

The dimensions of light duty or high power side and face cutters shall be as given in the table. The cutters shall have keyways in accordance with BS 122: Pt 3 Clause 3.2. Each side of a cutter may be ground to provide $\frac{1}{4}^\circ$ side clearance, when the clearance shall be amplified by recessing. For further information see BS 122: Pt 3: 1987.

3.15.4 Staggered tooth side and face cutters



The dimensions of staggered tooth side and face cutters shall be as given in the table. The cutters shall have keyways in accordance with BS 122: Pt 3: Clause 3.2. Each side of a cutter may be ground to provide $\frac{1}{4}^{\circ}$ side clearance, when the clearance shall be amplified by recessing.

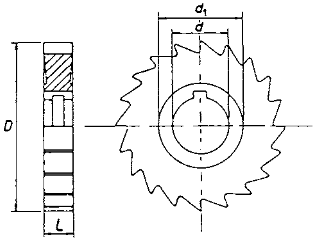
For further information see BS 122: Pt 3: 1987.

(Dimensions in millimetres)

Diameter of cutter D (js16)*	*Diameter of boss* d_1 (min.)	*Diameter of bore* d (H7)*	*Width*† L (k11)*
63	34	22	6, 8, 10, 12, (14), 16
80	41	27	6, 8, 10, 12, (14), 16, (18), 20
100	47	32	6, 8, 10, 12, (14), 16, (18), 20, (22), 25
125	47	32	8, 10, 12, (14), 16, (18), 20, (22), 25, (28)
160	55	40	10, 12, (14), 16, (18), 20, (22), 25, (28), 32
200	55	40	12, (14), 16, (18), 20, (22), 25, (28), 32, (36), 40

*For tolerances see BS 4500: Pt 1.
†Dimensions in parentheses are least preferred.

3.15.5 Slotting cutters



The dimensions of slotting cutters are as given in the table. The cutters have each side ground to provide side clearance and the clearance shall, where the width and diameter of the cutter permit, be amplified by recessing. The cutters have keyways in accordance with BS 122: Pt 3 Clause 3.2. The use of these cutters for cutting keyways is not recommended as the width of the slot produced cannot be guaranteed. If, however, the cutters are required for cutting keyways to BS 46: Pt 1, the special tolerances should be agreed between the purchaser and the manufacturer.

For further information see BS 122: Pt 3: 1987.

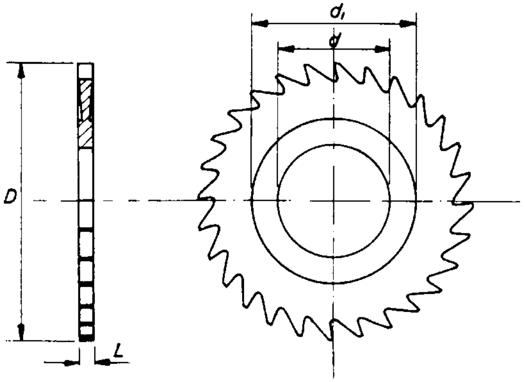
(Dimensions in millimetres)

Diameter of cutter *D* (js16)*	*Diameter of boss* d_1 (min.)	*Diameter of bore* *d* (H7)*	*Width*† *L* (js4)*
50	27	16	6, 7, 8, 10
63	34	22	6, 7, 8, 10, 12, 14
80	41	27	6, 7, 8, 10, 12, 14, 16, 18
100	47	32	6, 7, 8, 10, 12, 14, 16, 18, 20, (22), 25
125	47	32	8, 10, 12, 14, 16, 18, 20, (22), 25
160	55	40	10, 12, 14, 16, 18, 20, (22), 25, (28), 32
200	55	40	12, 14, 16, 18, 20, (22), 25, (28), 32, (36), 40

*For tolerances see BS 4500: Pt 1.

†Dimensions in parentheses are least preferred.

3.15.6 Metal slitting saws without side chip clearance: fine teeth



The dimensions of metal slitting saws without side chip clearance are as given in the tables in this section for fine teeth and in Section 3.15.7 for coarse teeth. The value for the tooth pitch in relation to the number of teeth of a saw of a given diameter is expressed as an approximate rounded figure. The saws have side clearance either up to the bore or up to the boss.

For further information see BS 122: Pt 3: 1987.

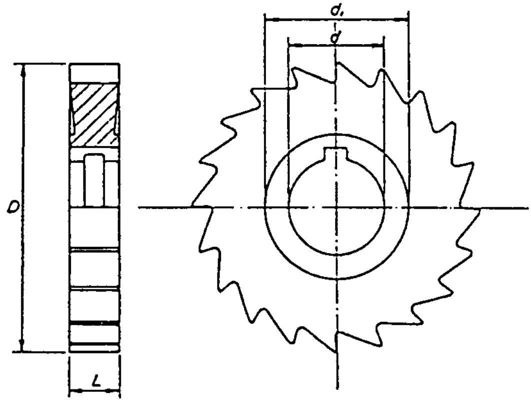
(Dimensions in millimetres)

<table>
<tr><td colspan="2">Diameter of saw
D (js16)*</td><td>20</td><td>25</td><td>32</td><td>40</td><td>50</td><td>63</td><td>80</td><td>100</td><td>125</td><td>160</td><td>200</td><td>250</td><td>315</td></tr>
<tr><td colspan="2">Diameter of boss
d_1 (min.)</td><td>–</td><td>–</td><td>–</td><td>–</td><td>–</td><td>–</td><td>34</td><td>34</td><td>34</td><td>47</td><td>63</td><td>63</td><td>80</td></tr>
<tr><td colspan="2">Diameter of bore
d (H7)*</td><td>5</td><td>8</td><td>8</td><td>10</td><td>13</td><td>16</td><td>22</td><td>22</td><td>22</td><td>32</td><td>32</td><td>32</td><td>40</td></tr>
<tr><td>Width
L (js11)*</td><td>Tooth pitch</td><td colspan="3">Number of teeth</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>0.2</td><td>0.8</td><td>80</td><td rowspan="3">80</td><td rowspan="2">100</td><td>128</td><td></td><td rowspan="2"></td><td rowspan="3"></td><td rowspan="4"></td><td rowspan="5"></td><td rowspan="8"></td><td rowspan="8"></td><td rowspan="8"></td><td rowspan="8"></td></tr>
<tr><td>0.25</td><td rowspan="3">1.0</td><td rowspan="3">64</td><td rowspan="3">100</td><td rowspan="2">128</td></tr>
<tr><td>0.3</td><td rowspan="3">80</td><td rowspan="3">128</td></tr>
<tr><td>0.4</td><td rowspan="3">64</td><td rowspan="3">100</td></tr>
<tr><td>0.5</td><td rowspan="3">1.25</td><td rowspan="3">48</td><td rowspan="3">80</td><td rowspan="3">128</td></tr>
<tr><td>0.6</td><td rowspan="3">64</td><td rowspan="3">100</td><td>160</td></tr>
<tr><td>0.8</td><td rowspan="2">48</td><td rowspan="2">80</td><td rowspan="2">128</td><td rowspan="2">160</td></tr>
<tr><td>1.0</td><td></td><td></td><td></td><td></td></tr>
</table>

1.2	1.6	40			64			100			160			
1.6				48			80			128				
2.0		32		40			64			100			160	200
2.5	2.0				48			80			128			200
3.0				40			64			100			160	
4.0					40	48			80			128		
5.0	2.5							64			100		128	160
6.0							48		64	80		100		
				3.15			4.0		5.0			6.3		

*For tolerances see BS 4500: Pt 1.

3.15.7 Metal slitting saws without side chip clearance: coarse teeth



The value of the tooth pitch in relation to the number of teeth of a saw of a given diameter is expressed as an approximate rounded figure. The saws have side clearance either up to the bore or up to the boss.

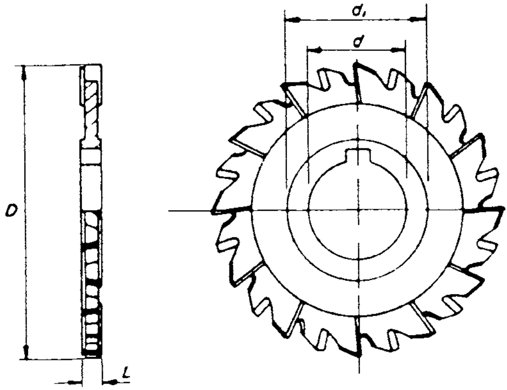
(Dimensions in millimetres)

Diameter of saw D (js16)*		32	40	50	63	80	100	125	160	200	250	315
Diameter of boss d_1 (min.)		—	—	—	—	34	34	34	47	63	63	80
Diameter of bore d (H7)		8	10	13	16	22	22	22	32	32	32	40
Width L (js 11)*	*Tooth pitch*	*Number of teeth*										
0.3			48	64								
0.4	2.5	40			64							
0.5				48								
0.6			40			64						
0.8	3.15	32			48							
1.0				40			64	80				
1.2			32			48			80			
1.6	4.0	24			40			64				
2.0				32			48			80	100	
2.5			24			40			64			100
3.0	5.0	20			32			48			80	
4.0			20	24			40			64		
5.0					24	32			48			80
								40				
6.0							32			48	64	
	6.3			8.0			10.0			12.5		

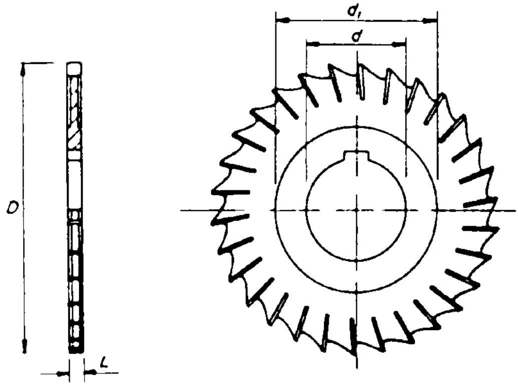
*For tolerances see BS 4500: Pt 1.

3.15.8 Metal slitting saws with side chip clearance

Type A: staggered teeth



Type B: straight teeth



(Dimensions in millimetres)

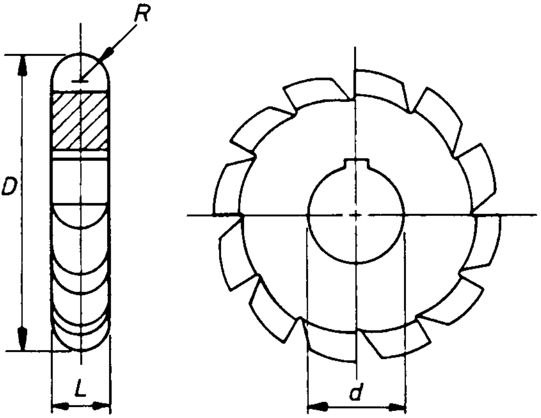
Diameter of saw D (js16)*	63	80	100	125	160	200	250
Diameter of boss d_1 (min.)	—	34	34	34	47	63	63
Diameter of bore d (H7)*	16	22	22	22	32	32	32

Type A: staggered teeth							
Width L (js10)*	*Number of teeth (and pitch)*						
4.0 5.0 6.0	28 (7.1)	32 (7.8)	36 (8.7)	40 (9.8)	44 (11.4)	52 (12.0)	64 (12.3)

Type B: straight teeth							
Width L (js10)*	*Number of teeth (and pitch)*						
1.6 2.0 2.5 3.0	32 (6.2)	36 (7.0)	40 (7.8)	44 (8.9)	48 (10.5)	56 (11.2)	68 (11.5)

*For tolerances see BS 4500: Pt 1.
For further information see BS 122: Pt 3: 1987.

3.15.9 Convex milling cutters



Convex milling cutters
The dimensions of convex milling cutters are as given in the table. The cutters have keyways in accordance with BS 122: Pt 3 Clause 3.2.

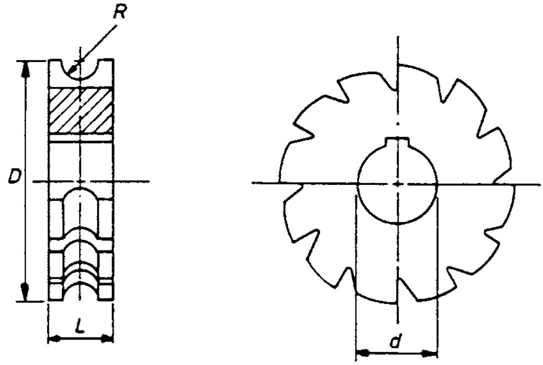
For further information see BS 122: Pt 3: 1987.

(Dimensions in millimetres)

R (k11)*	*D* (js16)*	*d* (H7)*	*L*
1	50	16	2
1.25			2.5
1.6			3.2
2			4
2.5	63	22	5
3.15 or 3			6.3 or 6
4			8
5			10
6.3 or 6	80	27*	12.6 or 12
8			16
10	100	32	20
12.5 or 12			25 or 24
16	125		32
20			40

*For tolerances see BS 4500: Pt 1.

3.15.10 Concave milling cutters



Concave milling cutters

The dimensions of concave milling cutters are as given in the table. For these cutters, radius *R* is struck from the outside diameter of the cutter and chamfers have been eliminated from the intersection of the profile and the outside diameter. The cutters have keyways in accordance with BS 122: Pt 3 Clause 3.2.

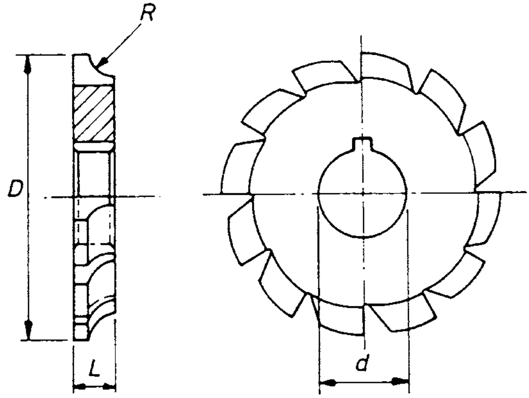
For further information see BS 122: Pt 3: 1987.

(Dimensions in millimetres)

R (N11)*	*D* (js16)*	*d* (h7)*	*L*
1	50	16	6
1.25			
1.6			8
2			9
2.5	63	22	10
3.15 or 3			12
4			16
5			20
6.3 or 6	80	27	24
8			32
10	100	32	36
12.6 or 12			40
16	125		50
20			60

*For tolerances see BS 4500: Pt 1.

3.15.11 Corner rounding concave milling cutters



The dimensions of corner rounding concave milling cutters are as given in the table. For these cutters, radius *R* is struck from the outside diameter of the cutter and chamfers have been eliminated from the intersection of the profile and the outside diameter. The cutters have keyways in accordance with BS 122: Pt 3 Clause 3.2.

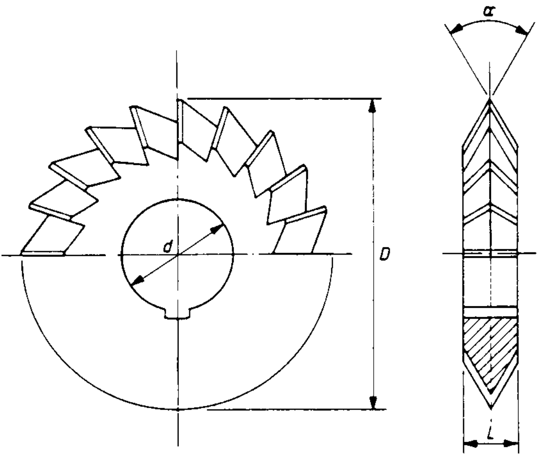
For further information see BS 122: Pt 3: 1987.

(Dimensions in millimetres)

R (N11)*	D (js16)*	d (H7)*	L
1	50	16	4
1.25			
1.6			5
2			
2.5	63	22	
3.15 or 3			6
4			8
5			10
6.3 or 6	80	27	12
8			16
10	100	32	18
12.5 or 12			20
16	125		24
20			28

*For tolerances see BS 4500: Pt 1.

3.15.12 Double equal angle milling cutters



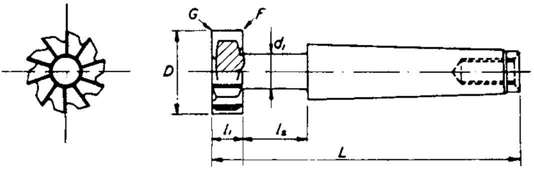
The dimensions of double equal angle milling cutters are as given in the table. The cutters have keyways in accordance with BS 122: Pt 3 Clause 3.2.

For further information see BS 122: Pt 3: 1987.

D (js16)* mm	d (H7)* mm	$\alpha(\pm 15')$* degrees	L (js16)* mm
		45	8
50	16	60	10
		90	14
		45	10
63	22	60	14
		90	20
		45	12
80	27	60	18
		90	22
		45	18
100	32	60	25
		90	32

*For tolerances see BS 4500: Pt 1.

3.15.13 T-slot cutters with Morse taper shanks



The dimensions of T-slot cutters with Morse taper shanks are as given in the table. However, the cutters may be made with square corners throughout, as an alternative to the radiused corners *G* and *F* shown. It is recommended that the corners be radiused when considerations of strength preclude the use of slots with square corners. The cutter teeth shall be either straight (as shown) or staggered. The cutters shall be designated by the nominal size of the slot.

For further information see BS 122: Pt 3: 1987.

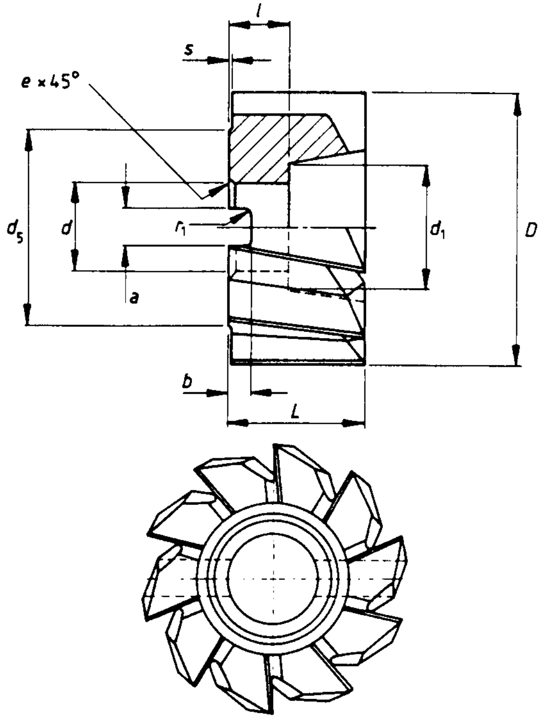
(Dimensions in millimetres)

T-slot					*T-slot cutter*			
*Nominal size of slot**	*Diameter of cutter* D (h12)†	*Width of cutter* l_1 (h12)†	*Diameter of neck* d_1 (max.)	*Length of neck* l_2	*No. of Morse taper shank, tapped*	*Overall length* L	*Radius* G (max.)	*Radius* F (max.)
10	18	8	8	17^{+1}_{-0}	1	82	1.0	0.6
12	21	9	10	20^{+1}_{-0}	2	98	1.0	0.6
14	25	11	12	23^{+1}_{-0}	2	103	1.6	0.6
18	32	14	15	28^{+1}_{-0}	2	111	1.6	1.0
22	40	18	19	34^{+1}_{-0}	3	138	2.5	1.0
28	50	22	25	42^{+1}_{-0}	4	173	2.5	1.0
36	60	28	30	51^{+1}_{-0}	4	188	2.5	1.0
42	72	35	36	58^{+1}_{-0}	5	229	4.0	1.6
48	85	40	42	64^{+1}_{-0}	5	240	6.0	2.0
54	95	44	44	71^{+1}_{-0}	5	251	6.0	2.0

*See BS 2485.

†For tolerances see BS 4500: Pt 1.

3.15.14 Shell end mills



The dimensions of shell end milling cutters are as given in the table. However, the boss d_5 and the side clearance *S* are optional. The milling cutters shall not be reversible on their arbors and the direction of rotation shall be specified by describing them as either right-hand or left-hand cutters. Milling cutters for right-hand rotation with right-hand helical cutting edges are normally supplied.

For further information see BS 122: Pt 3: 1987.

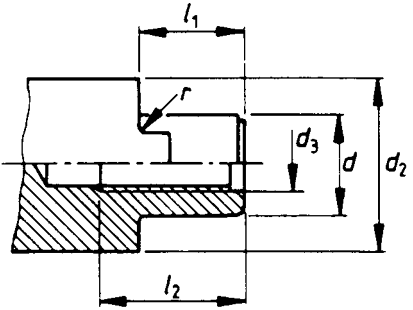
(Dimensions in millimetres)

Diameter of cutter D (js16)*	*Length of cutter* L (H15)*	*Diameter of bore* d (H7)*	*Length of bore* l (H14)*	*Diameter of boss* d_1	*Width of driving slot* a_1 (min.)	*Depth of driving slot* b_1 (min.)	*Maximum radius of driving slot* r_1	*Diameter of boss* d_5	*Chamfer on bore* e	*Shoulder* S
40	32	16	18	22	8.4	5.6	1.0	33	$0.6^{+0.2}_{-0}$	0.5
50	36	22	20	30	10.4	6.3	1.2	41	$0.6^{+0.2}_{-0}$	0.5
63	40	27	22	38	12.4	7.0	1.2	49	$0.8^{+0.2}_{-0}$	0.5
80	45	27	22	38	12.4	7.0	1.2	49	$0.8^{+0.2}_{-0}$	0.5
100	50	32	25	45	14.4	8.0	1.6	59	$0.8^{+0.2}_{-0}$	0.5
125	56	40	28	56	16.4	9.0	2.0	71	$1.0^{+0.3}_{-0}$	0.5
160	63	50	31	67	18.4	10.0	2.0	91	$1.0^{+0.3}_{-0}$	0.5

*For tolerances see BS 4500: Pt 1.

3.15.15 Arbors for shell end mills

Spigot



The dimensions of spigots, tenons and retaining bolts for shell end mills are as given in the tables.

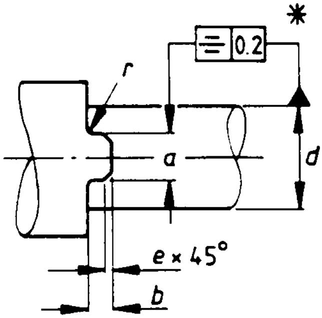
For further information see BS 122: Pt 3: 1987.

(Dimensions in millimetres)

d (h6)*	l_1 (max.)	d_2	d_3	l_2 (min.)	*r* (max.)
16	17^{+0}_{-1}	32	M8	22	0.6
22	19^{+2}_{-1}	40	M10	28	0.6
27	21^{+0}_{-1}	48	M12	32	0.8
32	24^{+0}_{-1}	58	M16	36	0.8
40	27^{+0}_{-1}	70	M20	45	1.0
50	30^{+0}_{-1}	90	M24	50	1.0

*For tolerances see BS 4500: Pt 1.

Tenon

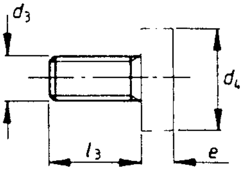


(Dimensions in millimetres)

	Arbor			*Chamfer*
d	*a*	*b*	*r* (max.)	*e*
16	8	5.0	0.6	$0.6^{+0.2}_{-0}$
22	10	5.6		
27	12	6.3	0.8	$0.8^{+0.2}_{-0}$
32	14	7.0		
40	16	8.0	1.0	$1.0^{+0.3}_{-0}$
50	18	9.0		

*See BS 308: Pt 3.

Retaining bolt

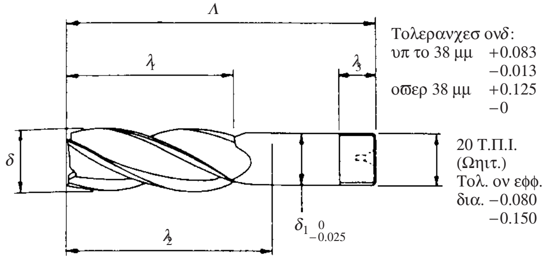


(Dimensions in millimetres)

Spigot diameter (nominal)	d_3	l_3	d_4 (max.)*	*e*
16	M8	16^{+3}_{-0}	20	6
22	M10	18^{+3}_{-0}	28	7
27	M12	22^{+3}_{-0}	35	8
32	M16	26^{+3}_{-0}	42	9
40	M20	30^{+3}_{-0}	52	10
50	M24	36^{+3}_{-0}	63	10

*The shape of the head of the bolt is not specified.

3.15.16 Screwed shank end mills: normal series



(Dimensions in millimetres)

Cutter diameter d	*Cut length* l_1	*Shank diameter* d_1	*Nominal length below chuck* l_2	*Overall length* L	*Thread length* l_3
2.5	6.5	6	13.5	51	
3	9.5	6	16.5	54	
3.5 4 4.5	12.5	6	19.5	57	
5 5.5 6	16	6	23	60.5	
6.5 7	16 15	10	22.5	60.5	9.5
7.5 8	18	10	25.5	63.5	
8.5 9 9.5 10	21	10	28.5	66.5	
10.5 11	19	12	28.5	66.5	
11.5 12 13	22.5 24 24.5	12	32	70	

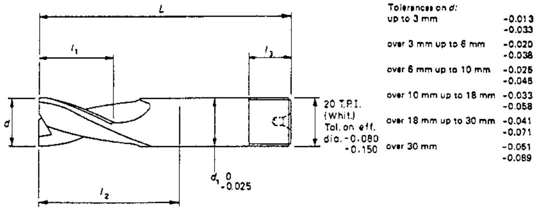
(*continued*)

3.15.16 (*continued*) (Dimensions in millimetres)

Cutter diameter d	*Cut length* l_1	*Shank diameter* d_1	*Nominal length below chuck* l_2	*Overall length* L	*Thread length* l_3
14	28.5	12	35	73	
15 16	26.5	16	38	77	
					9.5
17 18	32 35	16	41	80	
19 20	38	16	44.5	83.5	
21	38	25	42.5	95	
22 23 24	41.5	25	46	98.5	
25 26	44.5 43	25	49	101.5	
28 30	46	25	52	104.5	
32 34	49	25	55.5	108	
					15
35 36	52.5	25	58.5	111	
38	55.5	25	62	114.5	
40 42	58.5 60.5	25	65	117.5	
44 45	63.5	25	68	120.5	
32 33 34	51	32	58.5	112.5	
35 36 38	54	32	62	116	
40	55.5	32	63.5	117.5	
42	54	32	62	116	15
44 45	57	32	65	119	
50	65	32	73	127	

For further information see BS 122: Pt 4: 1980.

3.15.17 Screwed shank slot drills: normal series



(Dimensions in millimetres)

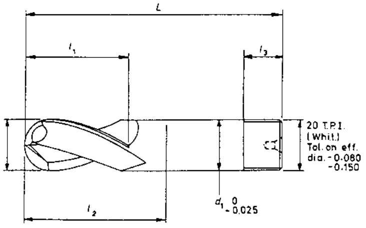
Cutter diameter d	*Cut length* l_1	*Shank diameter* d_1	*Nominal length below chuck* l_2	*Overall length* L	*Thread length* l_3
1.5	2.5	6	11	48.5	
2	3	6	11.5	49	
2.5	4.5	6	13.5	51	
3	7				
3.5	7.5	6	15	52.5	
4	9.5				
4.5					
5					
5.5	11	6	18	55.5	9.5
6			19	56.5	
6.5	11	10	20.5	58.5	
7					
7.5					
8	12.5	10	21.5	59.5	
8.5	14.5	10	22.5	60.5	
9					
9.5					
10					

(*continued*)

Cutter diameter d	*Cut length* l_1	*Shank diameter* d_1	*Nominal length below chuck* l_2	*Overall length* L	*Thread length* l_3
10.5					
11	17.5	12	27	65	
11.5					
12	19	12	28.5	66.5	
13					
14	22	12	30.5	68.5	9.5
15	22	16	33	72	
16					
17	24	16	35	74	
18					
19	25.5	16	38	77	
20					
21	25.5	25	46.0	98.5	
22	25.5	25	47.5	100	
23	25.5	25	49	101.5	
24	25.5	25	50.5	103	
25	27	25	42.5	95	
26					
27	28.5	25	41	93.5	
28	30	25	42.5	95	
29	30	25	41	93.5	
30					
32	38	25	49	101.5	
34					
35	39.5	25	50.5	103	
36					
38	43	25	54	106.5	15
40	46	25	58.5	111	
42	47.5	25	60	112.5	
44	51	25	63.5	116	
45					
32	35	32	63.5	117.5	
34	35	32	65	119	
35	39.5	32	57	111	
36					
38	43	32	60.5	114.5	
40	46	32	63.5	117.5	
42	47.5				
44	47.5	32	65	119	
45					
50	51	32	63.5	117.5	

For further information see BS 122: Pt 4: 1980.

3.15.18 Screwed shank slot drills, ball nosed: normal series



Tolerances on *d*:

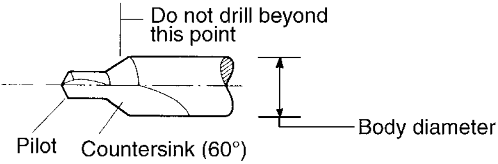
up to 3 mm	-0.013 -0.033
over 3 mm up to 6 mm	-0.020 -0.038
over 6 mm up to 10 mm	-0.025 -0.046
over 10 mm up to 18 mm	-0.033 -0.058
over 18 mm up to 30 mm	-0.041 -0.071
over 30 mm	-0.051 -0.089

(Dimensions in millimetres)

Cutter diameter d	*Cut length* l_1	*Shank diameter* d_1	*Nominal length below chuck* l_2	*Overall length* L	*Thread length* l_3
2	3	6	11.5	49	
2.5 3	4.5 7	6	13.5	51	
4 5	9.5	6	15	52.5	
6	11	6	19	56.5	
7	11	10	20.5	58.5	
8	12.5	10	21.5	59.5	
9	14.5	10	20.5	58.5	
10	14.5	10	22.5	60.5	9.5
11	17.5	12	27	65	
12 13	19	12	28.5	66.5	
14	22	12	30.5	68.5	
15 16	22	16	33	72	
17	24	16	34	73	
18	24	16	35	74	
19 20	25.5	16	38	77	
22	25.5	25	47.5	100	
24	25.5	25	50.5	103	
25 26	28.5	25	44.5	97	15
28	30	25	42.5	95	
30	30	25	41	93.5	
32	36.5	25	47.5	100	

For further information see BS 122: Pt 4: 1980.

3.16 British Standard centre drill (60°)



Centre drill

(Dimensions in inches)

Size	*Body diameter*	*Pilot diameter*	*Length overall*
BS1	1/8	3/64	1 1/2
BS2	3/16	1/16	1 3/4
BS3	1/4	3/32	2
BS4	5/16	1/8	2 1/4
BS5	7/16	3/16	2 1/2
BS6	5/8	1/4	3
BS7	3/4	5/16	3 1/2

For further information see BS 328.

Metric (Dimensions in mm)

Body diameter	*Pilot diameter*	*Length overall*
3.15	1.00	31.50
4.00	1.60	35.50
5.00	2.00	40.00
6.30	2.50	45.00
8.00	3.15	50.00
10.00	4.00	56.00

For further information see BS 328: Part 2: DIN333.

3.17 Engineers' files – popular stock sizes

Available grades of cut: rough*, bastard, second cut, smooth, deadsmooth*.

Hand

Parallel in width, cut on both sides and one edge.

Sizes	Millimetres	100	150	200	250	300	350
	Inch	4	6	8	10	12	14

Flat

Tapered in width, cut on both sides and edges.

Sizes	Millimetres	100	150	200	250	300	350
	Inch	4	6	8	10	12	14

Round

For circular openings and concave surfaces, tapers slightly towards the point.

Sizes	Millimetres	100	150	200	250	300	350
	Inch	4	6	8	10	12	14

Half round

For filing both flat and concave surfaces, parallel in width and thickness, but tapers slightly towards the point.

Sizes	Millimetres	100	150	200	250	300	350
	Inch	4	6	8	10	12	14

* These cuts are to special order only.
For further information see: BS 498.

Square

For slots and keyways, tapers slightly to a point. Double cut on all four sides.

Sizes	Millimetres	100	150	200	250	300
	Inch	4	6	8	10	12

Threesquare

For filing out sharp corners and internal angles. Double cut on all three sides. Tapers slightly towards point.

Sizes	Millimetres	100	150	200	250	300
	Inch	4	6	8	10	12

Warding

Uniform in thickness and tapered in width to a narrow point. Double cut on sides and single cut on edges. Made of a special flexible steel which will not snap under normal use.

Sizes	Millimetres	100	150	200
	Inch	4	6	8

Knife

Shaped like a wedge or knife with one thick edge tapering to a thin edge. For filing all work having acute angles. Double cut sides and single cut on thin edge.

Sizes	Millimetres	150	200
	Inch	6	8

Pillar

Parallel in width and thickness, cut on both sides.

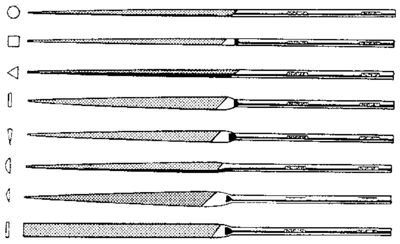
Sizes	Millimetres	150	200
	Inch	6	8

Safety

The tang of a file must always be protected with a properly fitted handle.

3.18 Miscellaneous files

3.18.1 Needle (Swiss) files



Cut 0	Lengths	14 cm 5 1/2 in	16 cm 6 1/4 in
Cut 2	Lengths	14 cm 5 1/2 in	16 cm 6 1/4 in

3.18.2 Milled tooth files

Due to the undercut and generous radius at the root of each tooth, milled tooth files clear themselves whilst in use. So instead of a build-up of irregular swarf that will eventually clog the file, the metal is simply removed quickly and efficiently in the form of spirals. This is both faster and safer. Milled tooth files are particularly efficient when used to cut soft materials such as aluminium and thermoplastics. They can also be used on harder materials such as cast irons and steels.

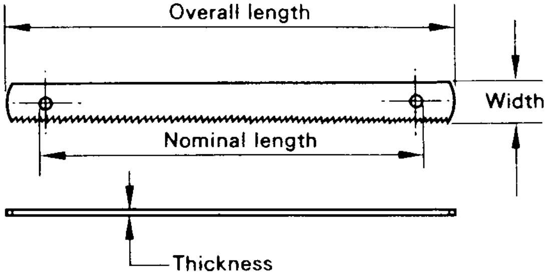
Dreadnought files (curved tooth, tanged)

Hand	millimetre inch	200 8	250 10	300 12	350 14	standard cut
Half round	millimetre inch	250 10	300 12			standard cut
Flat	millimetre inch	250 10	300 12	350 14		standard cut

Millenicut files (straight tooth, tanged)

Hand	millimetre	200	250	300	350	standard cut
	inch	8	10	12	14	
Half round	millimetre	200	250	300		standard cut
	inch	8	10	12		

3.19 Hacksaw blades (high-speed steel – all hard)



Sizes (Inch)

Length (nominal)	*Width*	*Thickness*	*Cut TPI**
10	1/2	0.025	18
10	1/2	0.025	24
12	1/2	0.025	14
12	1/2	0.025	18
12	1/2	0.025	24
12	1/2	0.025	32
12	5/8	0.032	14
12	5/8	0.032	18
12	5/8	0.032	24
12	1	0.050	10
12	1	0.050	14
14	1	0.050	10
14	1	0.050	14
14	1 1/4	0.062	6
14	1 1/4	0.062	10
14	1 1/2	0.075	6
16	1 1/4	0.062	6
16	1 1/4	0.062	10
16	1 1/2	0.075	4
16	1 1/2	0.075	6

17	1	0.050	10
17	1	0.050	14
17	1 1/4	0.062	6
17	1 1/4	0.062	10
18	1 1/4	0.062	6
21	1 1/2	0.075	6
21	1 3/4	0.088	6
24	1 3/4	0.088	6
24	2	0.100	4
24	2	0.100	6

Sizes (millimetres)

Length (nominal)	*Width*	*Thickness*	*Cut TPI**
250	13	0.65	18
250	13	0.65	24
300	13	0.65	14
300	13	0.65	18
300	13	0.65	24
300	13	0.65	32
300	16	0.80	14
300	16	0.80	18
300	16	0.80	24
300	25	1.25	10
300	25	1.25	14
350	25	1.25	10
350	25	1.25	14
350	32	1.6	6
350	32	1.6	10
350	40	2.0	6
400	32	1.6	6
400	32	1.6	10
400	40	2.0	4
400	40	2.0	6
425	25	1.25	10
425	25	1.25	4
425	32	1.6	6
425	32	1.6	10
450	32	1.6	6
450	32	1.6	10
450	40	2.0	6
525	40	2.0	6
525	45	2.25	6
600	45	2.25	6
600	50	2.5	4
600	50	2.5	6

*TPI = Teeth per inch despite other dimensions being metric.

3.20 Bonded abrasives

3.20.1 Example of the complete marking of an abrasive wheel

Order of marking	0	1	2	3	4	5	6
	Type of abrasive*	Nature of abrasive	Grain size	Grade	Structure*	Nature of bond	Type of bond etc.*
Example	51	A	36 3	L	5	V	23

Aluminium abrasives	A
Silicon carbides	C

Coarse	*Medium*	*Fine*	*Very fine*
8	30	70	220
10	36	80	240
12	46	90	280
14	54	100	320
16	60	120	400
20		150	500
24		180	600

Additional number for grain size mixtures (optional)	1
	2
	3
	etc.

Spacing from the closest to the most open	
0	8
1	9
2	10
3	11
4	12
5	13
6	14
7	etc.

V	Vitrified
B	Resinoid (synthetic resins)
BF	Resinoid (synthetic resins) reinforced
R	Rubber
RF	Rubber reinforced
E	Shellac
S	Silicate
Mg	Magnesia

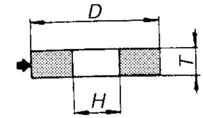
Soft	*Medium*	*Hard*
A B C D E F G H I J K	L M N O P Q R S T U V	W X Y Z

*Symbols at positions 0 and 6 are the manufacturer's own choice.

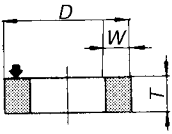
3.20.2 Classification of wheel and product shapes by type numbers

For further information see BS 4481: Pt 1: 1981.

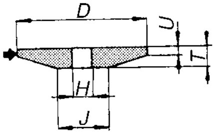
Type 1 Straight wheels



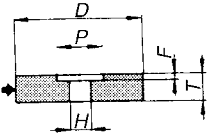
Type 2 Cylinder wheels



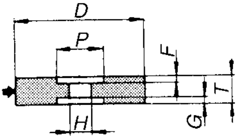
Type 3 Taper one side (for use only with straight flanges)



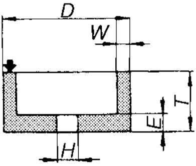
Type 4 Taper sided portable (for use with tapered flanges)



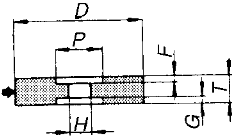
Type 5 Recessed one side



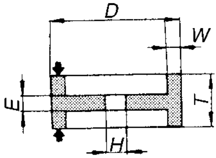
Type 6 Straight cup wheel



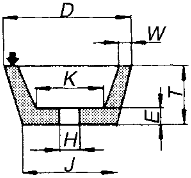
Type 7 Double recessed wheel



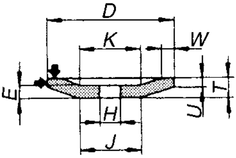
Type 9 Double cup wheels



Type 11 Taper cup wheels

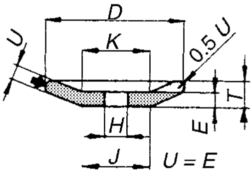


Type 12 Dish wheels

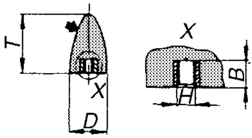


(continued)

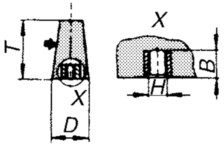
Type 13 Saucer wheels



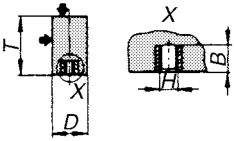
Type 16 Cone



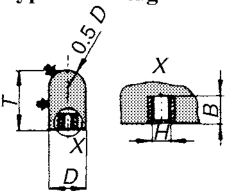
Type 17 Cone



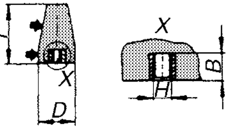
Type 18 Plug



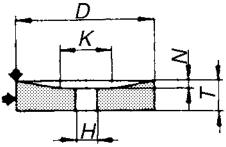
Type 18R Plug



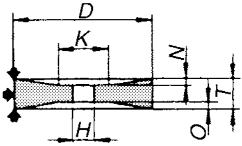
Type 19 Cone



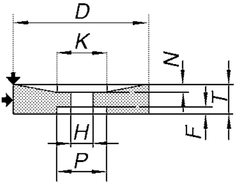
Type 20 Relieved one side



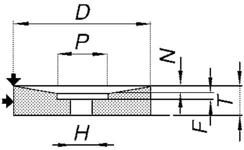
Type 21 Relieved two sides



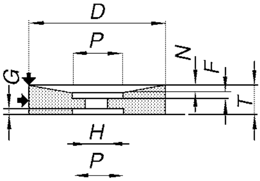
Type 22 Relieved o/s recess o/s



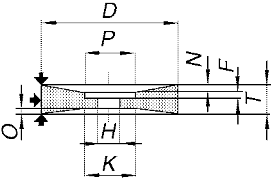
Type 23 Relieved o/s recess same side



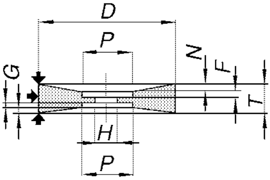
Type 24 Relieved o/s recessed b/s



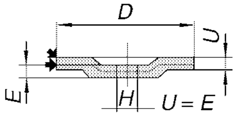
Type 25 Relieved b/s recessed o/s



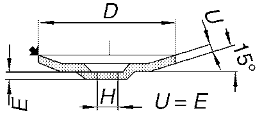
Type 26 Relieved and recessed b/s



Type 27 Depressed centre



Type 28 Coolie hat



Symbolisation of dimension

Symbols	*Designation*	*Typed of wheels concerned*
A	Small base of trapezoidal segment	31
B	Width of segment, stick or brick	31-54-90
	Length of threaded insert	16 to 19
C	Thickness of segment, stick or brick	31-54-90
D	Outside diameter	All types of wheels
E	Back thickness of cup or dish wheels	6-9-11-12-13
	Thickness at hole of relieved wheels with recess	20 to 28
F	Depth of first recess	5-7-22 to 26
G	Depth of second recess	7-24-26
H	Diameter of insert thread	All types of wheels with cut 2-37-51
J	Small outside diameter of tapered wheel, of taper cup, of dish or saucer wheels, outside diameter of hub	3-11-12-13-39-39
K	Back diameter of taper cup, of dish and saucer wheels, inner diameter relief	11-12-13-20-21-22-25
L	Spindle length of mounted wheels	31-52-54-90
	Length of segments, sticks or bricks	
N	Depth of first relief	20 to 26
O	Depth of second relief	21-25-26
P	Recess diameter	5-7-22 to 26
T	Overall thickness	All types of wheels
U	Thickness of grinding face when smaller than T for wheels used on their periphery	3-12-13-27-28-38-39
W	Width of grinding face for wheels used laterally	2-6-9-11-12-37

Profile elements: U no grinding face
V profile angle
X other profile element

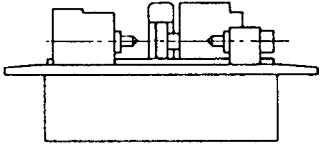
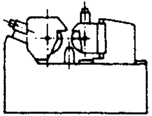
↓ Symbolises the grinding face of bonded abrasive products.

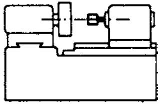
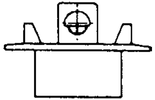
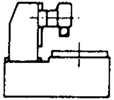
See also: BS 4481: Pt 2: for abrasive wheel sizes.
BS 4481: Pt 3: for abrasive wheel balancing.

3.20.3 Maximum permissible peripheral speeds of abrasive wheels

The maximum speeds listed in this table are not necessarily the recommended speeds of operation for optimum grinding efficiency. For higher speeds and further information see BS 4481: Pt 1: 1981.

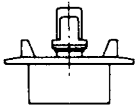
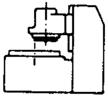
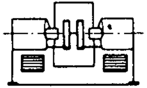
3.20.3 (*continued*)

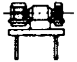
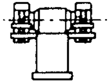
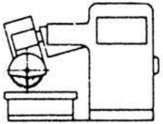
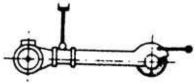
Machine classification and grinding operation		*Type of wheel* (Section 3.20.2)	*Max speed* m/s	*Special conditions*
	External cylindrical	1, 5, 7		
		20–26	35	
	Tool room (universal)	1, 5, 7	35	
	(Crankshaft)	1, 5, 7	43	
	Camshaft	1, 5, 7	43	
	Thread	1	60	
	Thread	5, 7	45	
	Thread	1	45	Thicker than 35 mm
	Centreless	1, 5, 7	35	
		1, 5, 7	12	
	Control wheels			

	Internal	1, 5 52	35 50	 Without overhang
	Surface Horizontal spindle, reciprocating table	 1, 5, 7	 35	
	Horizontal spindle, rotary table	1, 5, 7	35	

(*continued*)

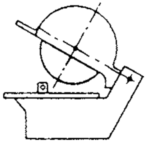
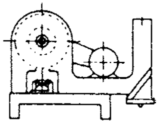
3.20.3 (*continued*)

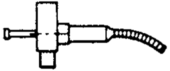
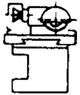
Machine classification and grinding operation		*Type of wheel* (Section 3.20.2)	*Max speed* m/s	*Special conditions*
	Surface Vertical spindle, reciprocating table	2, 37 6 35, 36	25 30 30 32	Inorganic bonds Organic bonds
	Vertical spindle, rotary table	2, 37 6 35, 36	25 30 30 32	Inorganic bonds Organic bonds
	Duplex	2, 37 6 35, 36	25 30 30 32	Inorganic bonds Organic bonds

	Off-hand grinding and fettling			
	Bench	1, 5, 7	35	
	Floor stand	1	50	Organic bond only
	Side grinding	6, 35, 36	32	
	Billet and slab			
	Mechanical control	1	63	Special high density organic bond
	Swing frame, manual control	1	50	Organic bond only

(*continued*)

3.20.3 (*continued*)

Machine classification and grinding operation		*Type of wheel* (Section 3.20.2)	*Max speed* m/s	*Special conditions*
	Cutting off	1	80	Reinforced organic bond only
	Cutting off (fully guarded)	1	80	Organic bonds only

	Portable, right angle Grinding	 6, 11 27	 50 80	 Organic bonds only Reinforced organic bonds only
	Cutting off	1, 27	80	Reinforced Organic bonds only
	Portable, vertical spindle grinder	6, 11	50	Organic bonds only
	Portable, straight grinder	1, 4 16, 17, 18, 18R, 19 52	50 50 50	Organic bonds only Without overhang
	Tool and cutter Grinding and sharpening	1, 5, 7 6, 11, 12, 13	35 32	

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Part 4

Miscellaneous

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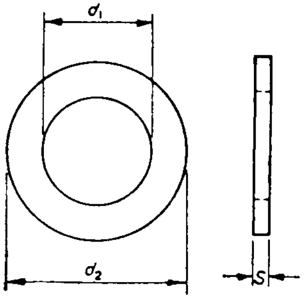
4.1 Washers

4.1.1 Plain washers, bright: metric series

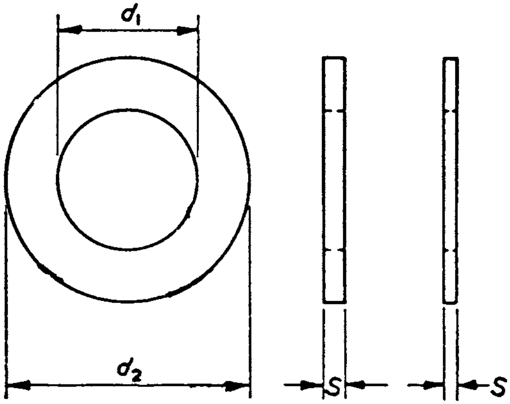


(Dimensions in millimetres)

*Designation (thread diameter)**	*Internal diameter* d_1		*External diameter* d_2		*Thickness S*			
					Thick (normal)		*Thin*	
	max.	*min.*	*max.*	*min.*	*max.*	*min.*	*max.*	*min.*
M1.0	1.25	1.1	2.5	2.3	0.4	0.2	—	—
M1.2	1.45	1.3	3.0	2.8	0.4	0.2	—	—
(M1.4)	1.65	1.5	3.0	2.8	0.4	0.2	—	—
M1.6	1.85	1.7	4.0	3.7	0.4	0.2	—	—
M2.0	2.35	2.2	5.0	4.7	0.4	0.2	—	—
(M2.2)	2.55	2.4	5.0	4.7	0.6	0.4	—	—
M2.5	2.85	2.7	6.5	6.2	0.6	0.4	—	—
M3	3.4	3.2	7.0	6.7	0.6	0.4	—	—
(M3.5)	3.9	3.7	7.0	6.7	0.6	0.4	—	—
M4	4.5	4.3	9.0	8.7	0.9	0.7	—	—
(M4.5)	5.0	4.8	9.0	8.7	0.9	0.7	—	—
M5	5.5	5.3	10.0	9.7	1.1	0.9	—	—
M6	6.7	6.4	12.5	12.1	1.8	1.4	0.9	0.7
(M7)	7.7	7.4	14.0	13.6	1.8	1.4	0.9	0.7
M8	8.7	8.4	17.0	16.6	1.8	1.4	1.1	0.9
M10	10.9	10.5	21.0	20.5	2.2	1.8	1.45	1.05
M12	13.4	13.0	24.0	23.5	2.7	2.3	1.8	1.4
(M14)	15.4	15.0	28.0	27.5	2.7	2.3	1.8	1.4
M16	17.4	17.0	30.0	29.5	3.3	2.7	2.2	1.8
(M18)	19.5	19.0	34.0	33.2	3.3	2.7	2.2	1.8
M20	21.5	21.0	37.0	36.2	3.3	2.7	2.2	1.8
(M22)	23.5	23.0	39.0	38.2	3.3	2.7	2.2	1.8
M24	25.5	25.0	44.0	43.2	4.3	3.7	2.7	2.3
(M27)	28.5	28.0	50.0	49.2	4.3	3.7	2.7	2.3
M30	31.6	31.0	56.0	55.0	4.3	3.7	2.7	2.3
(M33)	34.6	34.0	60.0	59.0	5.6	4.4	3.3	2.7
M36	37.6	37.0	66.0	65.0	5.6	4.4	3.3	2.7
(M39)	40.6	40.0	72.0	71.0	6.6	5.4	3.3	2.7

*Non-preferred sizes in parentheses ( ).
For full information see BS 4320.

4.1.2 Plain washers, black: metric series

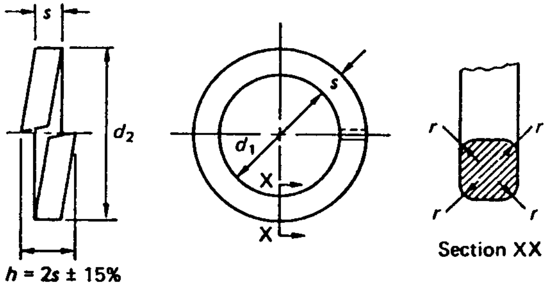


(Dimensions in millimetres)

Designation (thread diameter)*	Internal diameter d_1		External diameter d_2		Thickness S	
	max.	*min.*	*max.*	*min.*	*max.*	*min.*
M5	5.8	5.5	10.0	9.2	1.2	0.8
M6	7.0	6.6	12.5	11.7	1.9	1.3
(M7)	8.0	7.6	14.0	13.2	1.9	1.3
M8	9.4	9.0	17.0	16.2	1.9	1.3
M10	11.5	11.0	21.0	20.2	2.3	1.7
M12	14.5	14.0	24.0	23.2	2.8	2.2
(M14)	16.5	16.0	28.0	27.2	2.8	2.2
M16	18.5	18.0	30.0	29.2	3.6	2.4
(M18)	20.6	20.0	34.0	33.8	3.6	2.4
M20	22.6	22.0	37.0	35.8	3.6	2.4
(M22)	24.6	24.0	39.0	37.8	3.6	2.4
M24	26.6	26.0	44.0	42.8	4.6	3.4
(M27)	30.6	30.0	50.0	48.8	4.6	3.4
M30	33.8	33.0	56.0	54.5	4.6	3.4
(M33)	36.8	36.0	60.0	58.5	6.0	4.0
M36	39.8	39.0	66.0	64.5	6.0	4.0
(M39)	42.8	42.0	72.0	70.5	7.0	5.0
M42	45.8	45.0	78.0	76.5	8.2	5.8
(M45)	48.8	48.0	85.0	83.0	8.2	5.8
M48	53.0	52.0	92.0	90.0	9.2	6.8
(M52)	57.0	56.0	98.0	96.0	9.2	6.8
M56	63.0	62.0	105.0	103.0	10.2	7.8
(M60)	67.0	66.0	110.0	108.0	10.2	7.8
M64	71.0	70.0	115.0	113.0	10.2	7.8
(M68)	75.0	74.0	120.0	118.0	11.2	8.8

*Non-preferred sizes in parentheses ( ).
For full information see BS 4320.

4.1.3 Single coil square section spring washers: metric series, type A

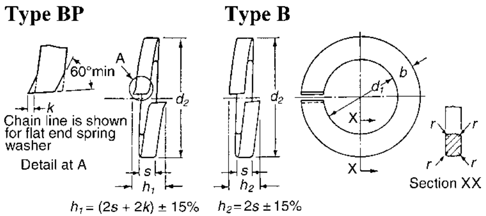


(Dimensions in millimetres)

Nominal size and thread diameter* d	Inside diameter d_1 max.	Inside diameter d_1 min.	Thickness and width s	Outside diameter d_2 max.	Radius r max.
M3	3.3	3.1	1 ± 0.1	5.5	0.3
(M3.5)	3.8	3.6	1 ± 0.1	6.0	0.3
M4	4.35	4.1	1.2 ± 0.1	6.95	0.4
M5	5.35	5.1	1.5 ± 0.1	8.55	0.5
M6	6.4	6.1	1.5 ± 0.1	9.6	0.5
M8	8.55	8.2	2 ± 0.1	12.75	0.65
M10	10.6	10.2	2.5 ± 0.15	15.9	0.8
M12	12.6	12.2	2.5 ± 0.15	17.9	0.8
(M14)	14.7	14.2	3 ± 0.2	21.1	1.0
M16	16.9	16.3	3.5 ± 0.2	24.3	1.15
(M18)	19.0	18.3	3.5 ± 0.2	26.4	1.15
M20	21.1	20.3	4.5 ± 0.2	30.5	1.5
(M22)	23.3	22.4	4.5 ± 0.2	32.7	1.5
M24	25.3	24.4	5 ± 0.2	35.7	1.65
(M27)	28.5	27.5	5 ± 0.2	38.9	1.65
M30	31.5	30.5	6 ± 0.2	43.9	2.0
(M33)	34.6	33.5	6 ± 0.2	47.0	2.0
M36	37.6	36.5	7 ± 0.25	52.1	2.3
(M39)	40.8	39.6	7 ± 0.25	55.3	2.3
M42	43.8	42.6	8 ± 0.25	60.3	2.65
(M45)	46.8	45.6	8 ± 0.25	63.3	2.65
M48	50.0	48.8	8 ± 0.25	66.5	2.65

* Sizes shown in parentheses are non-preferred and are not usually stock sizes.

For further information see BS 4464.



4.1.4 Single coil rectangular section spring washers: metric series, types B and BP

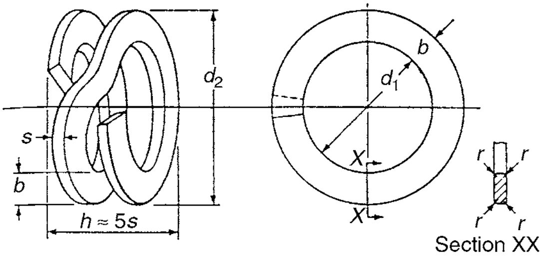
(Dimensions in millimetres)

Nominal size and thread diameter d*	*Inside diameter d_1*		*Width b*	*Thickness s*	*Outside diameter d_2 max.*	*Radius r max.*	*k (type BP only)*
	max.	*min.*					
M1.6	1.9	1.7	0.7 ± 0.1	0.4 ± 0.1	3.5	0.15	–
M2	2.3	2.1	0.9 ± 0.1	0.5 ± 0.1	4.3	0.15	–
(M2.2)	2.5	2.3	1.0 ± 0.1	0.6 ± 0.1	4.7	0.2	–
M2.5	2.8	2.6	1.0 ± 0.1	0.6 ± 0.1	5.0	0.2	–
M3	3.3	3.1	1.3 ± 0.1	0.8 ± 0.1	6.1	0.25	–
(M3.5)	3.8	3.6	1.3 ± 0.1	0.8 ± 0.1	6.6	0.25	0.15
M4	4.35	4.1	1.5 ± 0.1	0.9 ± 0.1	7.55	0.3	0.15

M5	5.35	5.1	1.8 ± 0.1	1.2 ± 0.1	9.15	0.4	0.15
M6	6.4	6.1	2.5 ± 0.15	1.6 ± 0.1	11.7	0.5	0.2
M8	8.55	8.2	3.0 ± 0.15	2.0 ± 0.1	14.85	0.65	0.3
M10	10.6	10.2	3.5 ± 0.2	2.2 ± 0.15	18.0	0.7	0.3
M12	12.6	12.2	4.0 ± 0.2	2.5 ± 0.15	21.0	0.8	0.4
(M14)	14.7	14.2	4.5 ± 0.2	3.0 ± 0.15	24.1	1.0	0.4
M16	16.9	16.3	5.0 ± 0.2	3.5 ± 0.2	27.3	1.15	0.4
(M18)	19.0	18.3	5.0 ± 0.2	3.5 ± 0.2	29.4	1.15	0.4
M20	21.1	20.3	6 ± 0.2	4 ± 0.2	33.5	1.3	0.4
(M22)	23.3	22.4	6 ± 0.2	4 ± 0.2	35.7	1.3	0.4
M24	25.3	24.4	7 ± 0.25	5 ± 0.2	39.8	1.65	0.5
(M27)	28.5	27.5	7 ± 0.25	5 ± 0.2	43.0	1.65	0.5
M30	31.5	30.5	8 ± 0.25	6 ± 0.25	48.0	2.0	0.8
(M33)	34.6	33.5	10 ± 0.25	6 ± 0.25	55.1	2.0	0.8
M36	37.6	36.5	10 ± 0.25	6 ± 0.25	58.1	2.0	0.8
(M39)	40.8	39.6	10 ± 0.25	6 ± 0.25	61.3	2.0	0.8
M42	43.8	42.6	12 ± 0.25	7 ± 0.25	68.3	2.3	0.8
(M45)	46.8	45.6	12 ± 0.25	7 ± 0.25	71.3	2.3	0.8
M48	50.0	48.8	12 ± 0.25	7 ± 0.25	74.5	2.3	0.8
(M52)	54.1	52.8	14 ± 0.25	8 ± 0.25	82.6	2.65	1.0
M56	58.1	56.8	14 ± 0.25	8 ± 0.25	86.6	2.65	1.0
(M60)	62.3	60.9	14 ± 0.25	8 ± 0.25	90.8	2.65	1.0
M64	66.3	64.9	14 ± 0.25	8 ± 0.25	93.8	2.65	1.0
(M68)	70.5	69.0	14 ± 0.25	8 ± 0.25	99.0	2.65	1.0

*Sizes shown in parentheses are non-preferred, and are not usually stock sizes.
For further information see BS 4464.

4.1.5 Double coil rectangular section spring washers: metric series, type D



(Dimensions in millimetres)

*Nominal size and thread diameter** *d*	*Inside diameter* d_1 *max.*	*max.*	*Width* *b*	*Thickness* *s*	*Outside diameter* d_2 *max.*	*Radius* *r* *max.*
M2	2.4	2.1	0.9 ± 0.1	0.5 ± 0.05	4.4	0.15
(M2.2)	2.6	2.3	1 ± 0.1	0.6 ± 0.05	4.8	0.2
M2.5	2.9	2.6	1.2 ± 0.1	0.7 ± 0.1	5.5	0.23
M3.0	3.6	3.3	1.2 ± 0.1	0.8 ± 0.1	6.2	0.25
(M3.5)	4.1	3.8	1.6 ± 0.1	0.8 ± 0.1	7.5	0.25
M4	4.6	4.3	1.6 ± 0.1	0.8 ± 0.1	8.0	0.25
M5	5.6	5.3	2 ± 0.1	0.9 ± 0.1	9.8	0.3
M6	6.6	6.3	3 ± 0.15	1 ± 0.1	12.9	0.33
M8	8.8	8.4	3 ± 0.15	1.2 ± 0.1	15.1	0.4
M10	10.8	10.4	3.5 ± 0.20	1.2 ± 0.1	18.2	0.4
M12	12.8	12.4	3.5 ± 0.2	1.6 ± 0.1	20.2	0.5
(M14)	15.0	14.5	5 ± 0.2	1.6 ± 0.1	25.4	0.5
M16	17.0	16.5	5 ± 0.2	2 ± 0.1	27.4	0.65
(M18)	19.0	18.5	5 ± 0.2	2 ± 0.1	29.4	0.65
M20	21.5	20.8	5 ± 0.2	2 ± 0.1	31.9	0.65
(M22)	23.5	22.8	6 ± 0.2	2.5 ± 0.15	35.9	0.8
M24	26.0	25.0	6.5 ± 0.2	3.25 ± 0.15	39.4	1.1
(M27)	29.5	28.0	7 ± 0.25	3.25 ± 0.15	44.0	1.1
M30	33.0	31.5	8 ± 0.25	3.25 ± 0.15	49.5	1.1
(M33)	36.0	34.5	8 ± 0.25	3.25 ± 0.15	52.5	1.1
M36	40.0	38.0	10 ± 0.25	3.25 ± 0.15	60.5	1.1
(M39)	43.0	41.0	10 ± 0.25	3.25 ± 0.15	63.5	1.1
M42	46.0	44.0	10 ± 0.25	4.5 ± 0.2	66.5	1.5
M48	52.0	50.0	10 ± 0.25	4.5 ± 0.2	72.5	1.5
M56	60.0	58.0	12 ± 0.25	4.5 ± 0.2	84.5	1.5
M64	70.0	67.0	12 ± 0.25	4.5 ± 0.2	94.5	1.5

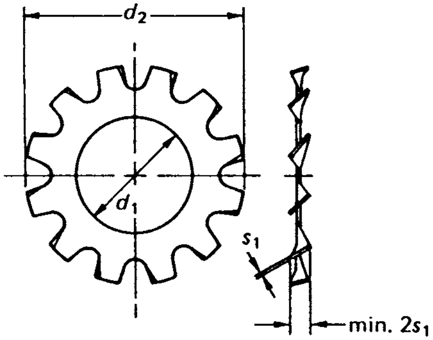
* Sizes shown in parentheses are non-preferred, and are not usually stock sizes.

Note: The free height of double coil washers before compression is normally approximately five times the thickness but, if required, washers with other free heights may be obtained by arrangement between the purchaser and the manufacturer.

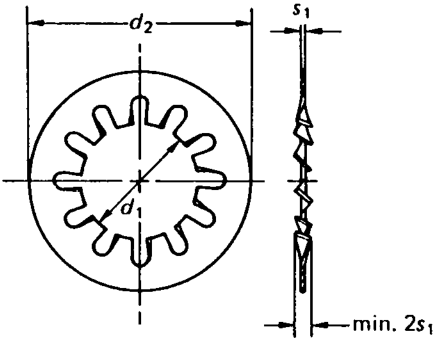
For further information see BS 4464.

4.1.6 Toothed lock washers, metric

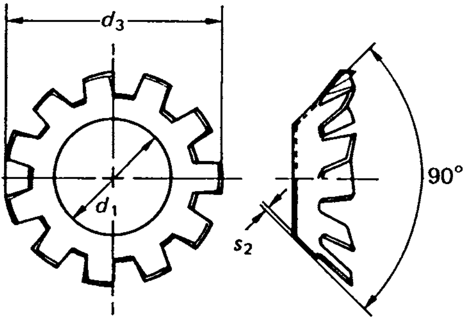
Type A externally toothed



Type J internally toothed



Type V countersunk



Details left unspecified are to be designed as appropriate.

Designation of a toothed lock washer type J with hole diameter $d_1 = 6.4$ mm of spring steel, surface phosphated for protection against rusting (phr): toothed lock washer J 6.4 DIN 6797 – phr.

If toothed lock washers are required for left-hand threaded bolts, the designation reads: toothed lock washer J 6.4 left DIN 6797 – phr.

(Dimensions in millimetres)

d_1 (H13)	d_2 (h14)	d_3 ≈	s_1	s_2	*Number of teeth min.*		*Weight* (7.85 kg/dm^3) kg/1000 *pieces* ≈			*For thread diameter*
					A *and* J	V	A	J	V	
1.7	3.6	—	0.3	—	6	—	0.01	—	—	1.6
1.8	3.8	—	0.3	—	6	—	0.015	—	—	1.7
1.9	4	—	0.3	—	6	—	0.02	0.03	—	1.8
2.2	4.5	4.2	0.3	0.2	6	6	0.025	0.04	0.02	2
2.5	5	—	0.4	0.2	6	6	0.03	0.025	—	2.3
2.7	5.5	5.1	0.4	0.2	6	6	0.04	0.045	0.025	2.5
2.8	5.5	—	0.4	0.2	6	6	0.04	0.045	—	2.6
3.2	6	6	0.4	0.2	6	6	0.045	0.045	0.025	3
3.7	7	7	0.5	0.25	6	6	0.075	0.085	0.04	3.5
4.3	8	8	0.5	0.25	8	8	0.095	0.1	0.05	4
5.1*	9	—	0.5	—	8	—	0.14	0.15	—	5
5.3	10	9.8	0.6	0.3	8	8	0.18	0.2	0.12	5
6.4	11	11.8	0.7	0.4	8	10	0.22	0.25	0.2	6
7.4	12.5	—	0.8	—	8	—	0.3	0.35	—	7

8.2*	14	—	0.8	—	8	—	0.4	0.45	—	8
8.4	15	15.3	0.8	0.4	8	10	0.45	0.55	0.4	8
10.5	18	19	0.9	0.5	9	10	0.8	0.9	0.7	10
12.5	20.5	23	1.0	0.5	10	10	1.1	1.3	1.2	12
14.5	24	26.2	1.0	0.6	10	12	1.7	2.0	1.4	14
16.5	26	30.2	1.2	0.6	12	12	2.1	2.5	1.4	16
19	30	—	1.4	—	12	—	3.5	3.7	—	18
21	33	—	1.4	—	12	—	3.8	4.1	—	20
23	36	—	1.5	—	14	—	5	6.0	—	22
25	38	—	1.5	—	14	—	6	6.5	—	24
28	44	—	1.6	—	14	—	8	8.5	—	27
31	48	—	1.6	—	14	—	9	9.5	—	30

*Only for hexagon head bolts.
For further details see DIN 6797.

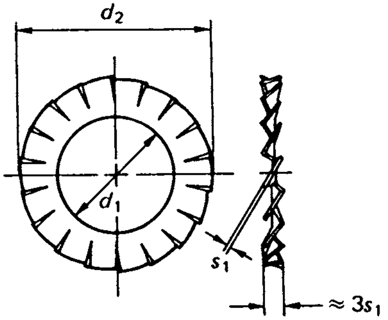
4.1.7 Serrated lock washers, metric

Details left unspecified are to be designed as appropriate.

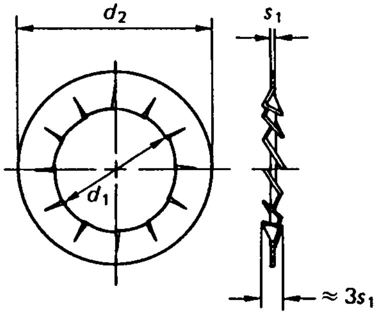
Designation of a serrated lock washer type J with hole diameter $d_1 = 6.4\,\mathrm{mm}$ in spring steel, surface phosphated for protection against rusting (phr): serrated lock washer J 6.4 DIN 6798 – phr.

If serrated lock washers are required for left-hand threaded bolts, the designation reads: serrated lock washer J 6.4 left DIN 6798 – phr.

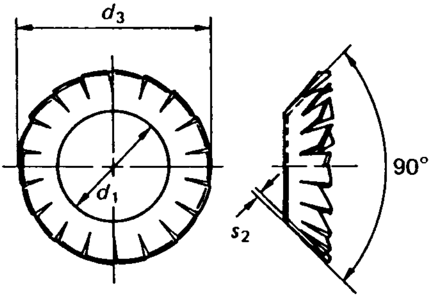
Type A serrated externally



Type J serrated internally



Type V countersunk



(Dimensions in millimetres)

d_1 (H13)	d_2 (h14)	d_3 ≈	s_1	s_2	*Number of teeth min.*			*Weight* (7.85 kg/dm^3) kg/1000 *pieces* ≈		*For thread diameter*
					A	J	V	A and J	V	
1.7	3.6	—	0.3	—	9	7	—	0.02	—	1.6
1.8	3.8	—	0.3	—	9	7	—	0.02	—	1.7
1.9	4	—	0.3	—	9	7	—	0.025	—	—
2.2	4.5	4.2	0.3	0.2	9	7	10	0.03	0.025	2
2.5	5	—	0.4	0.2	9	7	10	0.04	—	2.3
2.7	5.5	5.1	0.4	0.2	9	7	10	0.045	0.03	2.5
2.8	5.5	—	0.4	0.2	9	7	10	0.05	—	2.6
3.2	6	6	0.4	0.2	9	7	12	0.06	0.04	3
3.7	7	7	0.5	0.25	10	8	12	0.11	0.075	3.5
4.3	8	8	0.5	0.25	11	8	14	0.14	0.1	4
5.1*	9	—	0.5	—	11	8	—	0.22	—	5
5.3	10	9.8	0.6	0.3	11	8	14	0.28	0.2	5
6.4	11	11.8	0.7	0.4	12	9	16	0.36	0.3	6
7.4	12.5	—	0.8	—	14	10	—	0.5	—	7
8.2*	14	—	0.8	—	14	10	—	0.75	—	8

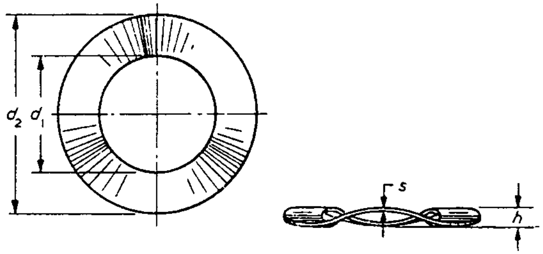
(*continued*)

4.1.7 (*continued*) (Dimensions in millimetres)

d_1 (H13)	d_2 (h14)	d_3 ≈	s_1	s_2	*Number of teeth min.*			*Weight* (7.85 kg/dm^3) kg/1000 *pieces* ≈		*For thread diameter*
					A	J	V	A and J	V	
8.4	15	15.3	0.8	0.4	14	10	18	0.8	0.5	8
10.5	18	19	0.9	0.5	16	12	20	1.25	1	10
12.5	20.5	23	1	0.5	16	12	26	1.7	1.5	12
14.5	24	26.2	1	0.6	18	14	28	2.4	2	14
16.5	26	30.2	1.2	0.6	18	14	30	3	2.4	16
19	30	—	1.4	—	18	14	—	5	—	18
21	33	—	1.4	—	20	16	—	6	—	20
23	36	—	1.5	—	20	16	—	7.5	—	22
25	38	—	1.5	—	20	16	—	8	—	24
28	44	—	1.6	—	22	18	—	12	—	27
31	48	—	1.6	—	22	18	—	14	—	30

*Only for hexagon head bolts.
For further details see DIN 6797.

4.1.8 ISO metric crinkle washers: general engineering

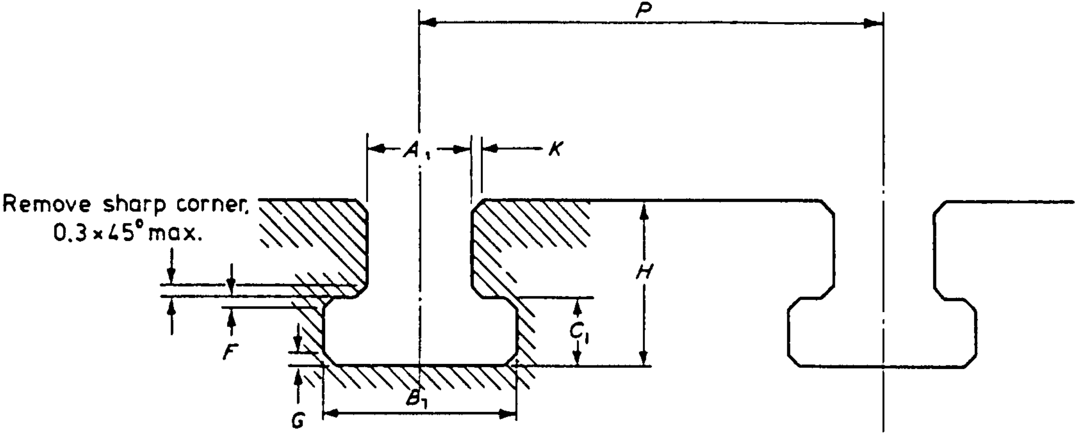


(Dimensions in millimetres)

*Nominal (thread) diameter**	*Inside diameter* d_1		*Outside diameter* d_2		*Height* h		*Thickness* s
	max.	*min.*	*max.*	*min.*	*max.*	*min.*	
M1.6	1.8	1.7	3.7	3.52	0.51	0.36	0.16
M2	2.3	2.2	4.6	4.42	0.53	0.38	0.16
M2.5	2.8	2.7	5.8	5.62	0.53	0.38	0.16
M3	3.32	3.2	6.4	6.18	0.61	0.46	0.16
M4	4.42	4.3	8.1	7.88	0.84	0.69	0.28
M5	5.42	5.3	9.2	8.98	0.89	0.74	0.30
M6	6.55	6.4	11.5	11.23	1.14	0.99	0.40
M8	8.55	8.4	15.0	14.73	1.40	1.25	0.40
M10	10.68	10.5	19.6	19.27	1.70	1.55	0.55
M12	13.18	13.0	22.0	21.67	1.90	1.65	0.55
(M14)	15.18	15.0	25.5	25.17	2.06	1.80	0.55
M16	17.18	17.0	27.8	27.47	2.41	2.16	0.70
(M18)	19.21	19.0	31.3	30.91	2.41	2.16	0.70
M20	21.21	21.0	34.7	34.31	2.66	2.16	0.70

*Second choice sizes in parentheses ( ).
For full range and further information see BS 4463.

4.2 T-slot profiles



(Dimensions in millimetres)

Designations of T-slot	Width of throat A_1			Width of recess B_1		Depth of recess c_1		Overall depth of T-slot H		Chamfer × 45° or radius			Pitch P (avoid pitch values in brackets as they lead to weakness)			
	Nominal	*Ordinary* (H12)	*For use as tenson* (HB)	*min.*	*max.*	*min.*	*max.*	*min.*	*max.*	*K* *max.*	*F* *max.*	*G* *max.*				
M4	5	+0.12	+0.018	10	11	3.5	4.5	8	10					20	25	32
M5	6	0	0	11	12.5	5	6	11	13					25	32	40
M6	8	+0.15	+0.022	14.5	16	7	8	15	18	1.0		1.0		32	40	50
M8	10	0	0	16	18	7	8	17	21		0.6			40	50	63
M10	12	+0.18	+0.027	19	21	8	9	20	25				(40)	50	63	80
M12	14	0	0	23	25	9	11	23	28			1.6	(50)	63	80	100
M16	18			30	32	12	14	30	36	1.6			(63)	80	100	125
M20	22	+0.21	+0.033	37	40	16	18	38	45		1.0		(80)	100	125	160
M24	28	0		46	50	20	22	48	56			2.5	100	125	160	200
M30	36	+0.25	+0.039	56	60	25	28	61	71				125	160	200	250
M36	42	0	0	68	72	32	35	74	85	2.5	1.6	4.0	160	200	250	320
M42	48			80	85	36	40	84	95		2.0	6.0	200	250	320	400
M48	54	+0.30 0	+0.046 0	90	95	40	44	94	106				250	320	400	500

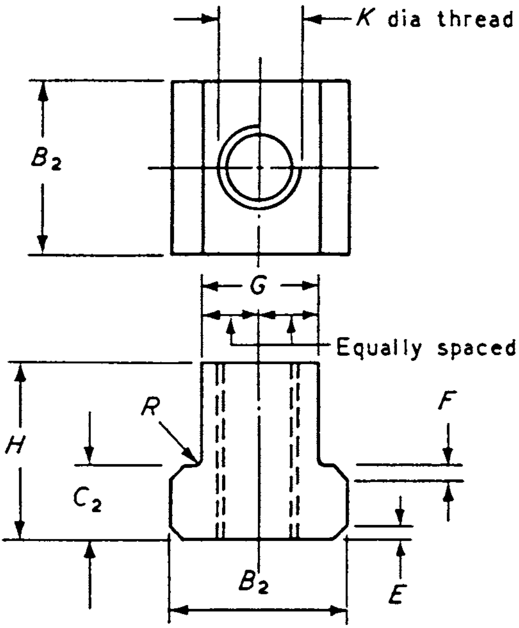
4.2.1 Tolerance on pitches p of T-slots

Pitch mm	*Tolerance* mm
20 to 25	±0.2
32 to 100	±0.3
125 to 250	±0.5
320 to 500	±0.8

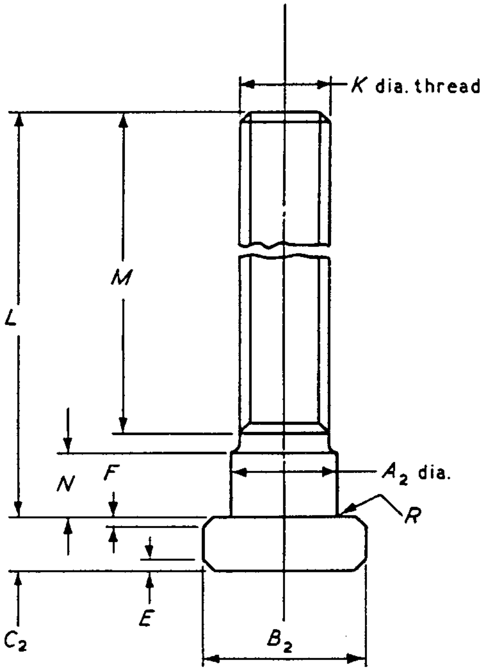
For further information see BS 2485.

4.3 Dimensions of T-bolts and T-nuts

4.3.1 T-nut



4.3.2 T-bolt



4.3.3 Dimensions of T-bolts and T-nuts

Designation of T-bolt and diameter of thread K	*Width of head (square)* B_2		*Depth of head* C_2 *tol.* ±0.25	*Length of shoulder* N	*Diameter of bolt* A_2	*Chamfer* E	*Radius* R	*Width of T-nut shank* G		*Height of T-nut* H	*Chamfer* F
	nom.	*tol.*				*max.*	*max.*	*nom.*	*tol.*	*max.*	*max.*
M4	9		2.5	–	4			5		6	
M5	10		4	–	5			6	−0.3	8	
M6	13		6	–	6	1.0		8	−0.5	10	
M8	15		6	–	8			10		12	
M10	18	0	7	–	10			12		16	
M12	22	−0.5	8	–	12		1.0	14	−0.3	19	0.3
M16	28		10	–	16			18	−0.6	25	×
M20	34		14	–	20			22		30	45°
M24	43		18	20	26	1.5		28		40	
M30	53		23	20	33			36	−0.4	45	
M36	64		28	25	39			42	−0.7	55	
M42	75		32	25	46	2.5		48		65	
M48	85		36	30	52			54	−0.4 −0.8	75	

(Dimension in millimetres)

Diameter of thread *K*	*Recommended length of bolt stem* *L*													*Length of threaded portion of bolt stem* *M*
M4	30	40	50	60	70	80	100							For $L \leq 100\, M = 0.5\, L$
M5	30	40	50	60	70	80	100							
M6				60	70	80	100							
M8				60	70	80	100							
M10				60	70	80	100	125	160	180				
M12					70	80	100	125	160	180				For $L > 100\, M = 0.3\, L$
M16					70	80	100	125	160	180	200	250	300	
M20					70	80	100	125	160	180	200	250	300	
M24														
M30														
M36							100	125	160	180	200	250	300	
M42														
M48														

For further information see BS 2485.

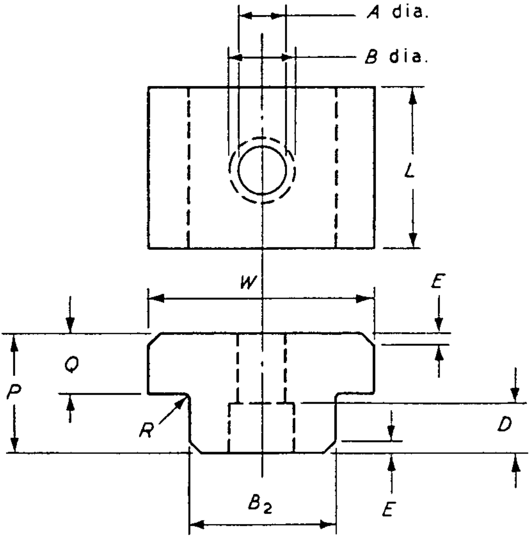
4.4 Dimensions of tenons for T-slots

(Dimensions in millimetres)

Designation of T-slot	*Width of tenon shank* B_2 *nom.*	*Width of tenon shank* B_2 *tol.* (h7)	*Overall width of tenon* W *nom.*	*Overall width of tenon* W *tol.* (h7)	*Depth of head of tenon* Q	*Overall height of tenon* P	*Length of tenon* L	*Radius* R *max.*	*Fixing hole*: *To suit socket head cap screw to BS 4168: Pt 1*	*Fixing hole*: *Clearance hole diameter A to BS 4186 medium fit*	*Fixing hole*: *Counterbores diameter B tolerance H13*	*Fixing hole*: *Counterbore depth D tolerance +0.2*
M4	5	0 −0.012							M2	2.4	4.3	2.5
M5	6	0	16	0	5	10	25					
M6	8	−0.015		−0.018				0.6	M3	3.4	6.0	3.5
M8	10	0										
M10	12	−0.018		0								
M12	14		30	−0.021	5.5	12	30					
M16	18								M6	6.6	11.0	6.5

M20	22	0						1.0				
M24	28	−0.021	50	0								
M30	36	0		−0.025	15	30	40					
M36	42	−0.025										
M42	48			0								
			70	−0.030	25	40	60	1.5	M8	9.0	14.0	8.5
M48	54	0										
		−0.030										

For further information see BS 2485: 1987.


A dia.
B dia.
L
W
E
Q
P
R
D
E
B_2

4.5 Taper pins, unhardened

Dimensions

Type A (ground pins): Surface finish $R_a = 0.8\,\mu m$
Type B (turned pins): Surface finish $R_a = 3.2\,\mu m$