The Starrett Data Book for Machinists

Starrett Books
Volume II

Pages 7, 9, 10, 12, 16, 17, 30 (lower half), 32, 33, 35, 37, 38, 41, 42, 43, 50 (lower half), 52, 53, 54, 55, 56, 57, 58, 59, 60, 65, 72, 73, 74, 88, 99, 114, 115, 118 (lower half) 119, 121, 136, 156, 157, and 168 in this book are copyrighted by THE INDUSTRIAL PRESS, Publishers of MACHINERY'S Handbook, and reprinted with their permission.

Pages 50 (lower part), 72, 73, and 74 should have been credited to MACHINERY'S Handbook instead of to the "American Machinist's" Handbook.

THE STARRETT DATA BOOK *for* MACHINISTS

Volume II of The Starrett Books

COLLABORATING EDITORS

H. P. FAIRFIELD
Assistant Professor of Machine Construction
Worcester Polytechnic Institute

J. N. BETHEL
Production Manager, The Taft-Peirce Mfg. Co.
Woonsocket, R. I.

H. H. EDGE
Factory Manager, The Locomobile Company
Bridgeport, Conn.

J. C. SPENCE
Superintendent, Norton Company
Worcester, Mass.

PRICE, 75 CENTS.

[redacted]

THE L. S. STARRETT COMPANY

The World's Greatest Toolmakers

ATHOL, MASSACHUSETTS

PREFACE

IT HAS been our endeavor to restrict this volume to a tabular presentation of information regarding machine-shop practice and the materials of manufacture. Little or no attempt has been made to explain the "why" or "how" of a statement.

We have assumed that the reader is already familiar with machines and tools and their uses, and the book is designed to help the machinist to a greater degree of efficiency. In this respect this work differs radically from Volume I of The Starrett Books, the Starrett Book for Machinists' Apprentices, which is essentially a book on "How to do it."

The collaborating editors were selected, not only because of the positions they hold and their knowledge of machine-shop work, but because each represents a different field with its own peculiar problems and methods, the aim of the publishers being to make the book of the greatest value to the largest possible number of practical machinists throughout the country.

THE L. S. STARRETT COMPANY

ATHOL, MASS.

THIS is a companion volume, or in a sense a sequel, to The Starrett Book for Machinists' Apprentices, a condensed index of which will be found at the end of this book.

HORSEPOWER TRANSMITTED

Based on 180° arc of contact, using the best oak tanned leather

SINGLE BELT

Width of Belt in Inches	Speed in Feet per Minute									
	600	1200	1800	2400	3000	3600	4200	4800	5400	6000
2	2	4	6	8	10	12	14	16	18	20
3	3	6	9	12	15	18	21	24	27	30
4	4	8	12	16	20	24	28	32	36	40
5	5	10	15	20	25	30	35	40	45	50
6	6	12	18	24	30	36	42	48	54	60
8	8	16	24	32	40	48	56	64	72	80
9	9	18	27	36	45	54	63	72	81	90
10	10	20	30	40	50	60	70	80	90	100
12	12	24	36	48	60	72	84	96	108	120
14	14	28	42	56	70	84	98	112	126	140
16	16	32	48	64	80	96	112	128	144	160

DOUBLE BELT

Width of Belt in Inches	Speed in Feet per Minute										
	400	800	1200	1600	2000	2400	2800	3200	3600	4000	5000
4	4	8	13	17	21	25	30	34	38	42	53
6	6	13	19	25	32	38	45	51	57	64	80
8	8	17	25	34	42	51	60	68	77	85	106
10	10	21	32	42	53	64	74	85	96	106	133
12	13	25	38	51	64	76	89	102	115	128	160
16	17	34	51	68	85	102	119	136	153	170	213
20	21	42	64	85	106	128	149	170	192	213	266
24	25	51	76	102	128	153	179	205	230	256	320
30	32	64	96	128	160	192	224	256	288	320	400
36	38	76	115	153	192	230	269	307	345	384	480
40	42	85	128	170	213	256	298	341	384	426	533

BELT LACES AND HOLES FOR LACED JOINTS

Light Lace

Width of Belt, Inches	Width of Light Lace, Inches	Number of Holes	Punch		Distance of Holes from End	
			Number	Diameter	First Row, Inches	Second Row, Ins.
1 –1¾	¼	2 or 3	6	$\frac{11}{64}$	⅜	...
2 –2½	$\frac{5}{16}$	3	6–7	$\frac{11}{64}$–$\frac{3}{16}$	⅜	¾
2¾–3¼	$\frac{5}{16}$	5	7–8	$\frac{3}{16}$–¼	½	1
3½–4½	⅜	5	9	$\frac{9}{32}$	⅝	1⅛
5	⅜	7	9	$\frac{9}{32}$	⅝	1⅛

Medium Lace

Width of Belt, Inches	Width of Medium Lace, Ins.	Number of Holes	Punch		Distance of Holes from End	
			Number	Diameter	First Row, Inches	Second Row, Ins.
6	⅜	9	9–10	$\frac{9}{32}$–$\frac{5}{16}$	¾	1¼
8	½	11	11	⅜	¾	1⅜
10	½	13	11	⅜	1	1¾
12	½	15	11	⅜	1	1¾
14	½	17	12	$\frac{11}{32}$	1¼	2

Courtesy of The
Graton & Knight Mfg. Co.

CIRCUMFERENTIAL SPEEDS OF PULLEYS IN FEET PER MINUTE

Diam. of Pulley in Inches	Revolutions per Minute																	
	75	100	125	150	175	200	225	250	275	300	325	350	375	400	450	500	550	600	650
4	78	105	131	157	183	209	236	262	288	314	340	367	393	419	471	524	576	628	**681**
5	98	131	164	196	229	262	295	327	360	393	425	458	491	524	589	654	720	785	**851**
6	118	157	196	236	275	314	353	393	432	471	511	550	589	628	707	785	864	942	**1021**
7	138	183	229	275	320	367	412	458	504	550	596	641	687	733	825	916	1008	1100	**1191**
8	157	209	262	314	367	419	471	524	576	628	681	733	785	838	942	1047	1152	1257	**1361**
9	177	236	295	353	412	471	530	589	648	707	766	825	884	942	1060	1178	1296	1414	**1531**
10	196	262	327	393	458	524	589	654	720	785	851	916	982	1047	1178	1309	1440	1571	**1702**
12	236	314	393	471	550	628	707	785	864	942	1021	1100	1178	1257	1414	1571	1728	1885	**2042**
14	275	367	458	550	641	733	825	916	1008	1100	1191	1283	1375	1466	1649	1833	2016	2199	**2382**
15	295	393	491	589	687	785	884	982	1080	1178	1276	1375	1473	1571	1767	1964	2160	2356	**2553**
16	314	419	524	628	733	838	942	1047	1152	1257	1361	1466	1571	1675	1885	2094	2304	2513	**2723**
18	353	471	589	707	825	942	1060	1178	1296	1414	1531	1649	1767	1885	2121	2356	2592	2827	**3063**
20	393	524	654	785	916	1047	1178	1309	1440	1571	1702	1833	1964	2094	2356	2618	2880	3142	**3403**
22	432	576	720	864	1008	1152	1296	1440	1584	1728	1872	2016	2160	2304	2592	2880	3168	3456	**3744**
24	471	628	785	942	1100	1257	1414	1571	1728	1885	2042	2199	2356	2513	2827	3142	3456	3770	**4084**
26	511	681	851	1021	1191	1361	1531	1702	1872	2042	2212	2382	2553	2723	3063	3403	3744	4084	**4424**
28	550	733	916	1100	1283	1466	1649	1833	2016	2199	2382	2566	2749	2932	3299	3665	4032	4398	**4764**
30	589	785	982	1178	1375	1571	1767	1964	2160	2356	2553	2749	2945	3142	3534	3927	4320	4712	**5105**
32	628	838	1047	1257	1466	1675	1885	2094	2304	2513	2723	2932	3142	3351	3770	4189	4608	5027	**5445**
34	668	890	1113	1335	1558	1780	2003	2225	2448	2670	2893	3115	3338	3560	4006	4451	4896	5341	**5785**
36	707	942	1178	1414	1649	1885	2121	2356	2592	2827	3063	3299	3534	3770	4241	4712	5184	5655	**6126**
38	746	995	1244	1492	1741	1990	2238	2487	2736	2985	3233	3482	3731	3979	4477	4974	5472	5969	**6466**
40	785	1047	1309	1571	1833	2094	2356	2618	2880	3142	3403	3665	3927	4189	4712	5236	5760	6283	

For rules for finding lengths of belts and calculating diameters and speeds of pulleys see Vol. I cf The Starrett Books.

Courtesy of The Graton & Knight Mfg. Co.

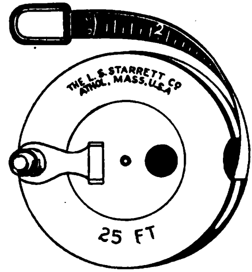
HORSEPOWER TRANSMITTED BY TURNED STEEL LINESHAFTING

Diam. of Shaft in Inches	Number of Revolutions per Minute												
	100	125	150	175	200	225	250	300	350	400	450	500	600
1½	3.7	4.7	5.6	6.6	7.5	8.4	9.4	11.2	13.1	15.0	16.9	18.8	22
1 9/16	4.2	5.3	6.4	7.4	8.5	9.5	10.6	12.7	14.8	17.0	19.0	21	25
1⅝	4.8	5.9	7.1	8.3	9.5	10.7	11.9	14.3	16.6	19.0	21	24	28
1 11/16	5.3	6.7	8.0	9.3	10.7	12.0	13.4	16.0	18.7	21	24	27	32
1¾	5.9	7.4	8.9	10.4	11.9	13.4	14.9	17.9	21	24	27	30	36
1 13/16	6.6	8.2	9.9	11.5	13.2	14.8	16.5	19.8	23	26	30	33	40
1⅞	7.3	9.1	11.0	12.8	14.7	16.5	18.3	22	26	29	33	37	44
1 15/16	8.1	10.0	12.1	14.1	16.1	18.2	20	24	28	32	36	40	48
2	8.9	11.1	13.3	15.6	17.8	20	22	27	31	35	40	44	53
2 1/16	9.8	12.3	14.7	17.2	19.6	22	24	29	34	39	44	49	59
2⅛	10.6	13.3	16.0	18.6	21	24	27	32	37	43	48	53	64
2 3/16	11.6	14.6	17.5	20.0	23	26	29	35	41	47	52	58	70
2¼	12.6	15.8	19.0	22.0	25	28	32	38	44	51	57	63	76
2 5/16	13.7	17.2	21	24	27	31	34	41	48	55	62	69	82
2⅜	14.9	18.6	22	26	30	33	37	45	52	60	67	74	89
2 7/16	16.0	20	24	28	32	36	40	48	56	64	72	80	96
2½	17.4	22	26	30	35	39	43	52	61	69	78	87	104
2 9/16	18.7	23	28	33	37	42	47	56	66	75	84	94	112
2⅝	20	25	30	35	40	45	50	60	71	80	90	100	120
2 11/16	21	27	32	38	43	48	54	65	76	86	97	108	129
2¾	23	29	35	40	46	52	58	69	81	92	104	115	138
2 13/16	25	31	37	43	49	56	62	74	87	99	111	124	148
2⅞	26	33	40	46	53	59	66	79	92	105	119	132	158
2 15/16	28	35	42	49	56	63	70	84	99	113	127	141	169
3	30	37	45	52	60	67	75	90	105	120	135	150	180
3⅛	34	42	51	59	68	76	85	102	119	136	152	170	203
3¼	38	48	57	67	76	86	95	114	134	153	172	191	229
3⅜	43	53	64	75	85	96	107	128	150	171	192	213	256
3½	48	60	72	83	95	107	119	143	167	190	214	238	286
3⅝	53	66	79	93	106	119	132	159	185	211	238	265	317
3¾	59	73	88	103	117	132	146	176	205	234	264	293	351
3⅞	65	81	97	113	129	145	161	194	226	258	291	322	387
4	71	89	107	125	142	160	178	213	249	284	320	356	427
4⅛	78	98	117	136	156	176	195	235	273	312	351	390	468
4¼	85	107	128	149	170	192	213	256	298	341	385	426	511
4⅜	93	116	139	163	186	210	233	279	326	372	419	466	559
4½	102	127	152	178	203	228	253	305	356	405	456	507	610
4⅝	110	138	165	193	220	247	275	330	385	440	495	550	660
4¾	119	149	179	209	238	268	298	357	416	476	537	595	714
4⅞	129	161	193	226	258	290	322	387	452	516	581	646	775
5	139	174	208	244	278	313	347	417	486	557	625	695	835

From "Machinery's" Handbook, The Industrial Press, New York

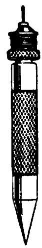
STARRETT TOOLS FOR USE IN CONNECTION WITH BELTING AND SHAFTING

Steel Measuring Tape



In steel or leather cases, flush handle with push button release on opposite side. Graduated in English or Metric systems, as desired. Finished in black background, with bright steel figures and graduations with the foot figures before each inch mark, insuring quick and accurate reading. Bright background and black figures if desired. Lengths from 25 to 100 feet.

Improved Mercury Plumb Bob

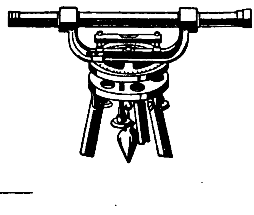


Made from solid steel, bored and filled with mercury. Nickel plated and knurled. Points hardened and ground. Patented slotted neck for fastening string without knots, allowing bob to hang perfectly true.

Improved Level

In addition to regular parallel vial, the base has a cross level, insuring the accuracy of the level when in a canted position. The concave groove running the length of the base, with flat margin on either side, improves the seat for flat work and gives an absolutely true seat for shafting, etc.

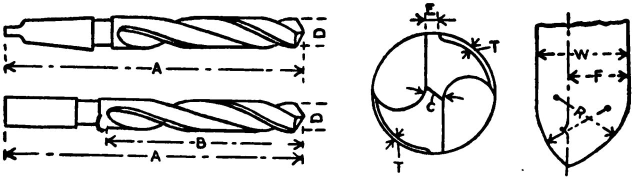
Leveling Instrument



Light in weight and of simple construction. Tripod of iron, with telescoping extension legs, adjustable to any length. Light tube fitted with eye aperture and cross wires. Head is held to tripod with bolt and nut, so as to make it stationary at any given point.

For further information concerning these and other tools which may be used to advantage with Belting and Shafting, see pages 51 and 158 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

DIMENSIONS OF TWIST DRILLS AND GROOVING CUTTERS



Diam. D	Total Length A	No. of M.T. Shank	Length Flutes, B	Thick-ness at C	Width of Land, E	Total Clear-ance, 2 T	Cutter Dimensions W	r	R	F
1/4	6 1/8	1	4	0.038	0.040	0.017	0.200	0.131	0.168	0.119
9/32	6 1/4	1	4	0.042	0.045	0.019	0.225	0.147	0.189	0.133
5/16	6 3/8	1	4 1/16	0.045	0.050	0.021	0.250	0.164	0.211	0.148
11/32	6 1/2	1	4 1/8	0.048	0.050	0.023	0.275	0.180	0.232	0.163
3/8	6 3/4	1	4 1/4	0.051	0.055	0.025	0.300	0.197	0.253	0.178
13/32	7	1	4 3/8	0.054	0.055	0.027	0.325	0.213	0.274	0.193
7/16	7 1/4	1	4 5/8	0.058	0.060	0.029	0.350	0.230	0.295	0.208
15/32	7 1/2	1	4 7/8	0.062	0.060	0.031	0.375	0.246	0.316	0.223
1/2	7 3/4	1	5	0.066	0.060	0.033	0.400	0.262	0.337	0.238
9/16	8 1/4	1	5 3/8	0.074	0.065	0.037	0.450	0.295	0.379	0.267
5/8	8 3/4	2	5 3/4	0.082	0.065	0.041	0.500	0.328	0.422	0.297
11/16	9 1/4	2	6	0.090	0.070	0.045	0.550	0.361	0.464	0.327
3/4	9 3/4	2	6 3/8	0.098	0.075	0.049	0.600	0.394	0.506	0.356
13/16	10	2	6 5/8	0.106	0.080	0.051	0.650	0.426	0.548	0.386
7/8	10 1/2	2	7	0.114	0.085	0.053	0.700	0.459	0.590	0.416
15/16	10 3/4	3	7	0.122	0.090	0.055	0.750	0.492	0.632	0.445
1	11	3	7 1/16	0.128	0.090	0.057	0.800	0.525	0.675	0.475
1 1/16	11 1/4	3	7 3/8	0.134	0.095	0.059	0.850	0.558	0.717	0.504
1 1/8	11 3/4	3	7 7/8	0.140	0.095	0.061	0.900	0.591	0.759	0.534
1 3/16	12	3	8 1/8	0.146	0.100	0.063	0.950	0.623	0.801	0.564
1 1/4	12 1/2	3	8 1/2	0.152	0.100	0.065	1.000	0.656	0.844	0.594
1 5/16	14 1/4	4	9 1/4	0.158	0.105	0.066	1.050	0.689	0.886	0.623
1 3/8	14 1/2	4	9 1/2	0.164	0.105	0.067	1.100	0.722	0.928	0.653
1 7/16	14 3/4	4	9 5/8	0.170	0.110	0.068	1.150	0.754	0.970	0.683
1 1/2	15	4	9 7/8	0.176	0.110	0.069	1.200	0.788	1.012	0.713
1 5/8	15 1/2	4	10	0.188	0.115	0.071	1.300	0.853	1.097	0.772
1 3/4	16	4	10 1/2	0.200	0.120	0.073	1.400	0.919	1.181	0.831
1 7/8	16 1/2	4	11	0.212	0.125	0.075	1.500	0.984	1.265	0.891
2	16 1/2	4	11	0.224	0.130	0.075	1.600	1.050	1.350	0.950
2 1/8	17	5	10 1/8	0.236	0.130	0.075	1.700	1.115	1.434	1.009
2 1/4	17 1/2	5	10 1/4	0.244	0.135	0.075	1.800	1.181	1.518	1.069
2 3/8	18	5	10 5/8	0.252	0.135	0.075	1.900	1.247	1.603	1.128
2 1/2	19	5	11 1/2	0.260	0.140	0.075	2.000	1.313	1.687	1.187
2 5/8	19 1/2	5	11 7/8	0.268	0.145	0.080	2.100	1.378	1.772	1.247
2 3/4	20 1/2	5	12 3/4	0.276	0.150	0.080	2.200	1.444	1.856	1.306
2 7/8	21	5	13 1/8	0.284	0.155	0.080	2.300	1.509	1.940	1.365
3	22	5	14	0.292	0.160	0.085	2.400	1.575	2.025	1.425

From "Machinery's" Handbook, The Industrial Press, New York

DIMENSIONS OF TWIST DRILLS AND GROOVING CUTTERS, WIRE GAGE SIZES

See illustrations with table on previous page.

Drill Gage No.	Diam. in Inches, *D*	Total Length *A*	Length of Flute *B*	Thickness of Web at Point, *C*	Width of Land, *E*	Total Clearance, 2 *T*	Cutter Dimensions *W*	*r*	*R*	*F*
80	0.0135	3/4	3/16	0.003	No clearance	No clearance	0.013	0.008	0.011	0.007
76	0.0200	1	1/4	0.004			0.018	0.011	0.014	0.010
72	0.0250	1 1/4	7/16	0.005			0.022	0.015	0.017	0.012
68	0.0310	1 7/16	9/16	0.006			0.027	0.017	0.021	0.015
64	0.0360	1 9/16	5/8	0.007	0.015	0.003	0.030	0.019	0.025	0.018
60	0.0400	1 11/16	11/16	0.008	0.015	0.003	0.033	0.022	0.028	0.020
56	0.0465	1 13/16	23/32	0.009	0.015	0.0035	0.043	0.027	0.035	0.025
52	0.0635	1 7/8	7/8	0.010	0.015	0.004	0.055	0.035	0.046	0.032
48	0.0760	2 1/16	1 1/16	0.012	0.020	0.0045	0.064	0.041	0.053	0.037
44	0.0860	2 3/16	1 3/16	0.014	0.020	0.0055	0.073	0.047	0.061	0.042
40	0.0980	2 3/8	1 11/32	0.016	0.020	0.0065	0.081	0.052	0.068	0.047
36	0.1065	2 9/16	1 1/2	0.017	0.025	0.007	0.088	0.055	0.073	0.051
32	0.1160	2 11/16	1 5/8	0.019	0.025	0.008	0.101	0.065	0.085	0.059
28	0.1405	2 7/8	1 11/16	0.021	0.025	0.009	0.116	0.075	0.097	0.068
24	0.1520	3 1/16	1 13/16	0.023	0.030	0.0095	0.124	0.081	0.104	0.073
20	0.1610	3 3/16	2 1/16	0.025	0.030	0.0105	0.133	0.087	0.112	0.079
16	0.1770	3 3/8	2 3/16	0.027	0.030	0.0115	0.143	0.094	0.119	0.085
12	0.1890	3 9/16	2 5/16	0.029	0.030	0.0125	0.152	0.100	0.128	0.090
8	0.1990	3 11/16	2 11/32	0.031	0.035	0.0135	0.160	0.105	0.135	0.096
4	0.2090	3 7/8	2 13/32	0.033	0.035	0.014	0.173	0.114	0.146	0.103
1	0.2280	4	2 21/32	0.035	0.035	0.015	0.187	0.123	0.157	0.111

CUTTING LUBRICANTS

Mixture is one third Crude Petroleum, two thirds Lard Oil. Oil is Lard. When two lubricants are mentioned the first is preferable.

Material	Drilling Milling	Turning	Chucking	Reaming	Tapping
Tool Steel	Oil	Dry or Oil	Oil or Soda Water	Lard Oil	Oil
Soft Steel	Oil or Soda Water	Dry or Soda Water	Soda Water	Lard Oil	Oil
Wrought Iron	Oil or Soda Water	Dry or Soda Water	Soda Water	Lard Oil	Oil
Cast Iron	Dry	Dry	Dry	Dry	Oil
Brass	Dry	Dry	Dry	Dry	Oil
Copper	Oil	Dry	Oil	Mixture	Oil
Babbitt	Dry	Dry	Dry	Dry	Oil
Glass	Turpentine			or Kerosene	

From "Machinery's" Handbook, The Industrial Press, New York

SPEED OF DRILLS

A feed per revolution of .004 to .007 for drills 1/4 inch and smaller, and from .007 to .015 for larger is about all that should be required.

This feed is based on a peripheral speed of a drill equal to:

30 feet per minute for steel; 35 feet per minute for iron; 60 feet per minute for brass.

It may also be found advisable to vary the speed somewhat according as the material to be drilled is more or less refractory.

We believe that these speeds should not be exceeded under ordinary circumstances.

TABLE OF CUTTING SPEEDS

Feet per Min.	15′	20′	25′	30′	35′	40′	45′	50′	60′	70′	80′
Dia.	REVOLUTIONS PER MINUTE										
1/16 in.	917.	1223.	1528.	1834.	2140.	2445.	2751.	3057.	3668.	4280.	4891.
1/8	459.	611.	764.	917.	1070.	1222.	1375.	1528.	1834.	2139.	2445.
3/16	306.	408.	509.	611.	713.	815.	917.	1019.	1222.	1426.	1630.
1/4	229.	306.	382.	458.	535.	611.	688.	764.	917.	1070.	1222.
5/16	183.	245.	306.	367.	428.	489.	550.	611.	733.	856.	978.
3/8	153.	204.	255.	306.	357.	408.	458.	509.	611.	713.	815.
7/16	131.	175.	218.	262.	306.	349.	393.	437.	524.	611.	699.
1/2	115.	153.	191.	229.	268.	306.	344.	382.	459.	535.	611.
5/8	91.8	123.	153.	184.	214.	245.	276.	306.	367.	428.	489.
3/4	76.3	102.	127.	153.	178.	203.	229.	254.	306.	357.	408.
7/8	65.5	87.3	109.	131.	153.	175.	196.	219.	262.	306.	349.
1	57.3	76.4	95.5	115.	134.	153.	172.	191.	229.	267.	306.
1 1/8	51.0	68.0	85.0	102.	119.	136.	153.	170.	204.	238.	272.
1 1/4	45.8	61.2	76.3	91.8	107.	123.	137.	153.	183.	214.	245.
1 3/8	41.7	55.6	69.5	83.3	97.2	111.	125.	139.	167.	195.	222.
1 1/2	38.2	50.8	63.7	76.3	89.2	102.	115.	127.	153.	178.	204.
1 5/8	35.0	47.0	58.8	70.5	82.2	93.9	106.	117.	141.	165.	188.
1 3/4	32.7	43.6	54.5	65.5	76.4	87.3	98.2	109.	131.	153.	175.
1 7/8	30.6	40.7	50.9	61.1	71.3	81.5	91.9	102.	122.	143.	163.
2	28.7	38.2	47.8	57.3	66.9	76.4	86.0	95.5	115.	134.	153.
2 1/4	25.4	34.0	42.4	51.0	59.4	68.0	76.2	85.0	102.	119.	136.
2 1/2	22.9	30.6	38.2	45.8	53.5	61.2	68.8	76.3	91.7	107.	122.
2 3/4	20.8	27.8	34.7	41.7	48.6	55.6	62.5	69.5	83.4	97.2	111.
3	19.1	25.5	31.8	38.2	44.6	51.0	57.3	63.7	76.4	89.1	102.

For more general information on Drills, Sizes, etc., see Vol. I of The Starrett Books.

SPEEDS AND FEEDS FOR DRILLING*

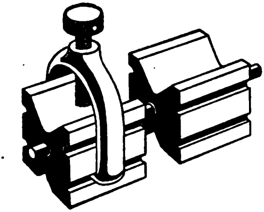
HIGH-SPEED STEEL DRILLS

Size of Drill	Feed per Rev.	Bronze Brass, 300 Feet	Cast Iron, Annealed, 170 Feet	Cast Iron, Hard, 80 Feet	Mild Steel, 120 Feet	Drop Forg., 60 Feet	Mal. Iron, 90 Feet	Tool Steel, 60 Feet	Cast Steel, 40 Feet
Ins.	Inches	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.
1/16	0.003	18300	10370	4880	7320	3660	3490	3660	2440
1/8	0.004	9150	5185	2440	3660	1830	2745	1830	1220
3/16	0.005	6100	3456	1626	2440	1210	1830	1220	807
1/4	0.006	4575	2593	1220	1830	915	1375	915	610
5/16	0.007	3660	2074	976	1464	732	1138	732	490
3/8	0.008	3050	1728	813	1220	610	915	610	407
7/16	0.009	2614	1482	698	1046	522	784	522	348
1/2	0.010	2287	1296	610	915	458	636	458	305
5/8	0.011	1830	1037	488	732	366	569	366	245
3/4	0.012	1525	864	407	610	305	458	305	203
7/8	0.013	1307	741	349	523	261	392	261	174
1	0.014	1143	648	305	458	229	349	229	153
1¼	0.016	915	519	244	366	183	275	183	122
1½	0.016	762	432	204	305	153	212	153	102
1¾	0.016	654	371	175	262	131	196	131	87
2	0.016	571	323	153	229	115	172	115	77

CARBON STEEL DRILLS

Size of Drill	Feed per Rev.	Bronze Brass, 150 Feet	Cast Iron, Annealed, 85 Feet	Cast Iron, Hard, 40 Feet	Mild Steel, 60 Feet	Drop Forg., 30 Feet	Mal. Iron, 45 Feet	Tool Steel, 30 Feet	Cast Steel, 20 Feet
Ins.	Ins.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.
1/16	0.003	9150	5185	2440	3660	1830	2745	1830	1220
1/8	0.004	4575	2593	1220	1840	915	1375	915	610
3/16	0.005	3050	1728	813	1220	610	915	610	407
1/4	0.006	2287	1296	610	915	458	636	458	305
5/16	0.007	1830	1037	488	732	366	569	366	245
3/8	0.008	1525	864	407	610	305	458	305	203
7/16	0.009	1307	741	349	523	261	392	261	174
1/2	0.010	1143	648	305	458	229	343	229	153
5/8	0.011	915	519	244	366	183	275	183	122
3/4	0.012	762	432	204	305	153	212	153	102
7/8	0.013	654	371	175	262	131	196	131	87
1	0.014	571	323	153	229	115	172	115	77
1¼	0.016	458	260	122	183	92	138	92	61
1½	0.016	381	216	102	153	77	106	77	51
1¾	0.016	327	186	88	131	66	98	66	44
2	0.016	286	162	77	115	58	86	58	39

STARRETT TOOLS FOR USE IN CONNECTION WITH DRILLING

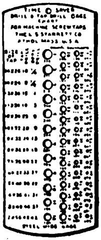


Steel Drill Blocks and Clamp

Of case hardened steel. May be used singly or in pairs, close together or separated, and are kept in line by a spindle passing through friction bushings. The blocks are 1¼ inch square and will hold round stock to 1¼ inch diameter.

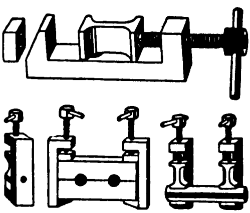
Machinists' Center Punch

Of fine tool steel, knurled, tempered ends, and points carefully ground. Made in five sizes.



Time Saver Tap and Drill Gage

Gage shows right sized drill to suit machine screw tap, leaving just enough stock for tap to cut as near a full thread as is practicable for one tap without breaking. Tested after hardening and warranted accurate.

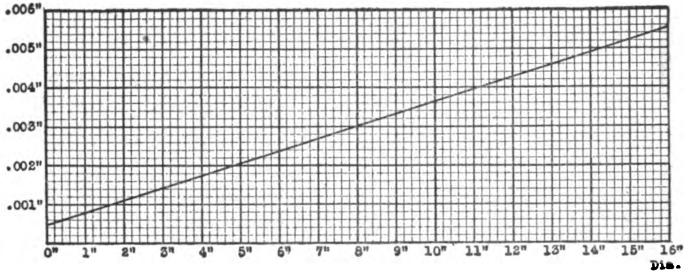


Toolmakers' Steel Clamps

Made from drop forgings, case hardened. Take-up blocks slip on and off end of screw. A hole in the block permits the insertion of a screw so that clamp may be fastened to bench and used as small vise.

For further information concerning these and other tools which may be used to advantage in Drilling, see pages 51, 61-62-63 and 122 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

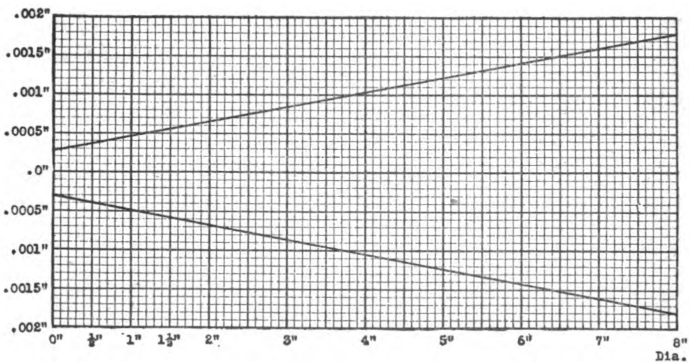
ALLOWANCES FOR RUNNING FITS



A = allowance in thousandths of an inch. D = nominal diameter of fit.

For running fits $\frac{A}{1000} = \frac{5}{16} D + .5$

TABLE OF LIMITS FOR LIMIT GAGES



L = total limit. D — nominal diameter of fit

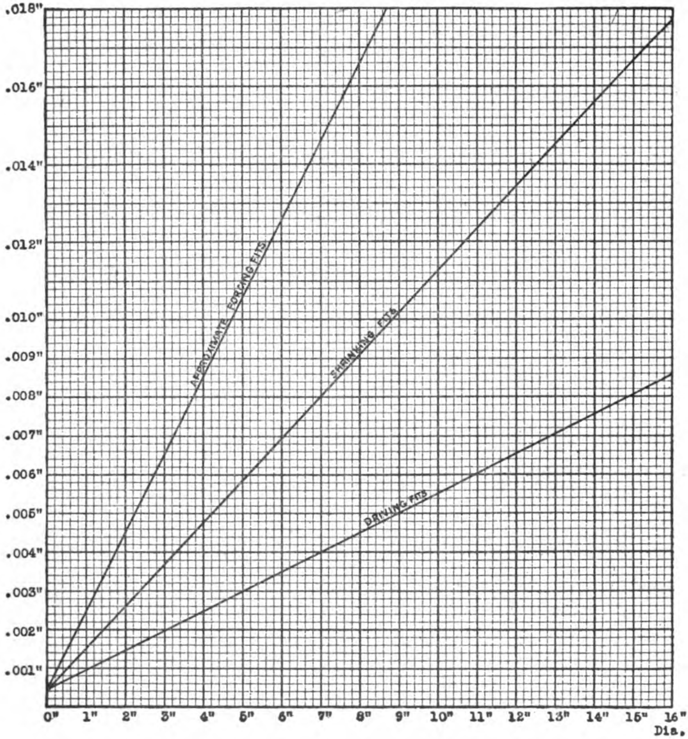
$$\frac{\frac{1}{2} L + \text{or} -}{1000} = \frac{3}{16} D + .3$$

Allowances for Shrinking Fits adopted by The American Master Mechanics' Association

Diameter of tire, in inches...	38	44	50	56	62	66
Shrinkage allowance, in inches	.040	.047	.053	.060	.066	.070

Courtesy of American Society of Mechanical Engineers

ALLOWANCES FOR FORCING, SHRINKING, AND DRIVING FITS



A = allowance in thousandths of an inch. *D* = nominal diameter of fit.

For forcing fits $\frac{A}{1000} = 2\,D + .5$ For shrinking fits $\frac{A}{1000} = \frac{17}{16}\,D + .5$

For driving fits $\frac{A}{1000} = \frac{1}{2}\,D + .5$

NOTE. — While the data given in the above table is the result of an investigation of the practice of a large number of shops, the allowances for the large diameters is considered excessive, as they give results which require presses of more than ordinary power to make the fits. It is the practice in a large number of shops to decrease the allowance per inch as the diameter increases. The general rule of .001 inch per inch of diameter has been found very satisfactory for sizes above 6 inches, while the allowances for the smaller sizes correspond more nearly to those given above.

For more general data on allowances and tolerances for forcing, shrinking, driving, and running fits, see Vol. I of The Starrett Books.

Courtesy of American Society of Mechanical Engineers

ALLOWANCES AND TOLERANCES FOR RUNNING FITS

Nominal Diameter	Shaft			Allowance (Minimum difference between shaft and hole)	Hole		
	Minimum Diameter	Tolerance Difference	Maximum Diameter		Minimum Diameter	Tolerance Difference	Maximum Diameter
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
¼	0.2495	0.0005	0.25	0.0005	0.2505	0.0003	0.2508
½	0.4993	0.0007	0.50	0.0007	0.5007	0.0007	0.5014
¾	0.7491	0.0009	0.75	0.0008	0.7508	0.0009	0.7517
1	0.9990	0.0010	1.00	0.0010	1.0010	0.0010	1.0020
1½	1.4988	0.0012	1.50	0.0012	1.5012	0.0013	1.5025
2	1.9985	0.0015	2.00	0.0015	2.0015	0.0015	2.0030
3	2.9982	0.0018	3.00	0.0018	3.0018	0.0017	3.0035
4	3.9980	0.0020	4.00	0.0020	4.0020	0.0020	4.0040
5	4.9980	0.0020	5.00	0.0020	5.0020	0.0020	5.0040
6	5.9975	0.0025	6.00	0.0025	6.0025	0.0025	6.0050
7	6.9975	0.0025	7.00	0.0025	7.0025	0.0025	7.0050
8	7.9975	0.0025	8.00	0.0025	8.0025	0.0025	8.0050
9	8.9970	0.0030	9.00	0.0030	9.0030	0.0030	9.0060
10	9.9970	0.0030	10.00	0.0030	10.0030	0.0030	10.0060
11	10.9970	0.0030	11.00	0.0030	11.0030	0.0030	11.0060
12	11.9970	0.0030	12.00	0.0030	12.0030	0.0030	12.0060

NOTE: The above allowances and tolerances for running fits are recommended by the Engineering Standards Committee of Great Britain, for first-class work. For second and third class work, multiply the tolerances by 2 and 3, respectively. For extra fine quality of work, about two fifths the above allowances for first-class work are recommended. The maximum diameter of the shaft is the nominal diameter in all grades of work.

ALLOWANCES FOR DIFFERENT CLASSES OF FITS

These allowances are intended for average machine work. If the bearings are long, the allowances for running fits may have to be increased.

Diameter, Inches	Running Fits	Push Fits
Up to ½	— 0.00075 to — 0.0015	— 0.00025 to — 0.00075
½ to 1	— 0.001 to — 0.002	— 0.0005 to — 0.001
1 to 2	— 0.0015 to — 0.0025	— 0.0005 to — 0.0015
2 to 3	— 0.0015 to — 0.003	— 0.0005 to — 0.0015
3 to 4	— 0.002 to — 0.0035	— 0.00075 to — 0.002
4 to 5	— 0.0025 to — 0.004	— 0.00075 to — 0.002
5 to 6	— 0.0025 to — 0.0045	— 0.00075 to — 0.002
Diameter, Inches	**Driving Fits**	**Forced Fits**
Up to ½	+ 0.0004 to + 0.0006	+ 0.0005 to + 0.001
½ to 1	+ 0.0005 to + 0.001	+ 0.001 to + 0.003
1 to 2	+ 0.00075 to + 0.002	+ 0.002 to + 0.004
2 to 3	+ 0.0015 to + 0.003	+ 0.003 to + 0.006
3 to 4	+ 0.002 to + 0.004	+ 0.005 to + 0.008
4 to 5	+ 0.002 to + 0.0045	+ 0.006 to + 0.010
5 to 6	+ 0.003 to + 0.005	+ 0.008 to + 0.012

From "Machinery's" Handbook, The Industrial Press, New York

ALLOWANCES FOR DIFFERENT CLASSES OF FITS

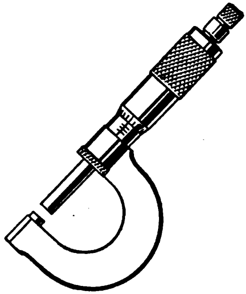
Class	Tolerances in Standard Holes*						
	Nominal Diameters	Up to ½″	$\frac{9}{16}$″–1″	1 $\frac{1}{16}$″–2″	2 $\frac{1}{16}$″–3″	3 $\frac{1}{16}$″–4″	4 $\frac{1}{16}$″–5″
A	High Limit	+0.0002	+0.0005	+0.0007	+0.0010	+0.0010	+0.0010
	Low Limit	−0.0002	−0.0002	−0.0002	−0.0005	−0.0005	−0.0005
	Tolerance	0.0004	0.0007	0.0009	0.0015	0.0015	0.0015
B	High Limit	+0.0005	+0.0007	+0.0010	+0.0012	+0.0015	+0.0017
	Low Limit	−0.0005	−0.0005	−0.0005	−0.0007	−0.0007	−0.0007
	Tolerance	0.0010	0.0012	0.0015	0.0019	0.0022	0.0024
Allowances for Forced Fits							
F	High Limit	+0.0010	+0.0020	+0.0040	+0.0060	+0.0080	+0.0100
	Low Limit	+0.0005	+0.0015	+0.0030	+0.0045	+0.0060	+0.0080
	Tolerance	0.0005	0.0005	0.0010	0.0015	0.0020	0.0020
Allowances for Driving Fits							
D	High Limit	+0.0005	+0.0010	+0.0015	+0.0025	+0.0030	+0.0035
	Low Limit	+0.0002	+0.0007	+0.0010	+0.0015	+0.0020	+0.0025
	Tolerance	0.0003	0.0003	0.0005	0.0010	0.0010	0.0010
Allowances for Push Fits							
P	High Limit	−0.0002	−0.0002	−0.0002	−0.0005	−0.0005	−0.0005
	Low Limit	−0.0007	−0.0007	−0.0007	−0.0010	−0.0010	−0.0010
	Tolerance	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Allowances for Running Fits†							
X	High Limit	−0.0010	−0.0012	−0.0017	−0.0020	−0.0025	−0.0030
	Low Limit	−0.0020	−0.0027	−0.0035	−0.0042	−0.0050	−0.0057
	Tolerance	0.0010	0.0015	0.0018	0.0022	0.0025	0.0027
Y	High Limit	−0.0007	−0.0010	−0.0012	−0.0015	−0.0020	−0.0022
	Low Limit	−0.0012	−0.0020	−0.0025	−0.0030	−0.0035	−0.0040
	Tolerance	0.0005	0.0010	0.0013	0.0015	0.0015	0.0018
Z	High Limit	−0.0005	−0.0007	−0.0007	−0.0010	−0.0010	−0.0012
	Low Limit	−0.0007	−0.0012	−0.0015	−0.0020	−0.0022	−0.0025
	Tolerance	0.0002	0.0005	0.0008	0.0010	0.0012	0.0013

*Tolerance is provided for holes, which ordinary standard reamers can produce, in two grades, Classes A and B, the selection of which is a question for the user's decision and dependent upon the quality of the work required; some prefer to use Class A as working limits and Class B as inspection limits.

†Running fits, which are the most commonly required, are divided into three grades: Class X for engine and other work where easy fits are wanted; Class Y for high speeds and good average machine work; Class Z for fine tool work.

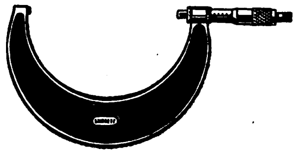
STARRETT TOOLS FOR USE IN CONNECTION WITH FITTING

Micrometer Caliper



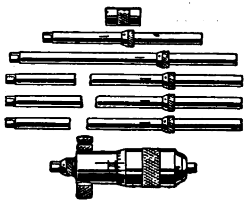
The use of a thin graduated sleeve on the barrel carrying the base or zero line, instead of putting it on the barrel itself and using the old style movable anvil, is the characteristic feature of Starrett Micrometers.

Large Micrometer Sets



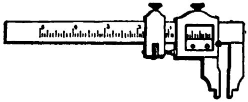
For Micrometer Sets, Special Purpose Micrometers, etc., see the Starrett Catalogue.

Inside Micrometer Calipers



The micrometer screw in the head has a movement varying from ½ to 1 inch. The extension rods are provided with a collar against which the rods are set in the micrometer head. All contact surfaces are hardened.

Vernier Calipers



Graduated in either or both English and Metric divisions for outside and inside measuring. Points are placed on the beams and slides for setting dividers to transfer distances. Full directions for use are sent with each caliper.

For further information concerning these and other tools which may be used to advantage in Fitting see pages 40 and 93 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

WIRE GAGE STANDARDS

Different Standards in Use in the United States
Dimensions of Sizes in Decimal Parts of an inch

Number of Wire Gage	American or Brown & Sharpe	Birmingham or Stubbs's Iron Wire	Washburn & Moen Mfg. Co. Worcester, Mass.	Imperial Wire Gage	Stubbs's Steel Wire	U. S. Standard for Plate	Number of Wire Gage
0000000	....	....	.4900	.500	....	.500	0000000
000000	....	....	.4615	.464	....	.46875	000000
00000	....	....	.4305	.432	....	.4375	00000
0000	.46	.454	.3938	.400	....	.40625	0000
000	.40964	.425	.3625	.372	....	.375	000
00	.3648	.38	.3310	.348	....	.34375	00
0	.32486	.34	.3065	.324	....	.3125	0
1	.2893	.3	.2830	.300	.227	.28125	1
2	.25763	.284	.2625	.276	.219	.265625	2
3	.22942	.259	.2437	.252	.212	.25	3
4	.20431	.238	.2253	.232	.207	.234375	4
5	.18194	.22	.2070	.212	.204	.21875	5
6	.16202	.203	.1920	.192	.201	.203125	6
7	.14428	.18	.1770	.176	.199	.1875	7
8	.12849	.165	.1620	.160	.197	.171875	8
9	.11443	.148	.1483	.144	.194	.15625	9
10	.10189	.134	.1350	.128	.191	.140625	10
11	.090742	.12	.1205	.116	.188	.125	11
12	.080808	.109	.1055	.104	.185	.109375	12
13	.071961	.095	.0915	.092	.182	.09375	13
14	.064084	.083	.0800	.080	.180	.078125	14
15	.057068	.072	.0720	.072	.178	.0703125	15
16	.05082	.065	.0625	.064	.175	.0625	16
17	.045257	.058	.0540	.056	.172	.05625	17
18	.040303	.049	.0475	.048	.168	.05	18
19	.03589	.042	.0410	.040	.164	.04375	19
20	.031961	.035	.0348	.036	.161	.0375	20
21	.028462	.032	.03175	.032	.157	.034375	21
22	.025347	.028	.0286	.028	.155	.03125	22
23	.022571	.025	.0258	.024	.153	.028125	23
24	.0201	.022	.0230	.022	.151	.025	24
25	.0179	.02	.0204	.020	.148	.021875	25
26	.01594	.018	.0181	.018	.146	.01875	26
27	.014195	.016	.0173	.0164	.143	.0171875	27
28	.012641	.014	.0162	.0149	.139	.015625	28
29	.011257	.013	.0150	.0136	.134	.0140625	29
30	.010025	.012	.0140	.0124	.127	.0125	30
31	.008928	.01	.0132	.0116	.120	.0109375	31
32	.00795	.009	.0128	.0108	.115	.01015625	32
33	.00708	.008	.0118	.0100	.112	.009375	33
34	.006304	.007	.0104	.0092	.110	.00859375	34
35	.005614	.005	.0095	.0084	.108	.0078125	35
36	.005	.004	.0090	.0076	.106	.00703125	36
37	.004453	....	....	.0068	.103	.006640625	37
38	.003965	....	....	.0060	.101	.00625	38
39	.003531	....	....	.0052	.099	....	39
40	.003144	....	....	.0048	.097	....	40

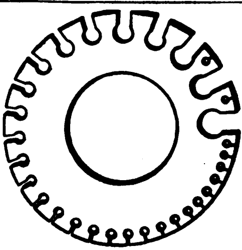
See also table in Starrett Catalogue

STEEL MUSIC WIRE GAGE
(Washburn & Moen Standard)

No. of Gage	Size of each No. in decimal parts of an inch	No. of Gage	Size of each No. in decimal parts of an inch
8–0	.0083″	12	.0296″
7–0	.0087	13	.0314
6–0	.0095	14	.0326
5–0	.010	15	.0345
4–0	.011	16	.036
3–0	.012	17	.0377
2–0	.0133	18	.0395
1–0	.0144	19	.0414
1	.0156	20	.0434
2	.0166	21	.046
3	.0178	22	.0483
4	.0188	23	.051
5	.0202	24	.055
6	.0215	25	.0586
7	.023	26	.0626
8	.0243	27	.0658
9	.0256	28	.072
10	.027	29	.076
11	.0284	30	.080

MUSIC WIRE GAGES
New Am. S. & W. Co., Standard

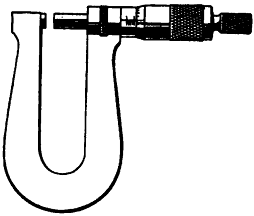
No. of Wire Gage	Size of Each No. in Decimal Parts of an Inch	No. of Wire Gage	Size of Each No. in Decimal Parts of an Inch	No. of Wire Gage	Size of Each No. in Decimal Parts of an Inch
6–0	.004	8	.020	21	.047
5–0	.005	9	.022	22	.049
4–0	.006	10	.024	23	.051
3–0	.007	11	.026	24	.055
00	.008	12	.029	25	.059
0	.009	13	.031	26	.063
1	.010	14	.033	27	.067
2	.011	15	.035	28	.071
3	.012	16	.037	29	.075
4	.013	17	.039	30	.080
5	.014	18	.041	31	.085
6	.016	19	.043	32	.090
7	.018	20	.045	33	.095



Wire and Sheet Gages for all standards tested after hardening and warranted.

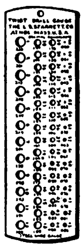
For further information on tools used in gaging wire and sheets see the Starrett Catalogue.

STARRETT TOOLS FOR USE IN CONNECTION WITH GAGING



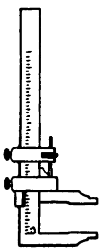
Micrometer Caliper Sheet Metal Gage

This gage has 2 inch depth of throat. Has ½ inch movement of screw. Solid anvil. Patent ratchet friction feed insures uniform pressure on work without springing frame. Lock nut makes solid gage if desired. Decimal equivalents stamped on frame. Metric or English measure.



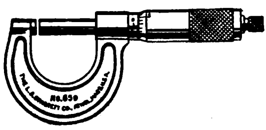
Drill and Steel Wire Gage

Of hardened steel, tested and warranted. Gives the number of drill to fit each hole, and the size of the hole in thousandths of an inch.



Caliper Square

Made with firm and adjustable jaw. The adjusting screw permits setting the sliding head most accurately to the graduations. Beam is graduated on one side in 64ths and on the other in 100ths of an inch. Also made in Metric and Metric and English.



Yankee One Inch Micrometer Caliper

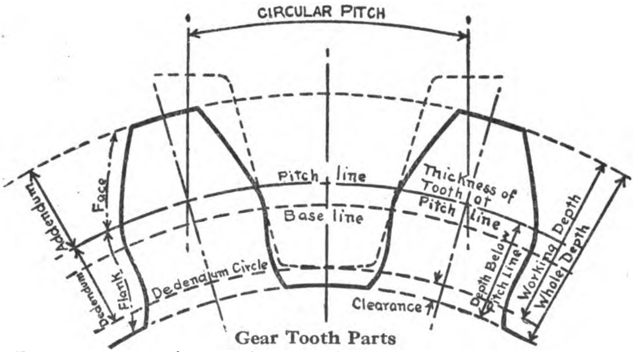
Made from drop forged steel, nickel plated, dull finish. Frame and sleeve in one piece. Has improved speeded screw. For measurements by thousandths up to one inch. Made with or without ratchet stop.

For other gages, see pages 34, 40, 95, 96, 122, 155 and 158 of this volume; also Vol. 1 of The Starrett Books, and the Starrett Catalogue.

RULES AND FORMULÆ FOR INTERNAL SPUR GEARS

(Where rules and formulæ are not given, they are the same as for external gears)

To Find	Rule	Formula
Center Distance	Subtract the number of teeth in the pinion from the number of teeth in the gear and divide the remainder by two times the diametral pitch.	$C = \frac{Ng - Np}{2P}$
Center Distance	Multiply the difference of the numbers of teeth in the gear and pinion by the circular pitch and divide the product by 6.2832.	$C = \frac{(Ng - Np) P'}{6.2832}$
Inside Diameter	Subtract 2 from the number of teeth and divide the remainder by the diametral pitch.	$I = \frac{N - 2}{P}$
Inside Diameter	Subtract 2 from the number of teeth, multiply the remainder by the circular pitch, and divide the product by 3.1416.	$I = \frac{(N - 2) P'}{3.1416}$
Pitch Diameter	Add twice the addendum to the inside diameter.	$D = I + 2S$
Inside Diameter	Subtract twice the addendum from the pitch diameter.	$I = D - 2S$



Gear Tooth Parts

The circular pitch is defined as the distance from center to center of two adjacent teeth along the pitch circle. The diametral pitch is a number found by dividing the number of teeth by the pitch diameter. In other words, it gives the number of teeth for each inch of pitch diameter.

RULES AND FORMULÆ FOR DIMENSIONS OF SPUR GEARS

In these tables the following notation is used:

P = diametral pitch.
P' = circular pitch.
N = number of teeth; (if the number of teeth in both gear and pinion are referred to, Ng = number of teeth in gear, and Np = number of teeth in pinion).
D = pitch diameter.
C = center distance.
S = addendum.
F = clearance.
W = whole depth of tooth.
T = thickness of tooth.
O = outside diameter of gear.

Courtesy of The Cincinnati Milling Machine Company

RULES AND FORMULÆ FOR DIMENSIONS OF SPUR GEARS MADE TO DIAMETRAL PITCH

To Find	Rule	Formula
Diametral Pitch	Divide number of teeth by pitch diameter.	$P = \frac{N}{D}$
Number of Teeth	Multiply pitch diameter by diametral pitch.	$N = P \times D$
Number of Teeth	Multiply the outside diameter by the pitch and subtract 2.	$O \times P - 2$
Total Number of Teeth in a Pair of Gears	Multiply the center distance by the diametral pitch times 2.	$C \times P \times 2$
Pitch Diameter	Subtract two times the addendum from outside diameter.	$D = O - 2S$
Pitch Diameter	Divide number of teeth by diametral pitch.	$D = \frac{N}{P}$
Outside Diameter	Add two times the addendum to the pitch diameter.	$O = D + 2S$
Outside Diameter	Add 2 to the number of teeth and divide the sum by diametral pitch.	$O = \frac{N + 2}{P}$
Whole Depth of Tooth	Divide 2.157 by diametral pitch.	$W = \frac{2.157}{P}$
Addendum	Divide 1 by diametral pitch.	$S = \frac{1}{P}$
Dedendum	Divide 1 by diametral pitch.	$\frac{1}{P}$
Clearance	Divide 0.157 by diametral pitch.	$F = \frac{0.157}{P}$
Thickness of Tooth	Divide 1.5708 by diametral pitch.	$T = \frac{1.5708}{P}$
Center Distance	Add the number of teeth in both gears and divide the sum by two times the diametral pitch.	$C = \frac{Ng + Np}{2P}$
Center Distance	Divide the sum of the pitch diameters of a pair of gears by 2.	$\frac{D + D}{2}$
Length of Rack	Multiply number of teeth in rack by 3.1416 and divide by diametral pitch.	$L = \frac{3.1416\,N}{P}$

Courtesy of The Cincinnati Milling Machine Company

RULES AND FORMULÆ FOR DIMENSIONS OF SPUR GEARS MADE TO CIRCULAR PITCH

To Find	Rule	Formula
Diametral Pitch	Divide 3.1416 by circular pitch.	$P = \frac{3.1416}{P'}$
Circular Pitch	Divide 3.1416 by diametral pitch.	$P' = \frac{3.1416}{P}$
Pitch Diameter	Multiply number of teeth by circular pitch and divide the product by 3.1416.	$D = \frac{NP'}{3.1416}$
Center Distance	Multiply the sum of the number of teeth in both gears by circular pitch and divide the product by 6.2832.	$C = \frac{(Ng + Np)\,P'}{6.2832}$
Addendum	Divide circular pitch by 3.1416.	$S = \frac{P'}{3.1416}$
Clearance	Divide circular pitch by 20.	$F = \frac{P'}{20}$
Whole Depth of Tooth	Multiply 0.6866 by circular pitch.	$W = 0.6866\,P'$
Thickness of Tooth	Divide circular pitch by 2	$T = \frac{P'}{2}$
Outside Diameter	Multiply the sum of the number of teeth plus 2 by circular pitch and divide the product by 3.1416.	$O = \frac{(N + 2)\,P'}{3.1416}$
Circular Pitch	Multiply pitch diameter by 3.1416 and divide by number of teeth.	$P = \frac{3.1416\,D}{N}$
Pitch Diameter	Subtract two times the addendum from outside diameter.	$D = O - 2\,S$
Number of Teeth	Multiply pitch diameter by 3.1416 and divide the product by circular pitch.	$N = \frac{3.1416\,D}{P'}$
Outside Diameter	Add two times the addendum to the pitch diameter.	$O = D + 2\,S$
Length of Rack	Multiply the number of teeth in the rack by circular pitch.	$L = NP'$

Courtesy of The Cincinnati Milling Machine Company

TABLE OF TOOTH PARTS

The "whole depth of tooth" is the depth to be cut in gear.

Diametral Pitch	Circular Pitch	Whole Depth of Tooth	Thickness at Pitch Line	Addendum	Working Depth of Tooth
1¼	2.5133	1.726	1.257	.8000	1.600
1½	2.094	1.438	1.047	.6666	1.333
1¾	1.795	1.233	.898	.5714	1.1429
2	1.570	1.078	.785	.5000	1.000
2¼	1.396	.959	.698	.4444	.888
2½	1.256	.863	.628	.4000	.800
2¾	1.142	.784	.571	.3636	.727
3	1.047	.719	.524	.3333	.666
3½	.897	.616	.449	.2857	.571
4	.785	.539	.393	.2500	.500
5	.628	.431	.314	.2000	.400
6	.523	.360	.262	.1666	.333
7	.448	.308	.224	.1429	.285
8	.392	.270	.196	.1250	.250
9	.349	.240	.175	.1111	.222
10	.314	.216	.157	.1000	.200
11	.285	.196	.143	.0909	.181
12	.261	.180	.131	.0833	.166
14	.224	.154	.112	.0714	.142
16	.196	.135	.098	.0625	.125
18	.174	.120	.087	.0555	.111
20	.157	.108	.079	.0500	.100
22	.142	.098	.071	.0455	.090
24	.130	.090	.065	.0417	.083
26	.120	.083	.060	.0385	.076
28	.112	.077	.056	.0357	.071
30	.104	.072	.052	.0312	.066
32	.098	.067	.049	.0294	.062

METRIC OR MODULE SYSTEM OF GEAR TEETH

The metric system of measurement does not use diametral pitches. In this system the dimensions of the teeth are expressed by reference to the MODULE of the Gear. The module is equal to the pitch diameter in millimeters divided by the number of teeth in the gear. For example, if the pitch diameter of a gear is 50 millimeters and the number of teeth 25, then the module equals 50 ÷ 25 = 2. The following table gives a comparison between diametral, circular, and metric pitches, together with their decimal equivalents. To convert module or metric (for example M 2) into the equivalent diametral pitch, proceed as follows:

M 2 = .247″, or in other words, it is the same as a circular pitch of .247″.

$$P = \frac{3.1416}{P' \text{ in inches}} \qquad \text{Therefore, } P = \frac{3.1416}{.247} = 12.70$$

Courtesy of The Cincinnati Milling Machine Company

COMPARATIVE TABLE OF DIAMETRAL, METRIC AND CIRCULAR PITCHES, WITH DECIMAL EQUIVALENTS

$$\text{Diametral Pitch, } P = \frac{\text{Number of Teeth}}{\text{Pitch Diameter in Inches}} = \frac{3.1416}{\text{Circular Pitch in Inches}}$$

$$\text{Module} = \frac{\text{Pitch Diameter in Millimeters}}{\text{Number of Teeth}} = \frac{\text{Circular Pitch in Millimeters}}{3.1416}$$

$$\text{Circular Pitch, } P' = \frac{\text{Pitch Diameter in Inches} \times 3.1416}{\text{Number of Teeth}} = \frac{3.1416}{\text{Diametral Pitch in Inches}}$$

Diametral Pitch	Module	Circular Pitch	Decimal Equivalent	Diametral Pitch	Module	Circular Pitch	Decimal Equivalent	Diametral Pitch	Module	Circular Pitch	Decimal Equivalent
26	...	...	.121	...	2¾	...	.340	...	7	...	.866
...	1	...	.124	...	...	$\frac{11}{32}$	.344	...	...	⅞	.875
...	...	⅛	.125	9	...	...	.349	3½	...	...	.898
24	...	...	.131	...	3	...	.371	...	8	...	.989
22	...	...	.143	...	...	⅜	.375	...	...	1	1.000
...	1¼	...	.155	8	...	...	.393	3	...	...	1.047
...	...	$\frac{5}{32}$	.156	...	3½	...	.433	...	9	...	1.113
20	...	...	.157	...	...	$\frac{7}{16}$	.437	...	...	1⅛	1.125
18	...	...	.175	7	...	...	.449	2¾	...	...	1.142
...	1½	...	.185	...	4	...	.495	...	10	...	1.237
...	...	$\frac{3}{16}$	.187	...	...	½	.500	...	...	1¼	1.250
16	...	...	.196	6	...	...	.524	2½	...	...	1.257
...	1¾	...	.216	...	4½	...	.556	...	11	...	1.360
...	...	$\frac{7}{32}$	.219	...	...	$\frac{9}{16}$	.562	...	...	1⅜	1.375
14	...	...	.224	5½	...	...	.571	2¼	...	...	1.396
...	2	...	.247	...	5	...	.618	...	12	...	1.484
...	...	¼	.250	...	...	⅝	.625	...	...	1½	1.500
12	...	...	.262	5	...	...	.628	2	...	...	1.571
...	2¼	...	.278	...	5½	...	.680	...	14	...	1.732
...	...	$\frac{9}{32}$	.281	...	...	$\frac{11}{16}$	.687	...	...	1¾	1.750
11	...	...	.286	4½	...	...	.698	1¾	...	...	1.795
...	2½	...	.309	...	6	...	.742	...	16	...	1.979
...	...	$\frac{5}{16}$	.312	...	...	¾	.750	...	...	2	2.000
10	...	...	.314	4	...	...	.785	1½	...	...	2.094

Courtesy of The Cincinnati Milling Machine Company

TURNING AND CUTTING GEAR BLANKS

For Standard Length Tooth

Pitch	16	12	10	8	Pitch	16	12	10	8
Depth of Tooth	.135	.180	.216	.270	Depth of Tooth	.135	.180	.216	.270
No. of Teeth	Outside Diameter				No. of Teeth	Outside Diameter			
10	3/4	1	1 2/10	1 1/2	51	3 5/16	4 5/12	5 3/10	6 5/8
11	13/16	1 1/12	1 3/10	1 5/8	52	3 3/8	4 6/12	5 4/10	6 3/4
12	7/8	1 2/12	1 4/10	1 3/4	53	3 7/16	4 7/12	5 5/10	6 7/8
13	15/16	1 3/12	1 5/10	1 7/8	54	3 1/2	4 8/12	5 6/10	7
14	1	1 4/12	1 6/10	2	55	3 9/16	4 9/12	5 7/10	7 1/8
15	1 1/16	1 5/12	1 7/10	2 1/8	56	3 5/8	4 10/12	5 8/10	7 1/4
16	1 1/8	1 6/12	1 8/10	2 1/4	57	3 11/16	4 11/12	5 9/10	7 3/8
17	1 3/16	1 7/12	1 9/10	2 3/8	58	3 3/4	5	6	7 1/2
18	1 1/4	1 8/12	2	2 1/2	59	3 13/16	5 1/12	6 1/10	7 5/8
19	1 5/16	1 9/12	2 1/10	2 5/8	60	3 7/8	5 2/12	6 2/10	7 3/4
20	1 3/8	1 10/12	2 2/10	2 3/4	61	3 15/16	5 3/12	6 3/10	7 7/8
21	1 7/16	1 11/12	2 3/10	2 7/8	62	4	5 4/12	6 4/10	8
22	1 1/2	2	2 4/10	3	63	4 1/16	5 5/12	6 5/10	8 1/8
23	1 9/16	2 1/12	2 5/10	3 1/8	64	4 1/8	5 6/12	6 6/10	8 1/4
24	1 5/8	2 2/12	2 6/10	3 1/4	65	4 3/16	5 7/12	6 7/10	8 3/8
25	1 11/16	2 3/12	2 7/10	3 3/8	66	4 1/4	5 8/12	6 8/10	8 1/2
26	1 3/4	2 4/12	2 8/10	3 1/2	67	4 5/16	5 9/12	6 9/10	8 5/8
27	1 13/16	2 5/12	2 9/10	3 5/8	68	4 3/8	5 10/12	7	8 3/4
28	1 7/8	2 6/12	3	3 3/4	69	4 7/16	5 11/12	7 1/10	8 7/8
29	1 15/16	2 7/12	3 1/10	3 7/8	70	4 1/2	6	7 2/10	9
30	2	2 8/12	3 2/10	4	71	4 9/16	6 1/12	7 3/10	9 1/8
31	2 1/16	2 9/12	3 3/10	4 1/8	72	4 5/8	6 2/12	7 4/10	9 1/4
32	2 1/8	2 10/12	3 4/10	4 1/4	73	4 11/16	6 3/12	7 5/10	9 3/8
33	2 3/16	2 11/12	3 5/10	4 3/8	74	4 3/4	6 4/12	7 6/10	9 1/2
34	2 1/4	3	3 6/10	4 1/2	75	4 13/16	6 5/12	7 7/10	9 5/8
35	2 5/16	3 1/12	3 7/10	4 5/8	76	4 7/8	6 6/12	7 8/10	9 3/4
36	2 3/8	3 2/12	3 8/10	4 3/4	77	4 15/16	6 7/12	7 9/10	9 7/8
37	2 7/16	3 3/12	3 9/10	4 7/8	78	5	6 8/12	8	10
38	2 1/2	3 4/12	4	5	79	5 1/16	6 9/12	8 1/10	10 1/8
39	2 9/16	3 5/12	4 1/10	5 1/8	80	5 1/8	6 10/12	8 2/10	10 1/4
40	2 5/8	3 6/12	4 2/10	5 1/4	81	5 3/16	6 11/12	8 3/10	10 3/8
41	2 11/16	3 7/12	4 3/10	5 3/8	82	5 1/4	7	8 4/10	10 1/2
42	2 3/4	3 8/12	4 4/10	5 1/2	83	5 5/16	7 1/12	8 5/10	10 5/8
43	2 13/16	3 9/12	4 5/10	5 5/8	84	5 3/8	7 2/12	8 6/10	10 3/4
44	2 7/8	3 10/12	4 6/10	5 3/4	85	5 7/16	7 3/12	8 7/10	10 7/8
45	2 15/16	3 11/12	4 7/10	5 7/8	86	5 1/2	7 4/12	8 8/10	11
46	3	4	4 8/10	6	87	5 9/16	7 5/12	8 9/10	11 1/8
47	3 1/16	4 1/12	4 9/10	6 1/8	88	5 5/8	7 6/12	9	11 1/4
48	3 1/8	4 2/12	5	6 1/4	89	5 11/16	7 7/12	9 1/10	11 3/8
49	3 3/16	4 3/12	5 1/10	6 3/8	90	5 3/4	7 8/12	9 2/10	11 1/2
50	3 1/4	4 4/12	5 2/10	6 1/2	91	5 13/16	7 9/12	9 3/10	11 5/8

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

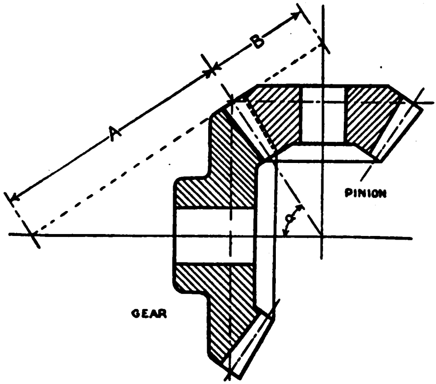
TURNING AND CUTTING GEAR BLANKS—*Continued*

For Standard Length Tooth

Pitch	16	12	10	8	Pitch	16	12	10	8
Depth of Tooth	.135	.180	.216	.270	Depth of Tooth	.135	.180	.216	.270
No. of Teeth	Outside Diameter				No. of Teeth	Outside Diameter			
92	5 7/8	7 10/12	9 4/10	11 3/4	133	8 7/16	11 3/12	13 5/10	16 7/8
93	5 15/16	7 11/12	9 5/10	11 7/8	134	8 1/2	11 4/12	13 6/10	17
94	6	8	9 6/10	12	135	8 9/16	11 5/12	13 7/10	17 1/8
95	6 1/16	8 1/12	9 7/10	12 1/8	136	8 5/8	11 6/12	13 8/10	17 1/4
96	6 1/8	8 2/12	9 8/10	12 1/4	137	8 11/16	11 7/12	13 9/10	17 3/8
97	6 3/16	8 3/12	9 9/10	12 3/8	138	8 3/4	11 8/12	14	17 1/2
98	6 1/4	8 4/12	10	12 1/2	139	8 13/16	11 9/12	14 1/10	17 5/8
99	6 5/16	8 5/12	10 1/10	12 5/8	140	8 7/8	11 10/12	14 2/10	17 3/4
100	6 3/8	8 6/12	10 2/10	12 3/4	141	8 15/16	11 11/12	14 3/10	17 7/8
101	6 7/16	8 7/12	10 3/10	12 7/8	142	9	12	14 4/10	18
102	6 1/2	8 8/12	10 4/10	13	143	9 1/16	12 1/12	14 5/10	18 1/8
103	6 9/16	8 9/12	10 5/10	13 1/8	144	9 1/8	12 2/12	14 6/10	18 1/4
104	6 5/8	8 10/12	10 6/10	13 1/4	145	9 3/16	12 3/12	14 7/10	18 3/8
105	6 11/16	8 11/12	10 7/10	13 3/8	146	9 1/4	12 4/12	14 8/10	18 1/2
106	6 3/4	9	10 8/10	13 1/2	147	9 5/16	12 5/12	14 9/10	18 5/8
107	6 13/16	9 1/12	10 9/10	13 5/8	148	9 3/8	12 6/12	15	18 3/4
108	6 7/8	9 2/12	11	13 3/4	149	9 7/16	12 7/12	15 1/10	18 7/8
109	6 15/16	9 3/12	11 1/10	13 7/8	150	9 1/2	12 8/12	15 2/10	19
110	7	9 4/12	11 2/10	14	151	9 9/16	12 9/12	15 3/10	19 1/8
111	7 1/16	9 5/12	11 3/10	14 1/8	152	9 5/8	12 10/12	15 4/10	19 1/4
112	7 1/8	9 6/12	11 4/10	14 1/4	153	9 11/16	12 11/12	15 5/10	19 3/8
113	7 3/16	9 7/12	11 5/10	14 3/8	154	9 3/4	13	15 6/10	19 1/2
114	7 1/4	9 8/12	11 6/10	14 1/2	155	9 13/16	13 1/12	15 7/10	19 5/8
115	7 5/16	9 9/12	11 7/10	14 5/8	156	9 7/8	13 2/12	15 8/10	19 3/4
116	7 3/8	9 10/12	11 8/10	14 3/4	157	9 15/16	13 3/12	15 9/10	19 7/8
117	7 7/16	9 11/12	11 9/10	14 7/8	158	10	13 4/12	16	20
118	7 1/2	10	12	15	159	10 1/16	13 5/12	16 1/10	20 1/8
119	7 9/16	10 1/12	12 1/10	15 1/8	160	10 1/8	13 6/12	16 2/10	20 1/4
120	7 5/8	10 2/12	12 2/10	15 1/4	161	10 3/16	13 7/12	16 3/10	20 3/8
121	7 11/16	10 3/12	12 3/10	15 3/8	162	10 1/4	13 8/12	16 4/10	20 1/2
122	7 3/4	10 4/12	12 4/10	15 1/2	163	10 5/16	13 9/12	16 5/10	20 5/8
123	7 13/16	10 5/12	12 5/10	15 5/8	164	10 3/8	13 10/12	16 6/10	20 3/4
124	7 7/8	10 6/12	12 6/10	15 3/4	165	10 7/16	13 11/12	16 7/10	20 7/8
125	7 15/16	10 7/12	12 7/10	15 7/8	166	10 1/2	14	16 8/10	21
126	8	10 8/12	12 8/10	16	167	10 9/16	14 1/12	16 9/10	21 1/8
127	8 1/16	10 9/12	12 9/10	16 1/8	168	10 5/8	14 2/12	17	21 1/4
128	8 1/8	10 10/12	13	16 1/4	169	10 11/16	14 3/12	17 1/10	21 3/8
129	8 3/16	10 11/12	13 1/10	16 3/8	170	10 3/4	14 4/12	17 2/10	21 1/2
130	8 1/4	11	13 2/10	16 1/2	171	10 13/16	14 5/12	17 3/10	21 5/8
131	8 5/16	11 1/12	13 3/10	16 5/8	172	10 7/8	14 6/12	17 4/10	21 3/4
132	8 3/8	11 2/12	13 4/10	16 3/4	173	10 15/16	14 7/12	17 5/10	21 7/8

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

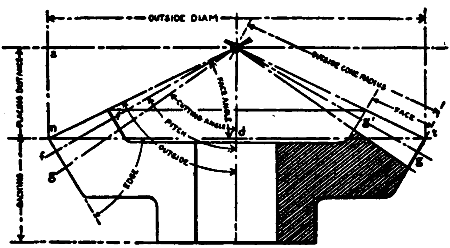
DIAGRAM AND FORMULA FOR THE SELECTION OF BEVEL GEAR CUTTERS



Na = Number of teeth in gear.
Nb = Number of teeth in pinion.
a = Center angle of gear.

Measure the back cone radius A for the gear or B for the pinion. This is equal to the radius of a spur gear, the number of teeth in which would determine the cutter to use. Hence twice A times the diametral pitch equals the number of teeth for which the cutter should be selected for the gear. Looking in the list on page 31 the proper number for the cutter can be found.

Thus, let the back cone radius A be 3 inches and the diametral pitch be 6. Twice 3 is 6 and 6 × 6 is 36, from which it can be seen that the cutter must be of shape No. 3, as 36 is between 35 and 54, the range covered by a No. 3 cutter.



Bevel Gear Parts

FORMULA FOR THE SELECTION OF BEVEL GEAR CUTTERS—*Continued*

The number of teeth for which the cutter should be selected can also be found by following formula:

$$\text{Tan. } a = \frac{Na}{Nb}$$

$$\text{No. of teeth to select cutter for gear} = \frac{Na}{\text{Cos. } a}$$

$$\text{No. of teeth to select cutter for pinion} = \frac{Nb}{\text{Sin. } a}$$

If the gears are mitres or alike, only one cutter is needed; if one gear is larger than the other, two may be needed.

COMPUTING THE OFFSET

The formula quite generally used is:

$$O = \frac{T}{2} - \frac{R}{P}$$

in which O is the amount of offset.

T is the thickness of cutter tooth at the pitch line corresponding to the large end of the tooth.

R is the factor selected from the table.

P is the pitch of the gear.

The factor R is taken from the table for set-over.

First find the value $\left(\frac{C}{F}\right)$ which is the ratio between the pitch cone radius and the face of tooth.

TABLE FOR OBTAINING SET-OVER FOR CUTTING BEVEL GEARS

No. of Cutter	Ratio of Pitch Cone Radius to Width of Face $\left(\frac{C}{F}\right)$												
	$\frac{3}{1}$	$\frac{3\frac{1}{4}}{1}$	$\frac{3\frac{1}{2}}{1}$	$\frac{3\frac{3}{4}}{1}$	$\frac{4}{1}$	$\frac{4\frac{1}{4}}{1}$	$\frac{4\frac{1}{2}}{1}$	$\frac{4\frac{3}{4}}{1}$	$\frac{5}{1}$	$\frac{5\frac{1}{2}}{1}$	$\frac{6}{1}$	$\frac{7}{1}$	$\frac{8}{1}$
1	.254	.254	.255	.256	.257	.257	.257	.258	.258	.259	.260	.262	.264
2	.266	.268	.271	.272	.273	.274	.274	.275	.277	.279	.280	.283	.284
3	.266	.268	.271	.273	.275	.278	.280	.282	.283	.286	.287	.290	.292
4	.275	.280	.285	.287	.291	.293	.296	.298	.298	.302	.305	.308	.311
5	.280	.285	.290	.293	.295	.296	.298	.300	.302	.307	.309	.313	.315
6	.311	.318	.323	.328	.330	.334	.337	.340	.343	.348	.352	.356	.362
7	.289	.298	.308	.316	.324	.329	.334	.338	.343	.350	.360	.370	.376
8	.275	.286	.296	.309	.319	.331	.338	.344	.352	.361	.368	.380	.386

NOTE: For obtaining set-over by above table, use this formula:

$$\text{Set-over} = \frac{T}{2} - \frac{\text{factor from table}}{P}$$

P = diametral pitch of gear to be cut.
T = thickness of cutter used, measured at pitch line.

 Courtesy of The Union Twist Drill Co.

INVOLUTE GEAR CUTTERS

Eight cutters are required for each pitch and are interchangeable with half number cutters where a finer division of teeth is required. Gears cut with the half number cutters, on account of the smaller range covered are more accurate and better running. The cutters are adapted to cut from a pinion of 12 teeth to a rack and are numbered as shown in the table below, the range being the number of teeth.

No. Cutter	Range	No. Cutter	Range	No. Cutter	Range
1	135 to a rack	3½	30 to 34	6	17 to 20
1½	80 to 134	4	26 to 34	6½	15 to 16
2	55 to 134	4½	23 to 25	7	14 to 16
2½	42 to 54	5	21 to 25	7½	13
3	35 to 54	5½	19 to 20	8	12 to 13

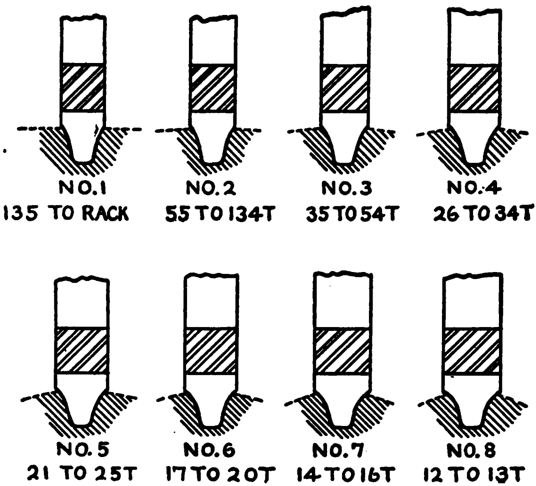
COMPARATIVE CURVES OF INVOLUTE TOOTH SHAPES

The diagram will illustrate how the curves vary in the eight different cutters necessary to make a complete set of one pitch.

It will be noticed that there is a gradual increase in the curve of the tooth outline from the No. 1 to the No. 8 cutter, which will make it clear that one cutter cannot be suitable for cutting all sizes of gears.

It has been found by experiment that the set of eight cutters will cut gears from 12 teeth to a rack and give very good results, but a cutter should never be used for any gear other than those included in the range which it is designed to cut.

All gears of the same pitch cut with these cutters will be interchangeable.



The above cutters represent eight Diametral Pitch

FEEDS FOR GEAR CUTTING — 1

The gears are assumed to be of substantial design, and the belts on the machine to be in good condition. For steel gears, a lard oil lubricant is used. For teeth coarser than 1¾ diametral pitch, feeds are not given for finishing in one cut, because satisfactory results cannot be obtained with a single cut on the No. 7 machine.

For *Carbon-steel Cutters* with a peripheral speed on cast iron of 35 feet per minute, and on steel of 30 feet per minute.

Diametral Pitch of Gear	Cast Iron Gears	Soft Steel Gears	High Carb'n Steel	Nickel Steel Alloy	Cast Iron Gears	Soft Steel Gears	High Carb'n Steel	Nickel Steel Alloy	Arrows Indicate Range of Different Sizes of Machines
	Feed, inches per minute, when Finishing in One Cut				Feed, inches per minute, for Roughing Cut, leaving 0.010 to 0.030 inch for Finishing				
1	....	....	....	....	1⅝	1¼	1	1	
1¼	....	....	....	....	1⅝	1¼	1	1	
1½	....	....	....	....	2 1/16	1⅝	1¼	1	
1¾	2 1/16	1 11/16	1 5/16	1	3⅜	2 11/16	2 1/16	1 11/16	
2	2½	2	1 11/16	1¼	4 1/16	3⅛	2½	2	
2½	2½	2	1 11/16	1¼	4 1/16	3⅛	2½	2	
3	3 7/16	2½	1⅝	1¼	4 1/16	3 7/16	2½	2	
4	3 7/16	2½	2	1⅝	4¼	3 7/16	2½	2	
5	3 7/16	2½	2	1⅝	4¼	3 7/16	2½	2	
6	3 7/16	2½	2	1⅝	4¼	3 7/16	2½	2	
7	3 7/16	2½	2	1⅝	4¼	3 7/16	2½	2	
8	3 7/16	2½	2	1⅝	5 7/16	4¼	3 7/16	2½	No. 3 No. 4 No. 5 No. 6 No. 7
9	4¼	3 7/16	2½	2	5 7/16	4¼	3 7/16	2½	
10	4¼	3 7/16	2½	2	5 7/16	4¼	3 7/16	2½	
	When using Shearing Tooth Cutter for Roughing Cut				Finishing Cut				
1	2 1/16	1⅝	1¼	1¼	2 1/16	1⅝	1⅝	1¼	
1¼	2 1/16	1⅝	1¼	1¼	2 1/16	1⅝	1⅝	1¼	
1½	2 11/16	2 11/16	1⅝	1¼	2 11/16	2 1/16	2 1/16	1⅝	
1¾	4⅜	4⅜	3⅜	2 11/16	4⅜	3⅜	2 11/16	2 1/16	
2	5⅛	4 1/16	3⅛	2½	4 1/16	3⅛	2½	2	
2½	5⅛	4 1/16	3⅛	2½	4 1/16	3⅛	2½	2	
3	5 7/16	4¼	3 7/16	2½	4¼	3 7/16	2½	2	
4	5 7/16	4¼	3 7/16	2½	4¼	3 7/16	2½	2	
5	5 7/16	4¼	3 7/16	2½	4¼	3 7/16	2½	2	
6	5 7/16	4¼	3 7/16	2½	4¼	3 7/16	2½	2	
7	5 7/16	4¼	3 7/16	2½	4¼	3 7/16	2½	2	
8	6 11/16	5 7/16	4¼	3 7/16	5 7/16	4¼	3 7/16	2½	No. 3 No. 4 No. 5 No. 6 No. 7
9	6 11/16	5 7/16	4¼	3 7/16	5 7/16	4¼	3 7/16	2½	
10	6 11/16	5 7/16	4¼	3 7/16	5 7/16	4¼	3 7/16	2½	

Courtesy of The Cincinnati Milling Machine Company

FEEDS FOR GEAR CUTTING — 2

The gears are assumed to be of substantial design, and the belts on the machine to be in good condition. For steel gears, a lard oil lubricant is used. For teeth coarser than 1¾ diametral pitch, feeds are not given for finishing in one cut, because satisfactory results cannot be obtained with a single cut on the No. 7 machine.

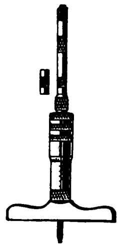
For *High-Speed Steel Cutters* with a peripheral speed on cast iron of 55 feet per minute and 80 feet per minute on steel.

Diametral Pitch of Gear	Cast Iron Gears	Soft Steel Gears	High Carbon Steel	Nickel Steel Alloy	Cast Iron Gears	Soft Steel Gears	High Carbon Steel	Nickel Steel Alloy	Arrows Indicate Range of Different Sizes of Machines
	Feed, inches per minute, when Finishing in One Cut				Feed, inches per minute, for Roughing Cut, leaving 0.010 to 0.030 inch for Finishing				
1	....	....	....	....	2	1⅝	1⅝	1¼	
1¼	....	....	....	....	2½	2	2	1⅝	
1½	....	....	....	....	3⅜	2 1/16	2 1/16	2 1/16	
1¾	2 11/16	2 1/16	2 1/16	1 11/16	4⅜	3⅜	3⅜	2 11/16	
2	3⅛	2½	2½	1 13/16	5⅛	4	4	3⅛	
2½	3⅛	2½	2½	1 13/16	5⅛	4	4	3⅛	
3	3 7/16	2½	2½	2	5 7/16	4¼	4¼	3 7/16	
4	3 7/16	2½	2½	2	5 7/16	4¼	4¼	3 7/16	
5	3 7/16	2½	2½	2	5 7/16	4¼	4¼	3 7/16	
6	4¼	3 7/16	3 7/16	2½	5 7/16	4¼	4¼	3 7/16	No. 3 No. 4 No. 5 No. 6 No. 7
7	4¼	3 7/16	3 7/16	2½	5 7/16	4¼	4¼	3 7/16	
8	4¼	3 7/16	3 7/16	2½	5 7/16	4¼	4¼	3 7/16	
9	5 7/16	4¼	4¼	3 7/16	6 11/16	5 7/16	5 7/16	4¼	
10	5 7/16	4¼	4¼	3 7/16	6 11/16	5 7/16	5 7/16	4¼	
	When using Shearing Tooth Cutter for Roughing Cut				Finishing Cut				
1	2½	2	2	1⅝	2 11/16	2 11/16	2 11/16	2 1/16	
1¼	3 5/16	2½	2½	2	3 5/16	3 5/16	3 5/16	2 11/16	
1½	4⅜	4⅜	3⅜	3⅜	4⅜	4⅜	4⅜	3⅜	
1¾	5 9/16	5 9/16	4⅜	4 1/16	5 9/16	5 9/16	5 5/16	4⅜	
2	6 9/16	6 9/16	5⅛	4 1/16	6 9/16	6 9/16	6 9/16	5⅛	
2½	6 9/16	6 9/16	5⅛	4 1/16	6 9/16	6 9/16	6 9/16	5⅛	
3	8½	8½	6 11/16	5 7/16	6 11/16	6 11/16	6 11/16	5 7/16	
4	8½	8½	6 11/16	5 7/16	6 11/16	6 11/16	6 11/16	6 11/16	
5	8½	8½	6 11/16	5 7/16	6 11/16	6 11/16	6 11/16	6 11/16	
6	8½	8½	6 11/16	5 7/16	6 11/16	6 11/16	6 11/16	6 11/16	No. 3 No. 4 No. 5 No. 6 No. 7
7	8½	8½	6 11/16	5 7/16	6 11/16	6 11/16	6 11/16	6 11/16	
8	10⅝	10⅝	8½	8½	6 11/16	6 11/16	6 11/16	6 11/16	
9	10⅝	10⅝	8½	8½	8½	8½	8½	8½	
10	10⅝	10⅝	8½	8½	8½	8½	8½	8½	

Courtesy of The Cincinnati Milling Machine Company

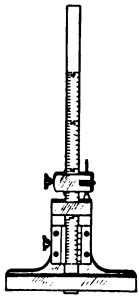
STARRETT TOOLS FOR USE IN CONNECTION WITH GEARS AND GEARING

Micrometer Depth Gage



Has $\frac{1}{2}$ inch movement of the screw reading in thousandths; with two $\frac{1}{2}$ inch and one 1 inch standard collars to slip on or off the spindle, $2\frac{1}{2}$ inches, reading in thousandths can be obtained. The head and the point of the measuring rod are hardened. May also be had in metric measurements.

Vernier Depth Gage



Blade is 6 inches long, $\frac{9}{32}$ inch wide and will measure to $3\frac{1}{2}$ inches in depth. The blade is graduated to read by means of a vernier to thousandths of an inch on one edge and to 64ths on the other. Also made in metric graduations.

Spring-Tempered Rule

A high grade rule graduated into parts of an inch as follows: first corner, 10, 20, 50, 100; second corner, 12, 24, 48; third corner, 16, 32, 64; fourth corner, 14, 28. Light and thin. Warranted to agree with the U. S. Government Standards.

For further information concerning these and other tools which may be used to advantage with Gears and Gearing, see page 98 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

GRADE AND GRAIN OF GRINDING WHEELS FOR DIFFERENT MATERIALS

The information contained in this table is general and intended only to give an approximate idea of the grade used under ordinary conditions.

Class of Work	Alundum		Crystolon	
	Grain	Grade	Grain	Grade
Aluminum castings	36 to 46	3 to 4 Elas	20 to 24	P to R
Brass or bronze castings (large)	....	....	20 to 24	Q to R
Brass or bronze castings (small)	....	....	24 to 36	P to R
Car wheels, cast iron	....	....	16 to 24	P to R
Car wheels, chilled	20	Q	16 to 24	O to Q
Cast iron, cylindrical	24 comb.	J to K	30 to 46	J to L
Cast iron, surfacing	20 to 46	H to K	16 to 30	J to L
Cast iron (small) castings	24 to 30	P to R	20 to 30	Q to S
Cast iron (large) castings	16 to 20	Q to R	16 to 24	Q to S
Chilled iron castings	20 to 30	P to U	20 to 30	Q
Dies, chilled iron	....	....	20 to 30	O to Q
Dies, steel	36 to 60	J to L	....	....
Drop-forgings	20 to 30	P to R	....	....
Internal cylinder grinding	....	....	30 to 60	I to L
Internal grinding, hardened steel	46 to 60	J to M	....	....
Machine shop use, general	20 to 36	O to Q	....	....
Malleable iron castings (large)	14 to 20	P to U	16 to 20	R to S
Malleable iron castings (small)	20 to 30	P to R	20 to 30	Q to S
Milling cutters, machine grinding	46 to 60	H to M	....	....
Milling cutters, hand grinding	46 to 60	J to M	....	....
Nickel castings	20 to 24	P to Q	20 to 25	R
Pulleys, surfacing cast iron	....	....	30 to 36	K to L
Reamers, taps, etc., hand grinding	46 to 60	K to O	....	....
Reamers, taps, special machines	46 to 60	J to M	....	....
Rolls (cast iron), wet	24 to 36	J to M	24 to 36	J to M
Rolls (chilled iron), finishing	70	1½ to 2 Elas.	70 to 80	1½ to 2 Elas.
Rolls (chilled iron), roughing	....	....	30 to 46	2 to 3 Elas.
Rubber	30 to 50	J to K	30 to 50	K to M
Saws, gumming and sharpening	36 to 50	M to N	....	....
Saws, cold cutting-off	60	O to Q	....	....
Steel (soft), cylindrical grinding	24 comb.	L to N	....	....
	46 to 60	L to N	....	....
Steel (soft), surface grinding	24 to 36	H to K	....	....
Steel (hardened), cylindrical grinding	24 comb.	K	....	....
	46 to 60	J to L	....	....
Steel (hardened), surface grinding	36 to 46	H to K	....	....
Steel, large castings	12 to 20	Q to U	....	....
Steel, small castings	20 to 30	P to R	....	....
Steel (manganese), safe work	16 to 46	L to P	....	....
Structural steel	16 to 24	P to R	....	....
Twist drills, hand grinding	46 to 60	M	....	....
Twist drills, special machines	36 to 60	K to M	....	....
Wrought iron	12 to 30	P to U	....	....
Woodworking tools	46 to 60	K to M	....	....

Courtesy of The Norton Company

GRAIN NUMBERS COMMONLY USED IN VARIOUS POLISHING OPERATIONS*

Aluminum — 120–150–180.
Auto Parts — 24–36–60–70–80–90–120–150.
Auto Springs — 36–54–70.
Axes — 46–54–60–70–80–120–150.
Bicycle Parts — 70–80–90–120–150.
Brass (Plumbers' Supplies) — 36–60–70–80–90–120–150.
Builders' Hardware — 46–80–90–120–180.
Carriage Hardware — 36–46–54.
Cast Iron — 54–60–70–80–200–F–FF–FFF.
Cleaning Lithograph Stones — 60–90.
Cultivator Parts — 24–36–80.
Cutlery — 24–30–36–46–60–70–80–90–180–XF.
Dies — 60–80–90.
Edge Tools — 36–54–60–70–80–90–120–150–180.
Electric Irons — 80.
Electric Starter Parts — 24–36–60–90–120–150–180.
Fence Tools — 70–100–120.
Fireplace Fronts (Cast Iron) — 36–46 60–70–80–90–100–120.
Forgings — 36–46–54–60–70–80–90.
Forks — 36–46–54–60–90–100–150.
Glass — 60–70–80–90–100–120–150–180–200–F–FFF–65F.
Glass (beveling) — 90–120–150.
German Silver — 100–F.
Granite — 60–70–80–90.
Hame Parts — 54–100.
Hammers — 46–54–60–70–80–90–120–180.
Heat Registers — 60.
High Speed Steel — 36–70–80.
Hoes — 30–36–46–54–60–70–90–100.
Iron Beds — 60.
Knives — 12–14–20–36–46–54–60–70–80–90–120.
Lapping Bushings — 90–150–180–FFF.
Lapping Gages — 65F.
Lapping Machine Parts — 200–FFF.
Lapping Steel Balls and Bushings — F–FFF.
Lapping Valves — FFF.
Lenses — 60–70–80–90–120–150–200–FF–FFF–65F.
Mattocks — 46–60–70–120.
Microscopic Specimens — 65F.
Monel Metal — F.
Machine Parts — 54–60–70–100–120–150–F.
Piano Parts — 60–90–120–150.
Picks — 46–54–60–70–80–90–120.
Pliers — 46–54–60–70–80–90–100–120.
Plows — 16–20–24–30–36–70–80–120–180–F.
Renewing Files — 36.
Sad Irons — 60–70–80–90–120–150.
Safes, Safe Deposit Boxes — 8–10–12–14–16.
Saws — 60–70–80–90–120–F–FF–FFF.
Scales — 36–46–54–60–70–80–90–120.
Screws — 46–60–70–80–90.
Shears — 54–60–70–80–90.
Shovels — 30–36–46–60–70–80–90–120.
Skates — 60–70–80–90–120–180–F.
Spark Plugs — 80–120–F.
Stoneware — 24–60.
Stove Parts — 36–46–54–60–70–80–90–120–150–180.
Tools — 46–54–60–70–80–90–100–120–190.
Typewriter Parts — 60–90–120–180.
Vises — 36–46–54–60–70–80–90.
Wood Barrels and Kegs — 20.
Wrenches — 36–46–54–60–70–80–90–100–120.

GRADES OF GRINDING WHEELS **

Grades	Vitrified Process	Silicate Process	Grades	Vitrified Process	Silicate Process
Very Soft	E	¾	Medium	M	3
	F	1		N	3½
	G	1¼		O	4
	H	1½		P	4½
Soft	I	1¾	Hard	Q	5
	J	2		R	5½
	K	2¼		S	6
	L	2½		T	6½
			Very Hard	U	7

*Courtesy of The Norton Company

**Courtesy of the Landis Tool Co.

GRADES OF GRINDING WHEELS

Norton Co.

Vitrified and Silicate: Grade	Grade Mark
Soft	E
	F
	G
Medium Soft	H
	I
	J
	K
	L
Medium	M
	N
	O
Medium Hard	P
	Q
	R
	S
	T
Hard	U
	V
	W
Extremely Hard	X
	Y
	Z
Elastic Wheels	
Soft	1
	1½
	2
	2½
	3
	4
	5
Hard	6

Vitrified Wheel Co.

Vitrified and Silicate: Grade	Grade Mark
Soft	C
	C^1
	C^2
Medium Soft	C^3
	D
	D^1
	D^2
	D^3
Medium	E
	E^1
	E^2
	E^3
Hard	F
	F^1
	F^2
Extremely Hard	F^3
	G
Elastic Wheels	
Soft	½ E
	1 E
	1½ E
Medium Soft	2 E
	2½ E
	3 E
	3½ E
	4 E
Medium	4½ E
	5 E
	5½ E
	6 E
Hard	6½ E

Star Corundum Wheel Co.

Grade	Grade Mark
Extremely Soft	H
	2-H
Very Soft	A
	1-A
	2-A
	3-A
Soft	B
	1-B
	2-B
Medium Soft	3-B
	C
	1-C
	2-C
	3-C
Medium	D
	1-D
	2-D
Medium Hard	3-D
	E
	1-E
	2-E
	3-E
Hard	F
	1-F
	2-F
	3-F
Very Hard	G
	Y
	Z
	2-Z

Safety Emery Wheel Co.

Grade	Grade Mark
Very Soft	H
	H½
Soft	A
	A¼
	A½
	A¾
Medium Soft	M
	M¼
	M½
	M¾
Medium	P
	P¼
	P½
	P¾
Medium Hard	I
	I¼
	I½
	I¾
Hard	O
	O¼
	O½
	O¾
Very Hard	N
	N¼
	N½
	N¾
Extra Hard	E

Chicago Wheel and Mfg. Co.

Grade	Grade Mark
Very Soft	A
	A1
	A2
	A3
Soft	B
	B1
	B2
	B3
Medium Soft	C
	C1
	C2
	C3
Medium	D
	D1
	D2
Medium Hard	D3
	E
	E1
	E2
	E3
Hard	F
	F1
	F2
	F3
Very Hard	G
Extremely Hard	G1

Carborundum Co.

Vitrified and Silicate: Grade	Grade Mark
Very Hard	D
	E
	F
	Gx
Hard	G
	Hx
	H
	Ix
Medium Hard	I
	J
	K
	L
Medium	M
	N
	O
Medium Soft	P
	R
	S
Soft	T
	U
	V
Very Soft	W
Very VerySoft	X
	Y
	Z

Sterling Emery Wheel Mfg. Co.

Vitrified and Silicate: Grade	Grade Mark
Extra Soft	1
	1¼
Very Soft	1½
	1¾
Soft	2
	2¼
	2½
	2¾
Medium	3
	3¼
Hard	3½
	3¾
Very Hard	4
	4¼
	4½
	4¾
Extra Hard	5
	5¼
	5½
	5¾
Special Extra Hard	6

Abrasive Material Co.

Vitrified and Silicate: Grade	Grade Mark
Very Soft	I
	J
Soft	K
	L
Medium	M
	N
Medium Hard	O
	P
Hard	Q
	R
	S
Very Hard	T
	U
Extra Hard	V
Elastic Wheels	
Soft	2
	2¼
	2½
	3
	3½
Hard	4

From "Machinery's" Handbook, The Industrial Press, New York

GRADES OF GRINDING WHEELS

American Emery Wheel Works

Grade	Grade Mark: Vitrified	Silicate	Elastic
Very Soft	G	½	½ E
	H	¾	¾ E
	I	1	1 E
Soft	J	1½	1½ E
	K	2	2 E
	L	2½	2½ E
Medium	M	3	3 E
	N	3½	3½ E
Medium Hard	O	4	4 E
	P	4½	4½ E
	Q	5	5 E
	R	6	6 E
Very Hard	S	7	7 E
	T	......	......
Extra Hard	U	......	......
	V	......	......

Monarch Grinding Wheel Co.

Grade	Grade Mark: Vitrified	Silicate	Elastic
Very Soft	1½	......	......
	1¾	¾	A
Soft	2	1	F
	2¼	1¼	I
	2½	1½	N
	2¾	1¾	E
Medium	3	2	P
	3¼	2¼	R
	3½	2½	O
Hard	3¾	3	D
	4	4	U
	4½	5	C
Very Hard	4¾	6	T
	5	......	......
	6	......	......
......	......	......	......

ALLOWANCES FOR GRINDING

Diameter, Inches	Length, Inches: 3	6	9	12	15	18	24	30	36	42	48
	Allowance, Inches										
½	0.010	0.010	0.010	0.010	0.015	0.015	0.015	0.020	0.020	0.020	0.020
¾	0.010	0.010	0.010	0.010	0.015	0.015	0.015	0.020	0.020	0.020	0.020
1	0.010	0.010	0.010	0.015	0.015	0.015	0.015	0.020	0.020	0.020	0.020
1¼	0.010	0.010	0.015	0.015	0.015	0.015	0.015	0.020	0.020	0.020	0.020
1½	0.010	0.015	0.015	0.015	0.015	0.015	0.020	0.020	0.020	0.020	0.020
2	0.015	0.015	0.015	0.015	0.015	0.020	0.020	0.020	0.020	0.020	0.025
2¼	0.015	0.015	0.015	0.015	0.020	0.020	0.020	0.020	0.020	0.025	0.025
2½	0.015	0.015	0.015	0.020	0.020	0.020	0.020	0.020	0.025	0.025	0.025
3	0.015	0.015	0.020	0.020	0.020	0.020	0.020	0.025	0.025	0.025	0.025
3½	0.015	0.020	0.020	0.020	0.020	0.020	0.025	0.025	0.025	0.025	0.025
4	0.020	0.020	0.020	0.020	0.020	0.025	0.025	0.025	0.025	0.025	0.030
4½	0.020	0.020	0.020	0.020	0.025	0.025	0.025	0.025	0.025	0.030	0.030
5	0.020	0.020	0.020	0.025	0.025	0.025	0.025	0.025	0.030	0.030	0.030
6	0.020	0.020	0.025	0.025	0.025	0.025	0.025	0.030	0.030	0.030	0.030
7	0.020	0.025	0.025	0.025	0.025	0.025	0.030	0.030	0.030	0.030	0.030
8	0.025	0.025	0.025	0.025	0.025	0.030	0.030	0.030	0.030	0.030	0.030
9	0.025	0.025	0.025	0.025	0.030	0.030	0.030	0.030	0.030	0.030	0.030
10	0.025	0.025	0.025	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
11	0.025	0.025	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
12	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030

TABLE OF GRINDING WHEEL SPEEDS

The R. P. M. at which wheels are run is dependent on conditions and style of machine and the work to be ground.

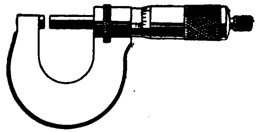
Wheels are run in actual practice from 4,000 to 6,000 feet per minute; in some instances as high as 7,500 feet.

Great care must be taken in operating at these higher speeds and precaution taken against bursting wheels.

Diameter Wheel	Millimeters	Rev. per Minute for Surface Speed of 4,000 Feet, or 1,200 Meters	Rev. per Minute for Surface Speed of 5,000 Feet, or 1,500 Meters	Rev. per Minute for Surface Speed of 5,000 Feet, or 1,800 Meters
1 inch	about 25	15,279	19,099	22,918
2 "	" 50	7,639	9,549	11,459
3 "	" 75	5,093	6,366	7,639
4 "	" 100	3,820	4,775	5,730
5 "	" 125	3,056	3,820	4,584
6 "	" 150	2,546	3,183	3,820
7 "	" 175	2,183	2,728	3,274
8 "	" 200	1,910	2,387	2,865
10 "	" 250	1,528	1,910	2,292
12 "	" 305	1,273	1,592	1,910
14 "	" 355	1,091	1,364	1,637
16 "	" 405	955	1,194	1,432
18 "	" 455	849	1,061	1,273
20 "	" 505	764	955	1,146
22 "	" 515	694	868	1,042
24 "	" 610	637	796	955
26 "	" 660	586	733	879
28 "	" 710	546	683	819
30 "	" 760	509	637	764
32 "	" 810	477	596	716
34 "	" 860	449	561	674
36 "	" 910	424	531	637
38 "	" 965	402	503	603
40 "	" 1,015	382	478	573
42 "	" 1,065	364	455	546
44 "	" 1,115	347	434	521
46 "	" 1,165	332	415	498
48 "	" 1,220	318	397	477
50 "	" 1,270	306	383	459
52 "	" 1,320	294	369	441
54 "	" 1,370	283	354	425
56 "	" 1,420	273	341	410
58 "	" 1,470	264	330	396
60 "	" 1,520	255	319	383

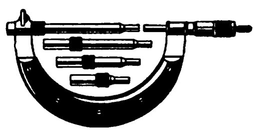
STARRETT TOOLS FOR USE IN CONNECTION WITH GRINDING

Heavy One Inch Micrometers



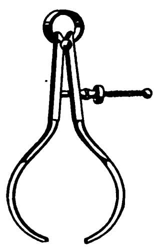
These calipers are made with frame and other parts much heavier than the regular one inch micrometer. Measuring surfaces and bearing parts are hardened. Have ratchet stop and lock nut. Decimal equivalents stamped on the frame measure by thousandths to one inch. Also made in Metric Measure.

U. S. Government Micrometer Caliper Gages



Frames are cut from steel plates. Sides are covered with hard rubber held by brass screws. The Micrometer screw adjusts one inch, reading in thousandths, and has lock nut. The different length tail spindles, forming anvils, are interchangeable. Micrometers are furnished with ratchet stop or speeded screw thumb piece as desired and are made in Metric as well as English Measure.

Toolmakers' Calipers



Made from round stock, with legs drawn down. The fulcrum stud is hardened, bows extra strong. Made with solid nut only.

For further information concerning these and other tools which may be used to advantage in connection with Grinding, see pages 18, 34, 38, 93 and 122 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

HEAT TREATMENT OF HIGH SPEED STEEL

If common forge is used for heating, have a deep fire, plenty of coke, and light blast. In general, an oil, gas, or coke furnace is preferred.

Kind of Steel	Method of Cutting-off Unannealed Bars	Forging Heat*	Directions for Annealing			
			Packing and Packing Material	Time Required for Heating	Temperature Required	Manner of Cooling
Burgess No. 4 and No. 5	Cut off hot	Even cherry-red	3 parts sand, 1 part lime	2 to 3 hours	Bright red	Very slowly
Ark	Cut off hot	Canary color	....	....	....	....
Midvale Special Self-hardening	Nick on wheel break cold	Dull orange	1 part lime, 1 part charcoal	....	Light cherry-red	Slowly
Capital High Speed	....	Full bright red	Heat in air-tight box lined with fire brick	1 to 4 hours	1650°F.	Very slowly
Heller's Alloy High Speed	....	Bright yellow	Powdered charcoal; airtight box	....	Bright yellow (2000°F.)	Slowly
Blue Chip	....	Cherry-red	Lime; air-tight box	....	Bright red or dark yellow	Very slowly
Allen's Air Hardening	....	Bright red	Lime; air-tight box	....	Bright red	Very slowly
Bethlehem Self-hardening	Cut off hot	Between bright cherry-red and full yellow	Heat and bury in lime	....	Bright cherry-red	Slowly
Rex High Speed	Cut off hot	Bright red	Charcoal, lime, or sand; air-tight box	2 to 8 hours	Full red	Very slowly
Novo	Cut off hot	High lemon color	Lime; airtight box	12 to 18 hours; soaking heat	Full red	Very slowly
Bohler's Styrian High Speed	Nick hot, break cold	Bright yellow	Charcoal; airtight box	4 to 6 hours	1830°F.	Slowly
McInnes Extra High Speed	....	Full red	Ashes or lime; air-tight box	....	Cherry-red	Slowly

From "Machinery's" Handbook, The Industrial Press, New York

HEAT TREATMENT OF HIGH SPEED STEEL — *Continued*

Kind of Steel	Hardening Heat, Cooling Medium, Temper and Grinding					
	Lathe and Planer Tools, etc.			Taps, Milling Cutters, etc.		
	Temperature	Cooling Medium	Condition of Wheel used for Grinding	Temperature	Cooling Medium	Temper Required
Burgess No. 4 and No. 5	White welding heat on point	Cold air blast or fish oil†	Dry wheel (grind slowly)	....	....	....
Ark	Fusing heat on point	Cold air blast or thin oil†	Very wet wheel	Light yellow heat	Oil†	....
Midvale Special Self-hardening	White heat	Cold air blast	....	Dark cherry heat; then heat in white hot lead	Oil, cool until color disappears	....
Capital High Speed	White heat	Cold air blast	Wet sandstone	Full white heat	Cold air blast	No temper
Heller's Alloy High Speed	Bright yellow heat	Air blast or fish oil†	Wet stone	Bright yellow heat*	Air blast†	Temper seldom required
Blue Chip	Clear white heat on point	Air blast or oil	Dry wheel	White heat just below fusing	Oil	Straw color
Allen's Air Hardening	White heat on point	Cold air blast or water at 150°F.	Wet stone	....	....	....
Bethlehem Self-hardening	White heat on point	Dry, cold air blast	....	As hot as possible without fusing	Oil	....
Rex High Speed	Fusing heat on point	Cold air blast (cool until tool can be held in the hand)†	Wet or dry	As hot as possible without fusing	Oil†	Temper if necessary
Novo	Fusing heat on point	Cold air blast or running lard or fish oil†	Wet wheel (grind slowly)	Red heat; then white heat in furnace	Thin fish or cotton-seed oil†	According to use of tool
Bohler's Styrian High Speed	White heat (not fusing)	Cold air blast	....	White heat just below fusing	Fish oil	....
McInnes Extra High Speed	Fusing heat on point	Air blast or fish oil	Dry stone	Light cherry-red heat	Air blast or fish oil	....

*Do not use gas fire.
†Steel must not be dipped in water while hot.

From "Machinery's" Handbook, The Industrial Press, New York

HIGH TEMPERATURE JUDGED BY COLOR
AND COLORS FOR TEMPERING

Degrees Centigrade	Degrees Fahrenheit	High Temperatures Judged by Color	Degrees Centigrade	Degrees Fahrenheit	Colors for Tempering
400	752	Red heat, visible in the dark	221.1	430	Very pale yellow
474	885	Red heat, visible in the twilight	226.7	440	Light yellow
			232.2	450	Pale straw-yellow
525	975	Red heat, visible in the daylight	237.8	460	Straw-yellow
			243.3	470	Deep straw-yellow
581	1077	Red heat, visible in the sunlight	248.9	480	Dark yellow
			254.4	490	Yellow-brown
700	1292	Dark red	260.0	500	Brown-yellow
800	1472	Dull cherry-red	265.6	510	Spotted red-brown
900	1652	Cherry-red	271.1	520	Brown-purple
1000	1832	Bright cherry-red	276.7	530	Light purple
1100	2012	Orange-red	282.2	540	Full purple
1200	2192	Orange-yellow	287.8	550	Dark purple
1300	2372	Yellow-white	293.3	560	Full blue
1400	2552	White welding heat	298.9	570	Dark blue
1500	2732	Brilliant white			
1600	2912	Dazzling white (bluish-white)			

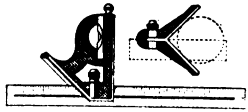
TEMPERING TEMPERATURES FOR VARIOUS TOOLS

Degrees F.	Class of Tool
495 to 500	Taps ½ inch or over, for use on automatic screw machines.
490 to 495	Taps ½ inch or over, for use on screw machines where they pass through the work.
495 to 500	Nut taps ½ inch and under.
515 to 520	Taps ¼ inch and under, for use on automatic screw machines.
525 to 530	Thread dies to cut thread close to shoulder.
500 to 510	Thread dies for general work.
495	Thread dies for tool steel or steel tube.
440 to 445	Circular thread chaser for use on lathes.
525 to 540	Dies for bolt threader threading to shoulder.
460 to 470	Thread rolling dies.
430 to 435	Hollow mills (solid type) for roughing on automatic screw machine work.
450 to 455	Hollow mills (solid type) for use on the drill press.
485	Knurls.
450	Twist drills for hard service.
450	Centering tools for automatic screw machine.
430	Forming tools for automatic screw machine.
430 to 435	Cut-off tools for automatic screw machine.
440 to 450	Profile cutters for milling machine.
430	Formed milling cutters.
435 to 440	Milling cutters.
430 to 440	Reamers.
460	Counterbores and countersinks.
440 to 450	Fly-cutters for use on the drill press.
480	Cutters for tube or pipe-cutting machine.
430 to 440	Dies for heading bicycle spokes.
430	Punches for heading bicycle spokes.
430	Backer blocks for spoke drawing dies.
400	Drawing dies for bicycle spokes.
800	Leaf or carriage springs.
460 and 520	Snaps for pneumatic hammers — harden full length, temper to 460 degrees, then bring point to 520 degrees.

From "Machinery's" Handbook,
The Industrial Press, New York

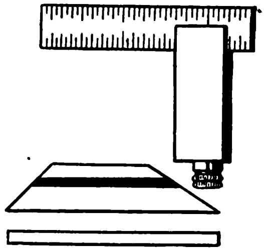
STARRETT TOOLS FOR PATTERN, TOOL, AND DIE MAKERS

Combination Square



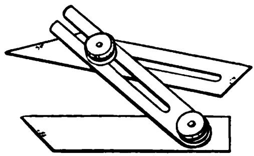
The same as the standard Starrett Combination Square with hardened blade, except that the blades are graduated the same as Shrink Rules, with $\frac{1}{8}$ or $\frac{3}{16}$ inch shrinkage to the foot.

Tool and Die Makers' Square



Blade can be adjusted to an angle with the beam. The rule is narrow and adjustable to any lengths. Comprises $2\frac{1}{2}$ inch sliding scale, graduated in 32ds and 64ths, very narrow straight blade and a bevel blade.

Combination Bevel

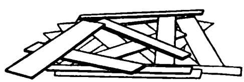


Bevel has stud in straightedge stock on which its split blade is hinged, permitting it to be set at any angle. Slotted auxiliary blade with clamp bolt slips onto split blade and may be set at any angle. Tool will lie flat on work.

Toolmakers' Buttons

Hardened and ground to standard size. The buttons furnished screwed to a small plate, which makes a convenient holder for them when not in use.

Ground Flat Stock



Ground to within .001 inch of the given thickness and of fine quality. Annealed. Furnished in $\frac{1}{16}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{5}{32}$, $\frac{3}{16}$, $\frac{7}{32}$, and $\frac{1}{4}$ inch.

For other tools especially adapted to the needs of tool, pattern, and die makers, see pages 13, 18, 21, 51, 58, 61, 62, 63, 89, 95 and 98 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

DIMENSIONS OF KEYS AND KEY-SEATS

Size of Hole	Decimal Equivalent	Preferred Width of Key-Seat	Nearest Size of Cutter	Preferred Thickness of Key	Nearest Fractional Thickness	Depth to be Cut in Hub for Straight Key	Depth at Large End for Taper Key
1	1.	.25	1/4	.166	3/16	.093	.112
1 1/16	1.062	.265	1/4	.177	3/16	.093	.112
1 1/8	1.125	.281	1/4	.187	3/16	.093	.112
1 3/16	1.187	.296	5/16	.198	7/32	.109	.131
1 1/4	1.25	.312	5/16	.208	7/32	.109	.131
1 5/16	1.312	.328	5/16	.219	7/32	.109	.131
1 3/8	1.375	.343	3/8	.229	1/4	.125	.15
1 7/16	1.437	.359	3/8	.239	1/4	.125	.15
1 1/2	1.5	.375	3/8	.25	1/4	.125	.15
1 9/16	1.562	.39	3/8	.26	1/4	.125	.15
1 5/8	1.625	.406	7/16	.271	9/32	.141	.168
1 11/16	1.687	.421	7/16	.281	9/32	.141	.168
1 3/4	1.75	.437	7/16	.292	9/32	.141	.168
1 13/16	1.812	.453	7/16	.302	9/32	.141	.168
1 7/8	1.875	.468	1/2	.312	11/32	.171	.206
1 15/16	1.937	.484	1/2	.323	11/32	.171	.206
2	2.	.5	1/2	.333	11/32	.171	.206
2 1/16	2.062	.515	1/2	.344	11/32	.171	.206
2 1/8	2.125	.531	1/2	.354	11/32	.171	.206
2 3/16	2.187	.547	1/2	.364	11/32	.171	.206
2 1/4	2.25	.563	1/2	.375	11/32	.171	.206
2 5/16	2.312	.578	1/2	.385	11/32	.171	.206
2 3/8	2.375	.593	5/8	.396	7/16	.218	.262
2 7/16	2.437	.609	5/8	.406	7/16	.218	.262
2 1/2	2.5	.625	5/8	.416	7/16	.218	.262
2 9/16	2.562	.641	5/8	.427	7/16	.218	.262
2 5/8	2.625	.656	5/8	.437	7/16	.218	.262
2 11/16	2.687	.672	5/8	.448	7/16	.218	.262
2 3/4	2.75	.687	5/8	.458	7/16	.218	.262
2 13/16	2.812	.703	5/8	.469	7/16	.218	.262
2 7/8	2.875	.719	3/4	.479	1/2	.25	.3
2 15/16	2.937	.734	3/4	.49	1/2	.25	.3
3	3.	.75	3/4	.5	1/2	.25	.3
3 1/8	3.125	.781	3/4	.521	1/2	.25	.3
3 3/16	3.187	.797	3/4	.531	1/2	.25	.3
3 1/4	3.25	.812	3/4	.542	1/2	.25	.3
3 3/8	3.375	.844	7/8	.562	5/8	.312	.375
3 7/16	3.437	.859	7/8	.573	5/8	.312	.375
3 1/2	3.5	.875	7/8	.583	5/8	.312	.375
3 5/8	3.625	.906	7/8	.604	5/8	.312	.375
3 11/16	3.687	.923	7/8	.614	5/8	.312	.375
3 3/4	3.75	.937	7/8	.625	5/8	.312	.375
3 7/8	3.875	.969	1	.646	11/16	.343	.412
3 15/16	3.937	.984	1	.656	11/16	.343	.412
4	4.	1.	1	.666	11/16	.343	.412

Courtesy of Baker Bros

DIMENSIONS OF STRAIGHT KEYS

Diameter of Shaft	Width of Key	Thickness of Key	Diameter of Shaft	Width of Key	Thickness of Key	Diameter of Shaft	Width of Key	Thickness of Key	Diameter of Shaft	Width of Key	Thickness of Key
0			1¼	5/16	5/16	2½	½	7/16	3¾	¾	11/16
1/16			1 5/16	5/16	5/16	2 9/16	9/16	½	3 13/16	¾	11/16
⅛			1⅜	5/16	5/16	2⅝	9/16	½	3⅞	13/16	¾
3/16			1 7/16	5/16	5/16	2 11/16	9/16	½	3 15/16	13/16	¾
¼			1½	5/16	5/16	2¾	9/16	½	4	13/16	¾
5/16	3/32	3/32	1 9/16	⅜	⅜	2 13/16	9/16	½	4⅛	13/16	¾
⅜	3/32	3/32	1⅝	⅜	⅜	2⅞	9/16	½	4¼	⅞	¾
7/16	⅛	⅛	1 11/16	⅜	⅜	2 15/16	⅝	9/16	4⅜	⅞	¾
½	⅛	⅛	1¾	⅜	⅜	3	⅝	9/16	4½	15/16	13/16
9/16	⅛	⅛	1 13/16	⅜	⅜	3 1/16	⅝	9/16	4¾	15/16	13/16
⅝	3/16	3/16	1⅞	7/16	⅜	3⅛	⅝	9/16	4⅞	1	⅞
11/16	3/16	3/16	1 15/16	7/16	⅜	3 3/16	⅝	9/16	5	1	⅞
¾	3/16	3/16	2	7/16	⅜	3¼	11/16	⅝	5⅛	1 1/16	⅞
13/16	3/16	3/16	2 1/16	7/16	⅜	3 5/16	11/16	⅝	5¼	1 1/16	⅞
⅞	3/16	3/16	2⅛	7/16	⅜	3⅜	11/16	⅝	5⅜	1 1/16	⅞
15/16	¼	¼	2 3/16	½	7/16	3 7/16	11/16	⅝	5½	1⅛	15/16
1	¼	¼	2¼	½	7/16	3½	11/16	⅝	5⅝	1⅛	15/16
1 1/16	¼	¼	2 5/16	½	7/16	3 9/16	¾	11/16	5¾	1⅛	15/16
1⅛	¼	¼	2⅜	½	7/16	3⅝	¾	11/16	5⅞	1 3/16	1
1 3/16	¼	¼	2 7/16	½	7/16	3 11/16	¾	11/16	6	1 3/16	1

DIMENSIONS OF KEYS AND KEY-SEATS

The following rules by Baker Bros., Toledo, Ohio, give dimensions of keys and key-seats:

The width of the key should equal one quarter, and the thickness of the key one sixth the diameter of the shaft. The depth in the hub for a straight key-seat should be one half the thickness of the key. For a taper key-seat, the depth in the hub at the large end should be three fifths the thickness of the key. The taper for key-seats should be 1/16 in. in one foot of length. The depth to be cut in the hub for taper key-seats, at the larger end, is greater than those cut straight, as otherwise the depth in the hub at the small end will not be sufficient, especially in long key-seats.

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

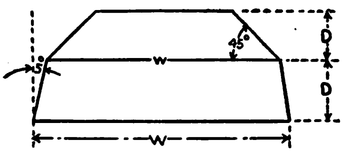
SQUARE FEATHER KEY SIZES

Diameter of Shaft	Size of Key	Diameter of Shaft	Size of Key
1 to 1 1/8	1/4 x 1/4	3 3/16 to 3 3/8	13/16 x 13/16
1 3/16 to 1 3/8	5/16 x 5/16	3 7/16 to 3 5/8	7/8 x 7/8
1 7/16 to 1 5/8	3/8 x 3/8	3 11/16 to 3 7/8	15/16 x 15/16
1 11/16 to 1 7/8	7/16 x 7/16	3 15/16 to 4 1/8	1 x 1
1 15/16 to 2 1/8	1/2 x 1/2	4 3/16 to 4 3/8	1 1/16 x 1 1/16
2 3/16 to 2 3/8	9/16 x 9/16	4 7/16 to 4 3/4	1 1/8 x 1 1/8
2 7/16 to 2 5/8	5/8 x 5/8	4 13/16 to 5 1/4	1 1/4 x 1 1/4
2 11/16 to 2 7/8	11/16 x 11/16	5 5/16 to 5 3/4	1 3/8 x 1 3/8
2 15/16 to 3 1/8	3/4 x 3/4	5 13/16 to 6 1/4	1 1/2 x 1 1/2

STRAIGHT KEY SIZES

Diameter of Shaft	Size of Key	Diameter of Shaft	Size of Key
1 to 1 1/8	1/4 x 3/16	3 3/16 to 3 3/8	13/16 x 17/32
1 3/16 to 1 3/8	5/16 x 7/32	3 7/16 to 3 5/8	7/8 x 19/32
1 7/16 to 1 5/8	3/8 x 1/4	3 11/16 to 3 7/8	15/16 x 5/8
1 11/16 to 1 7/8	7/16 x 9/32	3 15/16 to 4 1/8	1 x 11/16
1 15/16 to 2 1/8	1/2 x 11/32	4 3/16 to 4 3/8	1 1/16 x 11/16
2 3/16 to 2 3/8	9/16 x 3/8	4 7/16 to 4 3/4	1 1/8 x 3/4
2 7/16 to 2 5/8	5/8 x 13/32	4 13/16 to 5 1/4	1 1/4 x 27/32
2 11/16 to 2 7/8	11/16 x 15/32	5 5/16 to 5 3/4	1 3/8 x 29/32
2 15/16 to 3 1/8	3/4 x 1/2	5 13/16 to 6 1/4	1 1/2 x 1

THE BARTH KEY

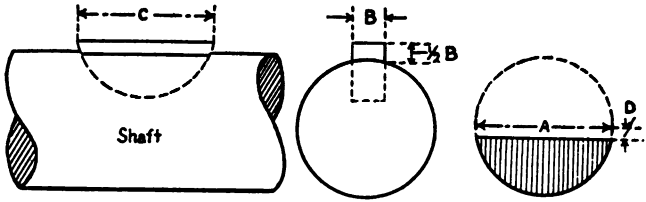


No. of Key	w	W	D
1	1/8	.132	5/128
2	5/32	.165	3/64
3	3/16	.199	1/16
4	1/4	.264	5/64
5	5/16	.329	3/32

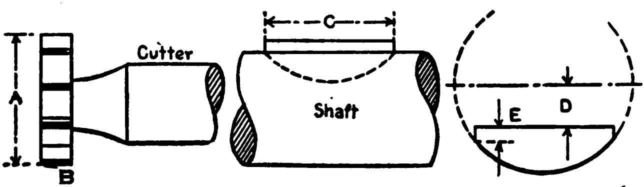
From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

WHITNEY KEYS AND CUTTERS. Nos. 1 to 26

(Woodruff's Patent)



No. of Key and Cutter	Diam. of Cutter	Thick-ness of Key and Cutter	Length of Key	Key Cut Below Center	No. of Key and Cutter	Diam. of Cutter	Thick-ness of Key and Cutter	Length of Key	Key Cut Below Center
	A	B	C	D		A	B	C	D
1	1/2	1/16	1/2	3/64	16	1 1/8	3/16	1 1/8	5/64
2	1/2	3/32	1/2	3/64	17	1 1/8	7/32	1 1/8	5/64
3	1/2	1/8	1/2	3/64	18	1 1/8	1/4	1 1/8	5/64
4	5/8	3/32	5/8	1/16	C	1 1/8	5/16	1 1/8	5/64
5	5/8	1/8	5/8	1/16	19	1 1/4	3/16	1 1/4	5/64
6	5/8	5/32	5/8	1/16	20	1 1/4	7/32	1 1/4	5/64
7	3/4	1/8	3/4	1/16	21	1 1/4	1/4	1 1/4	5/64
8	3/4	5/32	3/4	1/16	D	1 1/4	5/16	1 1/4	5/64
9	3/4	3/16	3/4	1/16	E	1 1/4	3/8	1 1/4	5/64
10	7/8	5/32	7/8	1/16	22	1 3/8	1/4	1 3/8	3/32
11	7/8	3/16	7/8	1/16	23	1 3/8	5/16	1 3/8	3/32
12	7/8	7/32	7/8	1/16	F	1 3/8	3/8	1 3/8	3/32
A	7/8	1/4	7/8	1/16	24	1 1/2	1/4	1 1/2	7/64
13	1	3/16	1	1/16	25	1 1/2	5/16	1 1/2	7/64
14	1	7/32	1	1/16	G	1 1/2	3/8	1 1/2	7/64
15	1	1/4	1	1/16	...	...	...	...	...
B	1	5/16	1	1/16	...	...	...	...	...



Note: Refer to table at top of page 49 for values of dimension E.

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

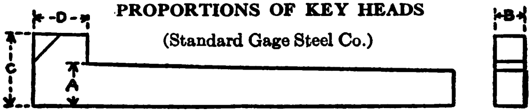
WHITNEY KEYS AND CUTTERS. Nos. 26 to 36

(See Cut on page 48)

No. of Key and Cutter	Diameter of Cutter A	Thickness of Key and Cutter B	Length of Key C	Key Cut Below Center D	Flat at End of Key E	No. of Key and Cutter	Diameter of Cutter A	Thickness of Key and Cutter B	Length of Key C	Key Cut Below Center D	Flat at End of Key E
26	2 1/8	3/16	1 21/32	17/32	3/32	30	3 1/2	3/8	2 7/8	11/16	3/16
27	2 1/8	1/4	1 21/32	17/32	3/32	31	3 1/2	7/16	2 7/8	11/16	3/16
28	2 1/8	5/16	1 21/32	17/32	3/32	32	3 1/2	1/2	2 7/8	11/16	3/16
29	2 1/8	3/8	1 21/32	17/32	3/32						
						33	3 1/2	9/16	2 7/8	11/16	3/16
R	2 3/4	1/4	2 5/16	5/8	1/8	34	3 1/2	5/8	2 7/8	11/16	3/16
S	2 3/4	5/16	2 5/16	5/8	1/8						
T	2 3/4	3/8	2 5/16	5/8	1/8	35	3 1/2	11/16	2 7/8	11/16	3/16
U	2 3/4	7/16	2 5/16	5/8	1/8	36	3 1/2	3/4	2 7/8	11/16	3/16
V	2 3/4	1/2	2 5/16	5/8	1/8						

PROPORTIONS OF KEY HEADS

(Standard Gage Steel Co.)



A	B	C	D	A	B	C	D
1/8	1/8	1/4	7/32	1 5/8	1 5/8	2 3/4	1 7/8
3/16	3/16	5/16	9/32	1 11/16	1 11/16	2 7/8	1 15/16
1/4	1/4	7/16	11/32	1 3/4	1 3/4	3	2
5/16	5/16	9/16	13/32	1 13/16	1 13/16	3 1/8	2 1/16
3/8	3/8	11/16	15/32	1 7/8	1 7/8	3 3/8	2 1/8
7/16	7/16	3/4	17/32	1 15/16	1 15/16	3 5/8	2 3/16
1/2	1/2	7/8	19/32	2	2	3 3/4	2 1/4
9/16	9/16	1	21/32	2 1/16	2 1/16	3 7/8	2 7/16
5/8	5/8	1 1/8	23/32	2 1/8	2 1/8	4	2 1/2
11/16	11/16	1 3/16	25/32	2 3/16	2 3/16	4 1/8	2 9/16
3/4	3/4	1 1/4	7/8	2 1/4	2 1/4	4 1/4	2 5/8
13/16	13/16	1 5/16	15/16	2 5/16	2 5/16	4 3/8	2 11/16
7/8	7/8	1 1/2	1	2 3/8	2 3/8	4 1/2	2 3/4
15/16	15/16	1 5/8	1 1/16	2 7/16	2 7/16	4 5/8	2 13/16
1	1	1 3/4	1 1/8	2 1/2	2 1/2	4 3/4	2 7/8
1 1/16	1 1/16	1 13/16	1 3/16	2 9/16	2 9/16	4 7/8	2 15/16
1 1/8	1 1/8	1 7/8	1 5/16	2 5/8	2 5/8	5	3
1 3/16	1 3/16	1 15/16	1 3/8	2 11/16	2 11/16	5	3 1/16
1 1/4	1 1/4	2	1 7/16	2 3/4	2 3/4	5 1/8	3 1/8
1 5/16	1 5/16	2 1/8	1 1/2	2 13/16	2 13/16	5 1/8	3 3/16
1 3/8	1 3/8	2 1/4	1 9/16	2 7/8	2 7/8	5 1/4	3 1/4
1 7/16	1 7/16	2 3/8	1 5/8	2 15/16	2 15/16	5 1/4	3 5/16
1 1/2	1 1/2	2 1/2	1 3/4	3	3	5 3/8	3 1/2
1 9/16	1 9/16	2 5/8	1 13/16				

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

STANDARD KEYWAYS FOR CUTTERS AND ARBORS*

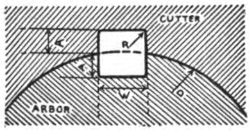


Fig. 80

Diameter of Hole (D) in Cutter, Inches	Width (W), Inches	Depth (A), Inches	Radius (R), Inches
3/8 to 9/16	3/32	3/64	.020
5/8 to 7/8	1/8	1/16	.030
15/16 to 1 1/8	5/32	5/64	.035
1 3/16 to 1 3/8	3/16	3/32	.040
*1 7/16 to 1 3/4	1/4	1/8	.050
*1 13/16 to 2	5/16	5/32	.060
2 1/16 to 2	3/8	3/16	.060
2 5/16 to 3	7/16	3/16	.060

*For all Gear Cutters of 1 1/2 inch, 1 3/4 inch, 2 inch diameters, use 5/16 inch, 3/8 inch, 1/2 inch keys, respectively.

PROPORTIONS OF SUNK KEYS (U. S. NAVY STANDARD)**

Diam. of Shaft	Width of Key	Thickness of Key	Diam. of Shaft	Width of Key	Thickness of Key	Diam. of Shaft	Width of Key	Thickness of Key	Diam. of Shaft	Width of Key	Thickness of Key
1/2	7/32	3/16	2 1/4	9/16	5/16	5	1 1/16	5/8	7 3/4	1 9/16	7/8
5/8	1/4	3/16	2 1/2	5/8	3/8	5 1/4	1 1/8	5/8	8	1 5/8	7/8
3/4	9/32	3/16	2 3/4	5/8	3/8	5 1/2	1 3/16	5/8	8 1/4	1 5/8	15/16
7/8	9/32	7/32	3	11/16	7/16	5 3/4	1 5/16	11/16	8 1/2	1 3/4	15/16
1	5/16	7/32	3 1/4	3/4	7/16	6	1 1/4	11/16	8 3/4	1 3/4	15/16
1 1/8	11/32	1/4	3 1/2	13/16	7/16	6 1/4	1 5/16	3/4	9	1 3/4	1
1 1/4	3/8	1/4	3 3/4	13/16	1/2	6 1/2	1 3/8	3/4	9 1/4	1 7/8	1
1 3/8	3/8	1/4	4	7/8	1/2	6 3/4	1 3/8	3/4	9 1/2	1 7/8	1 1/16
1 1/2	13/32	1/4	4 1/4	15/16	9/16	7	1 7/16	13/16	9 3/4	2	1 1/16
1 3/4	7/16	3/16	4 1/2	1	9/16	7 1/4	1 1/2	13/16	10	2	1 1/16
2	1/2	5/16	4 3/4	1	9/16	7 1/2	1 9/16	7/8	.....	.....	.....

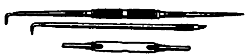
*Courtesy of The Cincinnati Milling Machine Company

**From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

STARRETT TOOLS FOR USE IN CONNECTION WITH KEYS

Key-Seat Rule

Consists of machinists' scale and an auxiliary straightedge held together to form a box square. The auxiliary straightedge is either plain or graduated in 32ds or 64ths, as desired. Is also made with graduations in the Metric system.

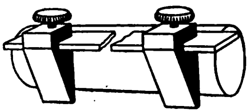


Improved Scriber

Points are made of fine grade steel, well tempered. Stock is knurled and nickeled and of sufficient size to be easily held without cramping or turning in the fingers. All parts are interchangeable.

Steel Rule

Made of light or heavy spring-tempered steel, flexible and semi-flexible, graduated in the English or Metric systems.



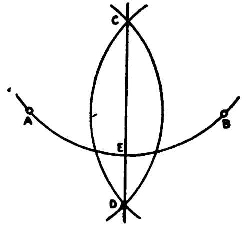
Key-Seat Clamps

Of case hardened steel and ground accurate; will transform any common scale into a Key-Seat Rule. May be used with Starrett Combination Square Blades or any straight rule.

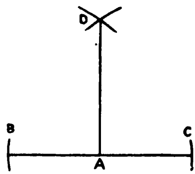
For further information concerning these and other tools which may be used to advantage with Keys, see pages 13, 61, 62, 63 and 122 of this volume; also Vol. I of The Strrrett Books, and the Starrett Catalogue.

GEOMETRIC PROBLEMS

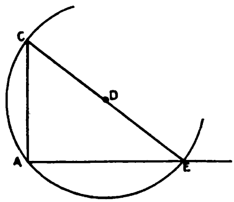
To divide a line into two equal parts. With the ends A and B as centers, and a radius greater than one half the line, draw intersecting arcs. Through the intersections C and D draw the line CD, which bisects the line AB and is also perpendicular to it.



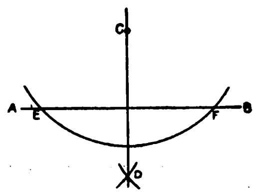
To erect a perpendicular at a given point. With the point A as a center and any radius, draw arcs intersecting the given line at B and C. With B and C as centers and a radius greater than AB, draw arcs intersecting at D. DA is perpendicular to BC at A.



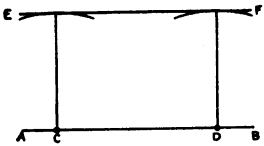
To erect a perpendicular at the end of a line. Take any point D outside the line and with the distance from this point to the end of the line A, as a radius draw an arc intersecting the line AB at E. Draw a line through E and D intersecting the arc at C. AC is the required perpendicular.



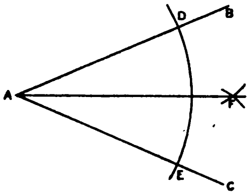
To erect a perpendicular to a line from a point outside it. With the point C as a center, draw an arc intersecting the given line at E and F. With E and F as centers and a radius greater than one half the distance EF, draw arcs intersecting at D. CD is the required perpendicular.



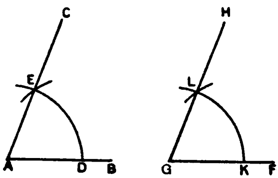
GEOMETRIC PROBLEMS



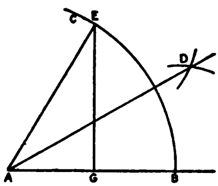
To draw a line parallel to a given line at a given distance, take any points, as C and D, on the line as centers and draw arcs with the given distance as a radius. The line EF tangent to these arcs is the required parallel.



To bisect an angle. With the vertex of the angle A as a center and any radius, draw an arc DE. With D and E as centers and a radius greater than one-half DE, draw arcs intersecting at F. Line AF bisects the angle.



To draw an angle on a line equal to a given angle FGH. With G as a center and any radius, draw arc KL. With the point A on the given line the vertex of the desired angle as a center and with the same radius draw the arc DE. With D as a center and a radius equal to the distance KL, strike an arc intersecting DE and draw the line AC through E. Angle BAC equals angle FGH.

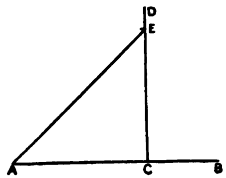


To lay out a 60° angle. With A as a center and any radius, draw the arc BC. With B as a center and AB as a radius draw an arc intersecting BC at E. EAB is a 60° angle.

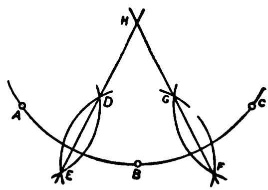
To obtain a 30° angle bisect the angle EAB by taking A as a center and any convenient radius as AB, draw the arc BE. With B and E as centers and any radius greater than one-half BE, draw arcs intersecting at D. Draw line AD. BAD is 30°.

GEOMETRIC PROBLEMS

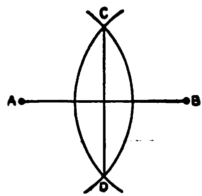
To draw a 45° angle. From point A on the line, lay off any distance, AC. Erect a perpendicular, DC, and lay off distance CE equal to AC. Draw AE. EAC is a 45° angle.



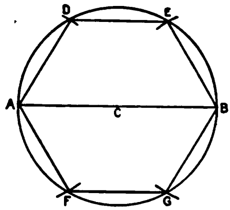
To find the center of a circle. Select three points on the circumference of the circle or an arc, as A, B, and C. With each of these points as a center and the same radius describe arcs intersecting each other. Through the intersections of these arcs draw the line DE and FG. Point H, the intersection of the prolongation of these lines, is the center of the circle.



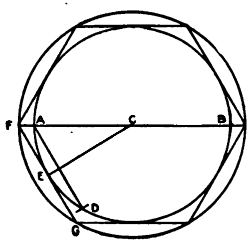
To bisect the arc of a circle. With A and B as centers and a radius greater than one-half the distance AB, draw arcs intersecting at C and D. Line CD bisects the arc AB.



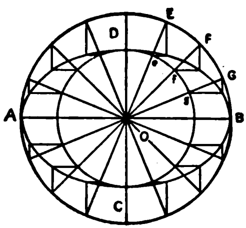
GEOMETRIC PROBLEMS



To inscribe a hexagon in a circle. Draw a diameter at AB. With A and B as centers and the radius of the circle as a radius, describe arcs intersecting the circle at D, E, F, and G. Connect these intersections by lines AD, DE, EB, etc., forming the hexagon.

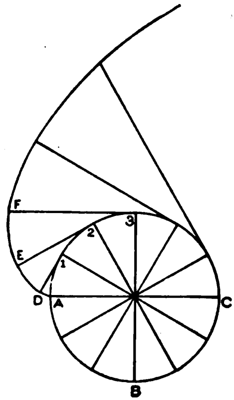


To describe a hexagon without a circle. Draw a diameter AB with A as a center and the radius of the circle as a radius. Strike an arc cutting the circumference of the circle at D. Join AD and bisect it with radius CE. Through E draw FG parallel to AD, intersecting line AB at F. With C as a center and CF as a radius, draw a circle and inscribe a hexagon as previously explained.

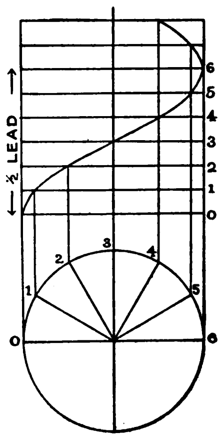


To describe an ellipse given the axes AB and CD. With O, the intersection of AB and CD as a center, describe circles with AB and CD as diameters. From a number of points, E, F, G, etc., on the outer circle draw radii intersecting the inner circle at e, f, g. From E, F, and G draw lines perpendicular to AB and from e, f, g, draw lines parallel to AB. The intersections of these perpendicular and parallel lines are points on the curve of the ellipse.

GEOMETRIC PROBLEMS



To construct an involute. Divide the circumference of the base circle ABC into any number of equal parts. Through the division points 1, 2, 3, etc., draw tangents to the circle, making the length of these tangents equal to the length of the corresponding arcs. Thus D1 equals A1, D2 equals A2, etc.



To construct a helix. Divide half the circumference of the cylinder on the surface of which the helix is to be described, into any number of equal parts. Divide half the lead of the helix into the same number of equal parts. From the division points on the circle representing the cylinder, draw vertical lines and from the division points on the lead draw horizontal lines. The intersections of the lines bearing corresponding numbers are points on the helix.

LENGTHS OF CHORDS FOR SPACING OFF THE CIRCUMFERENCE OF CIRCLES

On the following pages are given tables of the lengths of chords for spacing off the circumference of circles. The object of these tables is to make possible the division of the periphery into a number of equal parts without trials with the dividers. The first table is calculated for circles having a diameter equal to 1. For circles of other diameters, the length of chord given in the table should be multiplied by the diameter of the circle. Assume that it is required to divide the periphery of a circle of 20 inches diameter into thirty-two equal parts. This may be required, for example, when spacing the centers for the bolt holes in a cylinder flange. From the table the length of the chord is found to be 0.098 inch, if the diameter of the circle were 1 inch. With a diameter of 20 inches the length of the chord for one division would be $20 \times 0.098 = 1.96$ inch.

The following pages give an additional table for the spacing off of circles, the table in this case being worked out for diameters from $\frac{1}{16}$ inch to 14 inches. As an example, assume that it is required to divide a circle having a diameter of $6\frac{1}{2}$ inches into seven equal parts. Find first, in the column headed "6" and in line with 7 divisions, the length of the chord for a 6 inch circle, which is 2.604 inches. Then find the length of the chord for a $\frac{1}{2}$ inch diameter circle, 7 divisions, which is 0.217. The sum of these two values, $2.604 + 0.217 = 2.821$ inches, is the length of the chord required for spacing off the circumference of a $6\frac{1}{2}$ inch circle into seven equal divisions.

As another example, assume that it is required to divide a circle having a diameter of $9\frac{23}{32}$ inches into 15 equal divisions. First find the length of the chord for 9 inch circle, which is 1.871 inch. The length of the chord for a $\frac{23}{32}$ inch circle can easily be estimated from the table by taking the value that is exactly between those given for $\frac{11}{16}$ inch and $\frac{3}{4}$ inch. The value for $\frac{11}{16}$ inch is 0.143, and for $\frac{3}{4}$ inch, 0.156. Hence for $\frac{23}{32}$, the value would be 0.150. Then, $1.871 + 0.150 = 2.021$ inches.

TABLE FOR SPACING OFF THE CIRCUMFERENCE OF CIRCLES

(See page 57 for explanatory matter)

No. of Divisions	Degrees in Arc	Diameter of Circle to be Spaced Off														
		$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$
		Length of Chord														
3	120	0.054	0.108	0.162	0.216	0.270	0.324	0.378	0.432	0.486	0.541	0.595	0.649	0.703	0.757	0.811
4	90	0.044	0.088	0.132	0.176	0.221	0.265	0.309	0.353	0.397	0.442	0.486	0.530	0.574	0.618	0.662
5	72	0.037	0.073	0.110	0.146	0.183	0.220	0.257	0.293	0.330	0.367	0.403	0.440	0.477	0.514	0.551
6	60	0.031	0.063	0.094	0.125	0.156	0.188	0.219	0.250	0.281	0.312	0.343	0.375	0.406	0.438	0.469
7	$51\frac{3}{7}$	0.027	0.054	0.081	0.108	0.135	0.162	0.189	0.217	0.244	0.271	0.298	0.325	0.352	0.379	0.406
8	45	0.024	0.048	0.072	0.096	0.120	0.143	0.167	0.191	0.215	0.239	0.263	0.287	0.311	0.335	0.359
9	40	0.021	0.043	0.064	0.086	0.107	0.128	0.149	0.171	0.192	0.214	0.235	0.257	0.278	0.299	0.320
10	36	0.019	0.039	0.058	0.077	0.097	0.116	0.135	0.155	0.174	0.193	0.212	0.232	0.251	0.270	0.289
11	$32\frac{8}{11}$	0.018	0.035	0.053	0.070	0.088	0.105	0.123	0.141	0.158	0.176	0.193	0.211	0.228	0.246	0.264
12	30	0.016	0.032	0.048	0.065	0.081	0.097	0.114	0.130	0.146	0.162	0.178	0.194	0.211	0.227	0.243
13	$27\frac{9}{13}$	0.015	0.030	0.045	0.059	0.074	0.089	0.104	0.119	0.134	0.149	0.164	0.179	0.194	0.209	0.224
14	$25\frac{5}{7}$	0.014	0.028	0.042	0.056	0.069	0.083	0.097	0.111	0.125	0.139	0.153	0.167	0.180	0.194	0.208
15	24	0.013	0.026	0.039	0.052	0.065	0.078	0.091	0.104	0.117	0.130	0.143	0.156	0.169	0.182	0.195
16	$22\frac{1}{2}$	0.012	0.024	0.037	0.049	0.061	0.073	0.085	0.098	0.109	0.122	0.134	0.146	0.158	0.170	0.183
17	$21\frac{3}{17}$	0.011	0.023	0.034	0.046	0.057	0.069	0.080	0.092	0.103	0.115	0.126	0.138	0.149	0.160	0.172
18	20	0.011	0.022	0.032	0.043	0.054	0.065	0.076	0.087	0.097	0.108	0.119	0.130	0.141	0.152	0.163
19	$18\frac{18}{19}$	0.010	0.021	0.031	0.041	0.051	0.062	0.072	0.082	0.092	0.103	0.113	0.123	0.133	0.144	0.154
20	18	0.010	0.020	0.029	0.039	0.049	0.059	0.068	0.078	0.088	0.098	0.107	0.117	0.127	0.136	0.146
21	$17\frac{1}{7}$	0.009	0.019	0.028	0.037	0.047	0.056	0.065	0.075	0.084	0.093	0.102	0.112	0.121	0.130	0.139
22	$16\frac{4}{11}$	0.009	0.018	0.027	0.036	0.045	0.053	0.062	0.071	0.080	0.089	0.098	0.107	0.115	0.124	0.133
23	$15\frac{15}{23}$	0.009	0.017	0.026	0.034	0.043	0.051	0.059	0.068	0.077	0.085	0.094	0.102	0.111	0.119	0.128
24	15	0.008	0.016	0.024	0.033	0.041	0.049	0.057	0.065	0.073	0.082	0.090	0.098	0.106	0.114	0.122
25	$14\frac{2}{5}$	0.008	0.016	0.023	0.031	0.039	0.047	0.055	0.063	0.070	0.078	0.086	0.094	0.102	0.109	0.117
26	$13\frac{11}{13}$	0.008	0.015	0.023	0.030	0.038	0.045	0.053	0.060	0.068	0.075	0.083	0.090	0.098	0.105	0.113
28	$12\frac{6}{7}$	0.007	0.014	0.021	0.028	0.035	0.042	0.049	0.056	0.063	0.070	0.077	0.084	0.091	0.098	0.105
30	12	0.007	0.013	0.019	0.026	0.033	0.039	0.046	0.052	0.059	0.065	0.072	0.078	0.085	0.091	0.098
32	$11\frac{1}{4}$	0.006	0.012	0.018	0.024	0.031	0.037	0.043	0.049	0.055	0.061	0.067	0.074	0.080	0.086	0.092

From "Machinery's" Handbook, The Industrial Press, New York

TABLE FOR SPACING OFF THE CIRCUMFERENCE OF CIRCLES—*Continued*

No. of Divisions	Degrees in Arc	Diameter of Circle to be Spaced Off: 1	2	3	4	5	6	7	8	9	10	11	12	13	14
		Length of Chord													
3	120	0.866	1.732	2.598	3.464	4.330	5.196	6.062	6.928	7.794	8.660	9.526	10.392	11.258	12.124
4	90	0.707	1.414	2.121	2.828	3.536	4.243	4.950	5.657	6.364	7.071	7.778	8.485	9.192	9.900
5	72	0.588	1.176	1.763	2.351	2.939	3.527	4.115	4.702	5.290	5.878	6.465	7.053	7.641	8.229
6	60	0.500	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500	5.000	5.500	6.000	6.500	7.000
7	$51\frac{3}{7}$	0.434	0.868	1.302	1.736	2.170	2.604	3.037	3.471	3.905	4.339	4.773	5.207	5.641	6.075
8	45	0.383	0.765	1.148	1.531	1.913	2.296	2.679	3.061	3.444	3.827	4.210	4.592	4.975	5.358
9	40	0.342	0.684	1.026	1.368	1.710	2.052	2.394	2.736	3.078	3.420	3.762	4.104	4.446	4.788
10	36	0.309	0.618	0.927	1.236	1.545	1.854	2.163	2.472	2.781	3.090	3.399	3.708	4.017	4.326
11	$32\frac{8}{11}$	0.282	0.564	0.845	1.127	1.409	1.691	1.973	2.254	2.536	2.818	3.100	3.381	3.663	3.945
12	30	0.259	0.518	0.776	1.035	1.294	1.553	1.812	2.070	2.329	2.588	2.847	3.106	3.365	3.624
13	$27\frac{9}{13}$	0.239	0.479	0.718	0.958	1.197	1.436	1.676	1.915	2.154	2.393	2.633	2.873	3.112	3.352
14	$25\frac{5}{7}$	0.222	0.445	0.667	0.890	1.112	1.334	1.557	1.779	2.001	2.224	2.446	2.669	2.891	3.114
15	24	0.208	0.416	0.624	0.832	1.040	1.247	1.455	1.663	1.871	2.079	2.287	2.495	2.703	2.911
16	$22\frac{1}{2}$	0.195	0.390	0.585	0.780	0.975	1.171	1.366	1.561	1.756	1.951	2.146	2.341	2.536	2.731
17	$21\frac{3}{17}$	0.184	0.367	0.551	0.735	0.918	1.102	1.286	1.469	1.653	1.837	2.020	2.204	2.388	2.571
18	20	0.174	0.347	0.521	0.695	0.868	1.041	1.215	1.389	1.563	1.736	1.910	2.084	2.257	2.431
19	$18\frac{18}{19}$	0.165	0.329	0.493	0.658	0.822	0.987	1.151	1.316	1.480	1.645	1.809	1.974	2.138	2.303
20	18	0.156	0.313	0.469	0.626	0.782	0.938	1.095	1.251	1.408	1.564	1.721	1.877	2.033	2.190
21	$17\frac{1}{7}$	0.149	0.298	0.447	0.596	0.745	0.894	1.043	1.192	1.341	1.490	1.639	1.788	1.936	2.085
22	$16\frac{4}{11}$	0.142	0.286	0.428	0.570	0.712	0.855	0.997	1.139	1.281	1.423	1.566	1.708	1.850	1.993
23	$15\frac{15}{23}$	0.136	0.273	0.409	0.545	0.681	0.818	0.954	1.091	1.227	1.362	1.499	1.635	1.772	1.908
24	15	0.131	0.261	0.392	0.522	0.653	0.783	0.914	1.044	1.175	1.305	1.436	1.566	1.697	1.827
25	$14\frac{2}{5}$	0.125	0.251	0.376	0.501	0.627	0.752	0.877	1.003	1.128	1.253	1.379	1.504	1.629	1.755
26	$13\frac{11}{13}$	0.120	0.241	0.361	0.482	0.602	0.723	0.843	0.964	1.084	1.205	1.325	1.445	1.566	1.686
28	$12\frac{6}{7}$	0.112	0.224	0.336	0.448	0.560	0.672	0.784	0.896	1.008	1.120	1.232	1.344	1.456	1.568
30	12	0.105	0.209	0.314	0.418	0.523	0.627	0.732	0.836	0.941	1.045	1.150	1.254	1.359	1.463
32	$11\frac{1}{4}$	0.098	0.196	0.294	0.392	0.490	0.588	0.686	0.784	0.882	0.980	1.078	1.176	1.274	1.372

From "Machinery's" Handbook, The Industrial Press, New York

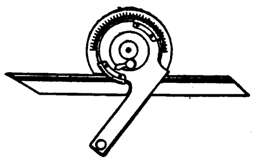
LENGTH OF CHORDS FOR SPACING OFF THE CIRCUMFERENCE OF CIRCLES WITH A DIAMETER EQUAL TO 1

For circles of other diameters multiply length given in table by diameter of circle.

No. of Spaces	Length of Chord	No. of Spaces	Length of Chord	No. of Spaces	Length of Chord	No. of Spaces	Length of Chord
3	0.8660	28	0.1120	53	0.0592	78	0.0403
4	0.7071	29	0.1081	54	0.0581	79	0.0398
5	0.5878	30	0.1045	55	0.0571	80	0.0393
6	0.5000	31	0.1012	56	0.0561	81	0.0388
7	0.4339	32	0.0980	57	0.0551	82	0.0383
8	0.3827	33	0.0951	58	0.0541	83	0.0378
9	0.3420	34	0.0923	59	0.0532	84	0.0374
10	0.3090	35	0.0896	60	0.0523	85	0.0370
11	0.2818	36	0.0872	61	0.0515	86	0.9365
12	0.2588	37	0.0848	62	0.0507	87	0.0361
13	0.2393	38	0.0826	63	0.0499	88	0.0357
14	0.2224	39	0.0805	64	0.0491	89	0.0353
15	0.2079	40	0.0785	65	0.0483	90	0.0349
16	0.1951	41	0.0765	66	0.0476	91	0.0345
17	0.1837	42	0.0747	67	0.0469	92	0.0341
18	0.1736	43	0.0730	68	0.0462	93	0.0338
19	0.1645	44	0.0713	69	0.0455	94	0.0334
20	0.1564	45	0.0698	70	0.0449	95	0.0331
21	0.1490	46	0.0682	71	0.0442	96	0.0327
22	0.1423	47	0.0668	72	0.0436	97	0.0324
23	0.1362	48	0.0654	73	0.0430	98	0.0321
24	0.1305	49	0.0641	74	0.0424	99	0.0317
25	0.1253	50	0.0628	75	0.0419	100	0.0314
26	0.1205	51	0.0616	76	0.0413	..	......
27	0.1161	52	0.0604	77	0.0408	..	......

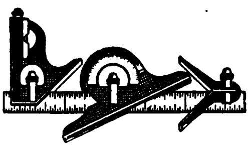
From "Machinery's" Handbook, The Industrial Press, New York

STARRETT TOOLS FOR USE IN CONNECTION WITH LAYING OUT



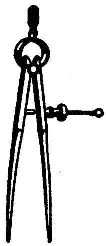
Universal Bevel Protractor with Vernier

Made from sheet steel. The blade is either 7 or 12 inches long by ½ inch wide and the stock is 4 inches long. The disc is graduated from zero to 90° each way and rotates the entire circle on a central stud. Made with verniers reading to five minutes, or one-twelfth of a degree, the vernier being so placed that the protractor is readable by vernier in any position.



Combination Square

Consists of the rule on which slide the square-, center-, and protractor heads. The reversible protractor head reads from zero to 180° both ways. All parts are of hardened, drop forged steel. Graduated in English or Metric systems.



Toolmakers' Dividers

Made of round tool steel with legs drawn down, making them hard and stiff. The fulcrum nut is hardened, bows made extra strong. Made with solid nut only.

Automatic Center Punch

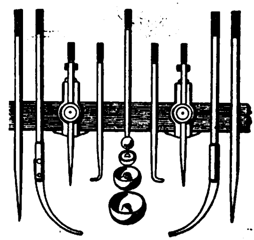
A knurled adjustable screw cap working in conjunction with a spring regulates the stroke, which may be made light or heavy. Made of tool steel, carefully hardened, with ground, renewable points.

For further information concerning these and other tools which may be used to advantage in Laying Out, see pages 51, 62, 63, and 158 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

STARRETT TOOLS FOR USE IN CONNECTION WITH LAYING OUT

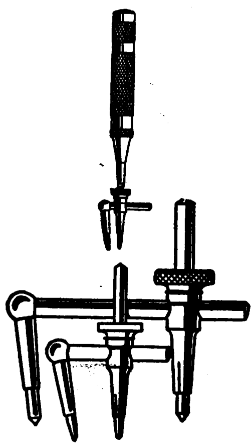
Trammels

These trammels are designed to be fastened to a wooden beam, which may be of any size from ¾ inch to 1⅝ inches wide and any desired thickness, adapting them to large or small work. Trammels are also made for use with sectional extension steel beam, made of $\frac{5}{16}$ inch round stock with one side flattened. The auxiliaries designed to go with the trammel heads are inside and outside caliper legs, extra pair of long points and a set of four ball points with holder, making possible the scribing of a circle from the center of any hole up to 1½ inches in diameter. A lead pencil may be substituted for either of the steel points.



Spacing Attachment for Center Punches

Designed for use with the Automatic Center Punches, the locating point is on the principle of a spring plunger, held in its lowest position by a light spiral spring. The attachment has a capacity of from $\frac{1}{16}$ inch to 1¾ inches.



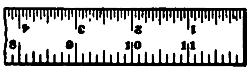
For further information concerning these and other tools which may be used to advantage in Laying Out, see pages 51, 61, 63 and 158 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

STARRETT TOOLS FOR USE IN CONNECTION WITH LAYING OUT

Improved Adjustable Sleeve Scriber

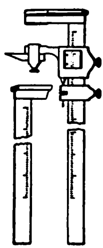
Made of fine steel, carefully tempered; the knurled sleeve has a hole running through it with a clamping device at one end, adapting it for slipping on or off different tools, securely holding them near to or away from the marking point. The sleeve is nickeled and of sufficient size to be easily held without cramping or turning in the fingers.

Graduated Steel Straightedge



Accurately ground and hardened edges, not beveled, graduated on one side only, one edge reading in 16ths and the other 8ths of an inch. Made in lengths of from 12 to 48 inches. Other styles are made plain, beveled, and not beveled, and with different graduations.

Vernier Height Gage



The bar is 10 inches long, graduated to read by means of the vernier to 1/1000 inch and measures to 8 inches in height. The hardened base is 2¾ inches by 1 inch wide, recessed on the bottom and ground square, allowing it to stand upright. An extension for the movable jaws permits reverse measurements being taken from the top or bottom side of the jaw. An attachment is also provided for the taking of measurements inside the frame of a jig, ascertaining the depth of recesses, etc. Made in English, Metric, and English and Metric measures.

For further information concerning these and other tools which may be used to advantage in Laying Out, see pages 51, 61, 62 and 158 of this volume; also, Vol. I of The Starrett Books, and the Starrett Catalogue.

COMPOSITION OF MISCELLANEOUS ALLOYS

Alloys	Antimony	Bismuth	Copper	Iron	Lead	Nickel	Tin	Zinc
Bell metal	......	....	4	......	......	......	1	......
Brass castings, common	......	....	20	......	......	......	2.5	1.25
Brass, common yellow	......	....	61.6	......	2.9	......	0.2	35.3
Brass, to be rolled	......	....	32	......	......	......	1.5	10
Britannia metal	50	25	......	......	......	......	25	......
Bronze Statuary	......	....	91.4	......	1.37	......	1.7	5.53
Chinese gongs	......	....	40.5	......	......	......	9.2	......
Chinese white copper	......	....	20.2	......	......	15.8	1.3	12.7
Copper flanges	......	....	9	......	......	......	0.26	1
German Silver	......	....	2	6.5	......	7.9	......	6.3
Gun metal	......	....	8	......	......	......	1	......
Pattern letters	15	15	......	......	70	......	......	......
Spelter	......	....	1	......	......	......	......	1
Type metal	1	....	......	......	3–7	......	......	......
White metal, ordinary	28.4	....	3.7	......	......	......	14.2	3.7

SHRINKAGE OF CASTINGS*

Shrinkage of Castings	Inch per foot
Aluminum, Pure	.2031
Aluminum, Nickel Alloy	.1875
Aluminum, Special Alloy	.1718
Iron, Small Cylinders	.0625
Iron Pipes	.125
Iron Girders and Beams	.100
Iron, Large Cylinders, Contraction of Diameter at Top	.625
Iron, Large Cylinders, Contraction of Diameter at Bottom	.083
Iron, Large Cylinders, Contraction of Length	.094
Brass, Thin	.167
Brass, Thick	.150
Copper	.1875
Bismuth	.1563
Lead	.3125
Zinc	.3125

*From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

SPECIFIC GRAVITY AND PROPERTIES OF METALS

Metal or Composition	Specific Gravity	Weight per Cubic inch, Pounds	Melting Point, Deg. F.	Linear Expansion per Unit Length per Deg. F.
Aluminum	2.56	0.0924	1200	0.00001234
Antimony	6.71	0.2422	1150	0.00000627
Barium	3.75	0.1354	1560	
Bismuth	9.80	0.3538	500	0.00000975
Boron	2.60	0.0939		
Brass: 80 C., 20 Z	8.60	0.3105	1700–1850	0.00000957
70 C., 30 Z	8.40	0.3032		
60 C., 40 Z	8.36	0.3018		
50 C., 50 Z	8.20	0.2960		
Bronze	8.85	0.3195	1675	0.00000986
Cadmium	8.60	0.3105	610	
Calcium	1.57	0.0567	1450	
Chromium	6.50	0.2347	2740	
Cobalt	8.65	0.3123	2700	
Copper	8.82	0.3184	1940	0.00000887
Gold	19.32	0.6975	1930	0.00000786
Iridium	22.42	0.8094	4100	0.00000356
Iron, cast	7.20	0.2600	2300	0.00000556
Iron, wrought	7.85	0.2834	2900	0.00000648
Lead	11.37	0.4105	620	0.00001571
Magnesium	1.74	0.0628	1200	
Manganese	7.42	0.2679	2200	
Mercury (60° F.)	13.58	0.4902	—39	
Molybdenum	8.56	0.3090	4500	
Nickel	8.80	0.3177	2600	0.00000695
Platinum, rolled	22.67	0.8184	3200	0.00001479
Platinum, wire	21.04	0.7595		
Potassium	0.87	0.0314	144	
Silver	10.53	0.3802	1740	0.00001079
Sodium	0.98	0.0354	200	
Steel	7.80	0.2816	2500	0.00000636
Tellurium	6.25	0.2256	840	
Tin	7.29	0.2632	446	0.00001163
Titanium	3.54	0.1278	3360	
Tungsten	18.77	0.6776	5400	
Vanadium	5.50	0.1986	3200	
Zinc, cast	6.86	0.2476	785	0.00001407
Zinc, rolled	7.15	0.2581		

WEIGHTS OF SHEET COPPER

Per Square Foot and Thickness, per Stubbs's Wire Gage

Stubbs's Wire Gage No.	Thickness Decimal Parts of an inch	Ounces per sq. foot	Sheets 24″ x 48″ Weight in pounds	Sheets 30″ x 60″ Weight in pounds	Sheets 36″ x 72″ Weight in pounds	Sheets 48″ x 72″ Weight in pounds
35	.005	4	2	3.12	4.5	6
33	.008	6	3	4.68	6.75	9
31	.010	8	4	6.25	9.00	12
29	.013	10	5	7.81	11.25	15
27	.016	12	6	9.37	13.50	18
26	.018	14	7	10.93	15.75	21
24	.022	16	8	12.5	18.00	24
23	.025	18	9	14.06	20.25	27
22	.021	20	10	15.62	22.50	30
21	.032	24	12	18.75	27	36
19	.042	32	16	25.00	36	48
18	.049	40	20	31.25	45	60
16	.065	48	24	37.50	54	72
15	.072	56	28	43.75	63	84
14	.083	64	32	50	72	96
13	.095	70	35	55	79	105
12	.109	81	40½	63	91	122
11	.120	89	44½	70	100	134
10	.134	100	50	78	112	150
9	.148	110	55	86	124	165
8	.165	123	61	96	138	184
7	.180	134	67	105	151	201
6	.203	151	75½	118	170	227
5	.220	164	82	128	184	246
4	.238	177	88½	138	199	266
3	.259	193	96	151	217	289
2	.284	211	105½	165	238	317
1	.300	233	111½	174	251	335
0	.340	253	126½	198	285	380

Courtesy of the Greenfield Tap and Die Corporation

WEIGHT OF FLAT-BAR STEEL PER LINEAL FOOT

Weight of one cubic inch = .2836 lb. WIDTH Weight of one cubic foot = 490 lbs.

Thickness	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/4	2 1/2	2 3/4	3	3 1/2	4	5
1/16	.106	.133	.160	.186	.213	.239	.265	.292	.320	.349	.372	.399	.425	.477	.53	.59	.64	.74	.85	1.06
1/8	.213	.266	.320	.372	.426	.479	.530	.585	.640	.698	.745	.798	.850	.955	1.07	1.18	1.28	1.49	1.70	2.13
3/16	.319	.399	.480	.558	.639	.718	.790	.878	.960	1.04	1.12	1.20	1.28	1.43	1.60	1.76	1.92	2.24	2.55	3.20
1/4	.425	.533	.640	.743	.852	.958	1.06	1.17	1.28	1.39	1.49	1.60	1.70	1.91	2.13	2.34	2.56	2.98	3.40	4.26
5/16	.531	.665	.800	.929	1.06	1.20	1.33	1.46	1.60	1.73	1.86	1.99	2.13	2.39	2.66	2.92	3.19	3.72	4.25	5.32
3/8	.638	.798	.960	1.12	1.28	1.43	1.59	1.75	1.91	2.07	2.23	2.39	2.55	2.87	3.20	3.51	3.83	4.46	5.10	6.40
7/16	.744	.931	1.12	1.30	1.49	1.67	1.86	2.05	2.23	2.42	2.60	2.79	2.98	3.35	3.72	4.09	4.46	5.21	5.95	7.44
1/2	....	1.07	1.28	1.49	1.70	1.91	2.13	2.34	2.55	2.77	2.98	3.19	3.40	3.83	4.26	4.68	5.10	5.96	6.80	8.52
9/16	....	1.20	1.44	1.67	1.91	2.15	2.39	2.63	2.87	3.11	3.35	3.59	3.83	4.30	4.78	5.26	5.74	6.69	7.65	9.56
5/8	....	....	1.60	1.86	2.12	2.39	2.66	2.92	3.19	3.46	3.72	3.99	4.26	4.79	5.32	5.86	6.39	7.44	8.52	10.64
11/16	....	....	1.76	2.04	2.34	2.63	2.92	3.22	3.51	3.80	4.09	4.39	4.68	5.26	5.84	6.43	7.01	8.18	9.35	11.70
3/4	....	....	....	2.23	2.55	2.86	3.19	3.50	3.83	4.15	4.46	4.78	5.10	5.74	6.40	7.02	7.65	8.92	10.20	12.80
13/16	....	....	....	2.41	2.76	3.11	3.45	3.80	4.14	4.49	4.83	5.18	5.53	6.22	6.91	7.60	8.29	9.67	11.10	13.80
7/8	....	....	....	....	2.98	3.34	3.72	4.09	4.46	4.84	5.21	5.59	5.96	6.70	7.46	8.19	8.94	10.42	11.92	14.92
15/16	....	....	....	....	3.19	3.59	3.98	4.38	4.78	5.18	5.58	5.98	6.38	7.17	7.97	8.77	9.56	11.20	12.80	15.90
1	....	....	....	....	....	3.82	4.25	4.68	5.10	5.53	5.96	6.38	6.80	7.66	8.52	9.36	10.20	11.92	13.60	17.04
1 1/8	....	....	....	....	....	....	4.78	5.27	5.74	6.23	6.71	7.18	7.65	8.61	9.56	10.54	11.48	13.41	15.30	19.17
1 1/4	....	....	....	....	....	....	....	5.85	6.38	6.92	7.45	7.98	8.50	9.57	10.65	11.71	12.76	14.90	17.00	21.30
1 3/8	....	....	....	....	....	....	....	....	7.02	7.60	8.18	8.78	9.36	10.52	12.68	12.86	14.02	16.36	18.70	23.40
1 1/2	....	....	....	....	....	....	....	....	....	8.32	8.94	9.57	10.20	11.49	12.78	14.04	15.30	17.85	20.40	25.56
1 5/8	....	....	....	....	....	....	....	....	....	....	9.66	10.36	11.06	12.44	13.82	15.20	16.58	19.34	22.20	27.60
1 3/4	....	....	....	....	....	....	....	....	....	....	....	11.18	11.92	13.40	14.92	16.38	17.88	20.84	23.84	29.84
1 7/8	....	....	....	....	....	....	....	....	....	....	....	....	12.76	14.34	15.94	17.54	19.12	22.40	25.60	31.80
2	....	....	....	....	....	....	....	....	....	....	....	....	....	15.32	17.04	18.72	20.40	23.84	27.20	34.08
2 1/4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	19.12	21.08	22.96	26.82	30.60	38.34
2 1/2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	23.42	25.52	29.80	34.00	42.60
2 3/4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	28.04	32.72	37.40	46.80
3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	35.70	40.80	51.12

WEIGHTS OF SHEET STEEL AND IRON

United States Standard Gage

(Adopted by U. S. Government July 1, 1893)

Number of Gage	App. Thickness	Weight per Sq. Ft.		No. of Gage	App. Thickness	Weight per Sq. Ft.	
		Steel	Iron			Steel	Iron
0000000	.5	20.320	20.00	17	.05625	2.286	2.25
000000	.46875	19.050	18.75	18	.05	2.032	2.
00000	.4375	17.780	17.50	19	.04375	1.778	1.75
0000	.40625	16.510	16.25	20	.0375	1.524	1.50
000	.375	15.240	15.00	21	.03437	1.397	1.375
00	.34375	13.970	13.75	22	.03125	1.270	1.25
0	.3125	12.700	12.50	23	.02812	1.143	1.125
1	.28125	11.430	11.25	24	.025	1.016	1.
2	.26562	10.795	10.625	25	.02187	1.389	.875
3	.25	10.160	10.00	26	.01875	.762	.75
4	.23437	9.525	9.375	27	.01718	.698	.687
5	.21875	8.890	8.75	28	.01562	.635	.623
6	.20312	8.255	8.125	29	.01406	.571	.562
7	.1875	7.620	7.5	30	.0125	.508	.5
8	.17187	6.985	6.875	31	.01093	.694	.437
9	.15625	6.350	6.25	32	.01015	.413	.406
10	.14062	5.715	5.625	33	.00937	.381	.375
11	.125	5.080	5.00	34	.00859	.349	.343
12	.10937	4.445	4.375	35	.00781	.317	.312
13	.09375	3.810	3.75	36	.00703	.285	.281
14	.07812	3.175	3.125	37	.00664	.271	.265
15	.07031	2.857	2.812	38	.00625	.254	.25
16	.0625	2.540	2.50				

Weight of 1 cubic foot is assumed to be 487.7 lbs. for steel plates and 480 lbs. for iron plates.

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company Inc.

WEIGHTS OF SEAMLESS BRASS TUBING PER LINEAR FOOT

(1/8 to 2 1/2 outside diameter. Nos. 1 to 25 Stubbs's gage.)

No. of Gage	Thickness in Inches	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2
1	.300	...	...	...	...	...	...	...	...	...	...	...	2.42	3.28	4.10	5.03	5.88	6.75	7.62
2	.284	...	...	...	...	...	...	...	...	...	...	...	2.35	3.16	4.03	4.80	5.57	6.45	7.26
3	.259	...	...	...	...	...	...	...	...	...	...	1.85	2.22	2.98	3.72	4.48	5.23	5.96	6.72
4	.238	...	...	...	...	...	...	...	...	...	...	1.76	2.10	2.79	3.49	4.18	4.82	5.51	6.25
5	.220	...	...	...	...	...	...	...	...	...	...	1.68	1.99	2.60	3.26	3.89	4.53	5.14	5.80
6	.203	...	...	...	...	...	...	...	...	1.00	1.29	1.58	1.88	2.46	3.04	3.60	4.20	4.80	5.39
7	.180	...	...	...	...	...	...	...	...	.90	1.19	1.44	1.71	2.23	2.77	3.28	3.78	4.33	4.83
8	.165	...	...	...	...	.40	.52	.64	.77	.87	1.11	1.35	1.59	2.07	2.54	3.02	3.50	3.98	4.46
9	.148	...	...	...	...	.39	.49	.61	.71	.82	1.04	1.25	1.46	1.89	2.32	2.75	3.17	3.60	4.03
10	.134	...	...	...	...	.38	.46	.58	.65	.77	.96	1.16	1.35	1.74	2.12	2.51	2.90	3.28	3.67
11	.120	...	...	.18	.26	.36	.43	.53	.61	.70	.87	1.05	1.22	1.57	1.91	2.27	2.16	2.96	3.31
12	.109	...	...	.177	.256	.334	.413	.491	.570	.650	.808	.965	1.12	1.43	1.76	2.07	2.39	2.70	3.01
13	.095	...	...	.170	.237	.306	.377	.445	.514	.580	.717	.855	1.00	1.27	1.55	1.82	2.09	2.37	2.65
14	.083	...	...	.160	.220	.280	.340	.400	.460	.520	.640	.760	.88	1.12	1.36	1.61	1.84	2.08	2.32
15	.072	...	.096	.144	.201	.251	.303	.355	.409	.461	.564	.667	.77	.99	1.19	1.40	1.61	1.81	2.02
16	.065	.045	.092	.138	.186	.232	.279	.326	.372	.420	.515	.609	.70	.89	1.07	1.26	1.45	1.64	1.82
17	.058	.044	.087	.128	.169	.212	.255	.295	.338	.380	.463	.548	.64	.80	.97	1.14	1.30	1.48	1.64
18	.049	.043	.078	.113	.150	.183	.220	.255	.291	.325	.397	.467	.54	.67	.82	.96	1.10	1.24	1.39
19	.042	.040	.070	.101	.130	.161	.193	.221	.252	.282	.343	.404	.46	.58	.71	.83	.95	1.07	1.19
20	.035	.036	.062	.086	.113	.136	.163	.188	.214	.238	.289	.339	.39	.49	.59	.69	.80	.893	1.00
21	.032	.034	.057	.081	.104	.128	.151	.173	.196	.219	.266	.312	.357	.450	.542	.635	.727	.820	.913
22	.028	.031	.051	.072	.093	.112	.133	.152	.174	.192	.233	.275	.315	.396	.477	.556	.638	.718	.799
23	.025	.029	.047	.066	.082	.102	.119	.136	.155	.173	.209	.245	.281	.354	.426	.497	.571	.641	.714
24	.022	.026	.042	.058	.074	.090	.107	.121	.137	.154	.186	.218	.249	.312	.376	.438	.502	.566	.629
25	.020	.024	.039	.052	.068	.081	.096	.110	.126	.140	.169	.197	.226	.285	.342	.399	.457	.516	.573

For weights of seamless copper tubing, add 5 per cent to the weights above.

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company. Inc.

WEIGHTS OF STEEL, WROUGHT IRON, BRASS AND COPPER PLATES

BIRMINGHAM OR STUBBS'S GAGE

No. of Gage	Thickness in Inches	Weight in Lbs. per Square Foot			
		Steel	Iron	Brass	Copper
0000	.454	18.52	18.16	19.431	20.556
000	.425	17.34	17.00	18.190	19.253
00	.380	15.30	15.20	16.264	17.214
0	.340	13.87	13.60	14.552	15.402
1	.300	12.24	12.00	12.840	13.590
2	.284	11.59	11.36	12.155	12.865
3	.259	10.57	10.36	11.085	11.733
4	.238	9.71	9.52	10.186	10.781
5	.220	8.98	8.80	9.416	9.966
6	.203	8.28	8.12	8 689	9.196
7	.180	7.34	7.20	7.704	8.154
8	.165	6.73	6.60	7.062	7.475
9	.148	6.04	5.92	6.334	6.704
10	.134	5.47	5.36	5.735	6.070
11	.120	4.90	4.80	5.137	5.436
12	.109	4.45	4.36	4.667	4.938
13	.095	3.88	3.80	4.066	4.303
14	.083	3.39	3.32	3.552	3.769
15	.072	2.94	2.88	3.081	3.262
16	.065	2.65	2.60	2.782	2.945
17	.058	2.37	2.32	2.482	2.627
18	.049	2.00	1.96	2.097	2.220
19	.042	1.71	1.68	1.797	1.902
20	.035	1.43	1.40	1.498	1.585
21	.032	1.31	1.28	1.369	1.450
22	.028	1.14	1.12	1.198	1.270
23	.025	1.02	1.00	1.070	1.132
24	.022	.898	.88	.941	.997
25	.020	.816	.80	.856	.906
26	.018	.734	.72	.770	.815
27	.016	.653	.64	.685	.725
28	.014	.571	.56	.599	.634
29	.013	.530	.52	.556	.589
30	.012	.490	.48	.514	.544
31	.010	.408	.40	.428	.453
32	.009	.367	.36	.385	.408
33	.008	.326	.32	.342	.362
34	.007	.286	.28	.2996	.317
35	.005	.204	.20	.214	.227
36	.004	.163	.16	.171	.181

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company. Inc.

TABLES FOR COMPUTING WEIGHT OF CAST STEEL

Weight in pounds of a lineal foot of round, square, and octagon steel.

Size in Inches	Round	Octagon	Square	Size in Inches	Round	Octagon	Square
1/16	.010	.011	.013	2 1/2	16.79	17.71	21.37
1/8	.042	.044	.053	2 5/8	18.51	19.52	23.56
3/16	.094	.099	.120	2 3/4	20.31	21.42	25.86
1/4	.168	.177	.214	2 7/8	22.20	23.41	28.27
5/16	.262	.277	.334	3	24.17	25.50	30.78
3/8	.378	.398	.481	3 1/8	26.23	27.66	33.40
7/16	.514	.542	.655	3 1/4	28.37	29.92	36.12
1/2	.671	.708	.855	3 3/8	30.59	32.27	38.95
9/16	.850	.896	1.082	3 1/2	32.90	34.70	41.89
5/8	1.049	1.107	1.336	3 5/8	35.29	37.23	44.94
11/16	1.270	1.339	1.616	3 3/4	37.77	39.84	48.09
3/4	1.511	1.594	1.924	3 7/8	40.33	42.54	51.35
13/16	1.773	1.870	2.258	4	42.97	45.33	54.72
7/8	2.056	2.169	2.618	4 1/4	48.51	51.17	61.77
15/16	2.361	2.490	3.006	4 1/2	54.39	57.37	69.25
1	2.686	2.833	3.420	4 3/4	60.60	63.92	77.16
1 1/8	3.399	3.585	4.328	5	67.15	70.83	85.50
1 1/4	4.197	4.427	5.344	5 1/4	74.03	78.08	94.26
1 3/8	5.078	5.356	6.466	5 1/2	81.25	85.70	103.45
1 1/2	6.044	6.374	7.695	5 3/4	88.80	93.67	113.07
1 5/8	7.093	7.481	9.031	6	96.69	101.99	123.12
1 3/4	8.226	8.674	10.474	7	131.61	138.82	167.58
1 7/8	9.443	9.960	12.023	8	171.90	181.32	218.88
2	10.744	11.332	13.680	9	217.57	229.48	277.02
2 1/8	12.129	12.793	15.443	10	268.60	283.31	342.00
2 1/4	13.598	14.343	17.314	11	325.01	342.80	413.82
2 3/8	15.151	15.981	19.291	12	386.79	407.97	492.48

AVERAGE ULTIMATE STRENGTH OF COMMON MATERIALS OTHER THAN METALS

(Pounds per square inch)

Material	Compression	Tension
Bricks, best hard	12,000	400
Bricks, light red	1,000	40
Brickwork, common	1,000	50
Brickwork, best	2,000	300
Cement, Portland, one month old	2,000	400
Cement, Portland, one year old	3,000	500
Concrete, Portland	1,000	200
Concrete, Portland, one year old	2,000	400
Hemlock	4,000	6,000
Pine, shortleaf yellow	6,000	9,000
Pine, Georgia	8,000	12,000
Pine, white	5,500	7,000
White oak	7,000	10,000

DIAMETER, STRENGTH, AND WEIGHT OF STEEL WIRE

The breaking stress of the wire is based on a tensile strength of 100,000 pounds per square inch. For wire of greater or less strength, simply multiply the values in the table by the ratio between actual strength per square inch and 100,000. Example: A No. 15 wire is made of material having a tensile strength of 150,000 pounds per square inch. Then, breaking stress of wire = (150,000 ÷ 100,000) × 407 = 610 pounds.

No. Washburn & Moen, Am. Steel & Wire Co. and Roebling Gage	Diam., Inches	Area, Sq. Ins.	Breaking Stress of Wire, based on 100,000 Lbs. Stress per Sq. In.	Weight in Pounds		Number of Feet in 2,000 Pounds
				Per 1000 Ft.	Per Mile	
000000	0.460	0.166191	16,620.0	558.4	2948.0	3,582
00000	0.430	0.145221	14,520.0	487.9	2576.0	4,099
0000	0.393	0.121304	12,130.0	407.6	2152.0	4,907
000	0.362	0.102922	10,290.0	345.8	1826.0	5,783
00	0.331	0.086049	8,605.0	289.1	1527.0	6,917
0	0.307	0.074023	7,400.0	248.7	1313.0	8,041
1	0.283	0.062902	6,290.0	211.4	1116.0	9,463
2	0.263	0.054325	5,430.0	182.5	964.0	10,957
3	0.244	0.046760	4,680.0	157.1	830.0	12,730
4	0.225	0.039761	3,980.0	133.6	705.0	14,970
5	0.207	0.033654	3,365.0	113.1	597.0	17,687
6	0.192	0.028953	2,895.0	97.3	514.0	20,559
7	0.177	0.024606	2,460.0	82.7	437.0	24,191
8	0.162	0.020612	2,060.0	69.3	366.0	28,878
9	0.148	0.017203	1,720.0	57.8	305.0	34,600
10	0.135	0.014314	1,430.0	48.1	254.0	41,584
11	0.120	0.011310	1,130.0	38.0	201.0	52,631
12	0.105	0.008659	866.0	29.1	154.0	68,752
13	0.092	0.006648	665.0	22.3	118.0	89,525
14	0.080	0.005027	503.0	16.9	89.2	118,413
15	0.072	0.004071	407.0	13.7	72.2	146,198
16	0.063	0.003117	312.0	10.5	55.3	191,022
17	0.054	0.002290	229.0	7.70	40.6	259,909
18	0.047	0.001735	174.0	5.83	30.8	343,112
19	0.041	0.001320	132.0	4.44	23.4	450,856
20	0.035	0.000962	96.0	3.23	17.1	618,620
21	0.032	0.000804	80.0	2.70	14.3	740,193
22	0.028	0.000616	62.0	2.07	10.9	966,651
23	0.025	0.000491	49.0	1.65	8.71	......
24	0.023	0.000415	42.0	1.40	7.37	......
25	0.020	0.000314	31.0	1.06	5.58	......
26	0.018	0.000254	25.0	0.855	4.51	......
27	0.017	0.000227	23.0	0.763	4.03	......
28	0.016	0.000201	20.0	0.676	3.57	......
29	0.015	0.000177	18.0	0.594	3.14	......
30	0.014	0.000154	15.0	0.517	2.73	......
31	0.0135	0.000143	14.0	0.481	2.54	......
32	0.013	0.000133	13.0	0.446	2.36	......
33	0.011	0.000095	9.5	0.319	1.69	......
34	0.010	0.000079	7.9	0.264	1.39	......
35	0.0095	0.000071	7.1	0.238	1.26	......
36	0.009	0.000064	6.4	0.214	1.13	......

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

AVERAGE ULTIMATE STRENGTH OF COMMON METALS

Pounds per Square Inch

Material	Tension	Compression	Shear	Modulus of Elasticity
Aluminum	15,000	12,000	12,000	11,000,000
Brass, cast	24,000	30,000	36,000	9,000,000
Bronze, gun metal	32,000	20,000	......	10,000,000
Bronze, manganese	60,000	120,000	......	....
Bronze, phosphor	50.000	......	......	14,000,000
Copper, cast	24,000	40,000	30,000	10,000,000
Copper wire, annealed	36,000	......	......	15,000,000
Copper wire, unannealed	60,000	......	......	18,000,000
Iron, cast	15,000	80,000	18,000	12,000,000
Iron wire, annealed	60,000	......	......	15,000,000
Iron wire, unannealed	80,000	......	......	25,000,000
Iron, wrought	48,000	46,000	40,000	27,000,000
Lead, cast	2,000	......	......	1,000,000
Steel castings	70,000	70,000	60,000	30,000,000
Steel, plow	270,000	......	......	....
Steel, structural	60,000	60,000	50,000	29,000,000
Steel wire, annealed	80,000	......	......	29,000,000
Steel wire, unannealed	120,000	......	......	30,000,000
Steel wire, crucible	180,000	......	......	30,000,000
Steel wire, susp. bridge	200,000	......	......	30,000,000
Steel wire, piano	300,000	......	......	....
Tin, cast	3,500	6,000	......	4,000,000
Zinc, cast	5,000	20,000	......	13,000,000

STRENGTH OF BRONZES*

Copper per cent	Tin, per cent	Tensile Strength lbs. per sq. in.	Yield-point, lbs. per sq. in.	Compressive Strength, lbs. per sq. in.	Elongation, per cent	Compression, per cent
100	......	27,000	14,000	41,000	8.0	44
95	5	31,000	17,000	46,000	10.0	41
90	10	29.000	21,000	54,000	4.0	31
85	15	33,000	26,000	74,000	1.6	24
80	20	32,000	28,000	124,000	0.5	14
75	25	18,000	18,000	150,000	......	8
70	30	6,500	6,500	143,000	......	2
65	35	2,800	2,800	75,000	......	4

STRENGTH OF BRASSES*

Copper, per cent	Zinc, per cent	Tensile Strength, lbs. per sq. in.	Yieldpoint, lbs. per sq. in.	Compressive Strength, lbs. per sq. in.	Elongation, per cent
100	....	27.000	14,000	41,000	7
95	5	28,000	12,000	28,000	12
90	10	30,000	10,000	29,000	18
85	15	32,000	9,000	33,000	25
80	20	34,000	8,000	39,000	33
75	25	37,000	9,000	46,000	38
70	30	41,000	10,000	54,000	38
65	35	46,000	13,000	63,000	33
60	40	49,000	17,000	74,000	19
55	45	44,000	20,000	90,000	10
50	50	30.000	24,000	116,000	4
45	55	14,000	14,000	126,000	..

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company. Inc.

* U. S. Government Tests

PERCENTAGE OF CARBON IN CARBON STEEL TOOLS

Name of Tool — Machinists' Tools	Carbon, Per Cent	Name of Tool — Blacksmiths' Tools	Carbon, Per Cent
Turning and Planing Tools	1.15	Cold Chisel	0.75
Chipping Chisels	0.85	Hot Chisel	0.85
Saw Arbor	0.75	Hot Punch	0.85
Lathe Center	1.05	Flatter	0.85
Chuck Jaw	0.85	Anvil Facing	0.75
Milling Cutters	1.15	Hammer	0.75
Twist Drills	1.15		
Ordinary Files	1.25	Miscellaneous	
Machinists' Hammer	0.95		
Mandrel	1.05	Rivet Set	0.70
Pliers	0.75	Roll Expander	1.05
Reamer Blades	1.10	Beading Tool	0.80
Hand Reamers	1.05	Threading Dies	1.05
Saw for Steel	1.60	Wire Drawing Dies	1.40
Screwdriver	0.65	Drop-forging Dies	0.70
Taps	1.10	Pipe Cutter	1.15
Vise Jaws	0.75	Circular Saw	0.85
Wrenches	0.75	Band Saw	0.75
		Ball Bearing Races	1.15
		Crowbar	0.75

The above table is intended as an approximate guide in selecting steels for various purposes. Average figures are given; the percentage of carbon might vary 0.05 per cent either way, in most cases, without seriously affecting the quality of the tool.

THE TEMPER OF STEEL

The term "temper" or "carbon-temper" is used by steel makers to designate the proportion of carbon in the steel. The temper marks or numbers are arbitrarily selected, their relation to the percentage of carbon varying with different makers. The following list of tempers and the purpose for which the various steels are adapted is given by Joseph T. Ryerson & Son:

Per Cent Carbon	Tools for which Steel is Adapted
0.65 to 0.75	Blacksmiths' hammers, table knives, dies for drop hammers, large hot forgings, flatters, fullers, track chisels, and tools.
0.75 to 0.85	Large shear knives, punches, chisels, hammers, boilers, boiler makers' tools, lathe centers, etc.
0.85 to 0.95	Punches and dies, hand chisels, mining tools, shear blades, etc.
0.95 to 1.05	Drills, large milling cutters, axes, taps, reamers, bolt header dies, and similar tools.
1.05 to 1.15	Granite chisels, milling cutters, taps, reamers, mill picks, threading dies, cups, cones, etc.
1.15 to 1.25	Milling cutters, small taps, threading dies, twist drills, forming and boring tools, mandrels, razors.
1.25 to 1.35	Inserted milling cutter teeth, lathe, planer and slotter tools, and tools requiring great hardness.
1.35 to 1.45	Cutting discs, granite lathe tools, paper knives, engravers' tools, roll corrugating, and chilled roll turning tools.
1.45 to 1.55	Steel for turning chilled rolls, etc., requiring great hardness.

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

COPPER WIRE TABLE

Of the American Institute of Electrical Engineers

(Condensed. Calculated for temperature of 20°C.)

For resistance at 0°C., multiply values by 0.9262; at 50°C., by 1.11723; and at 80°C. by 1.23815.

Gage B & S	Area, Circular mils.	Weight lb. per 1,000 ft.	Length ft. per ohm	Resistance ohms per 1,000 ft.	Gage B & S
0000	211,600.0	640.5	20440.0	0.04893	0000
000	167,800.0	508.0	16210.0	0.06170	000
00	133,100.0	402.8	12850.0	0.07780	00
0	105,500.0	319.5	10190.0	0.09811	0
1	83,690.0	253.3	8083.0	0.1237	1
2	66,370.0	200.9	6410.0	0.1560	2
3	52,630.0	159.3	5084.0	0.1967	3
4	41,740.0	126.4	4031.0	0.2480	4
5	33,100.0	100.2	3197.0	0.3128	5
6	26,250.0	79.46	2535.0	0.3944	6
7	20,820.0	63.02	2011.0	0.4973	7
8	16,510.0	49.98	1595.0	0.6271	8
9	13,090.0	39.63	1265.0	0.7908	9
10	10,380.0	31.43	1003.0	0.9972	10
11	8,234.0	24.93	795.3	1.257	11
12	6,530.0	19.77	630.7	1.586	12
13	5,178.0	15.68	500.1	1.999	13
14	4,107.0	12.43	396.6	2.521	14
15	3,257.0	9.858	314.5	3.179	15
16	2,583.0	7.818	249.4	4.009	16
17	2,048.0	6.200	197.8	5.055	17
18	1,624.0	4.917	156.9	6.374	18
19	1,288.0	3.899	124.4	8.038	19
20	1,022.0	3.092	98.66	10.14	20
21	810.1	2.452	78.24	12.78	21
22	642.4	1.945	62.05	16.12	22
23	509.5	1.542	49.21	20.32	23
24	404.0	1.223	39.02	25.63	24
25	320.4	0.9699	30.95	32.31	25
26	254.1	0.7692	24.54	40.75	26
27	201.5	0.6100	19.46	51.38	27
28	159.8	0.4837	15.43	64.79	28
29	126.7	0.3836	12.24	81.7	29
30	100.5	0.3042	9.707	103.0	30
31	79.7	0.2413	7.698	129.9	31
32	63.21	0.1913	6.105	163.8	32
33	50.13	0.1517	4.841	206.6	33
34	39.75	0.1203	3.839	260.5	34
35	31.52	0.09543	3.045	328.4	35
36	25.0	0.07568	2.414	414.2	36
37	19.83	0.06001	1.915	522.2	37
38	15.72	0.04759	1.519	658.5	38
39	12.47	0.03774	1.204	830.4	39
40	9.888	0.02993	0.955	1047.0	40

From Mechanical Engineers' Handbook by Lionel S. Marks. McGraw-Hill Book Co., Inc. New York

SPARK METHOD OF SELECTING IRON AND STEELS

By Prof. JOHN F. KELLER, Instructor in Forging at Purdue University

See Chart on Pages 41-42.

The spark method is based upon the action of the oxygen in the air upon the combustible elements in iron and especially on many of the alloying elements contained in different steels and which act explosively when heated to the temperature necessary for combustion. If a piece of iron or steel is touched with some pressure to a high-speed revolving emery wheel it will throw out a great number of sparks characteristic of the combustible elements in the metal. By the quantity and characteristics of the different sparks we are able to analyze and determine to a reasonable degree of accuracy the grade of iron or steel under investigation. For the Spark Method of selection there are three essentials. First: clean cutting emery wheel turning at 7,000 ft. per minute. Second: remember that iron is the base of all steels except "Stelite." Third: enough pressure on the wheel to throw a few sparks only.

Figure 1. A piece of wrought iron free from carbon. If held against the emery wheel the end of the bar will be heated by friction; as the small particles are thrown from the wheel they will follow a straight line which becomes broader and more luminous some distance from the source of heat, and then disappears. This is probably due to the action of oxygen of the air on the heated particles requiring some time to act. NOTE: Touch material lightly on wheel; observe individual spark. All commercial iron contains a small percentage of carbon which will be indicated by branching or forking of the luminous streak.

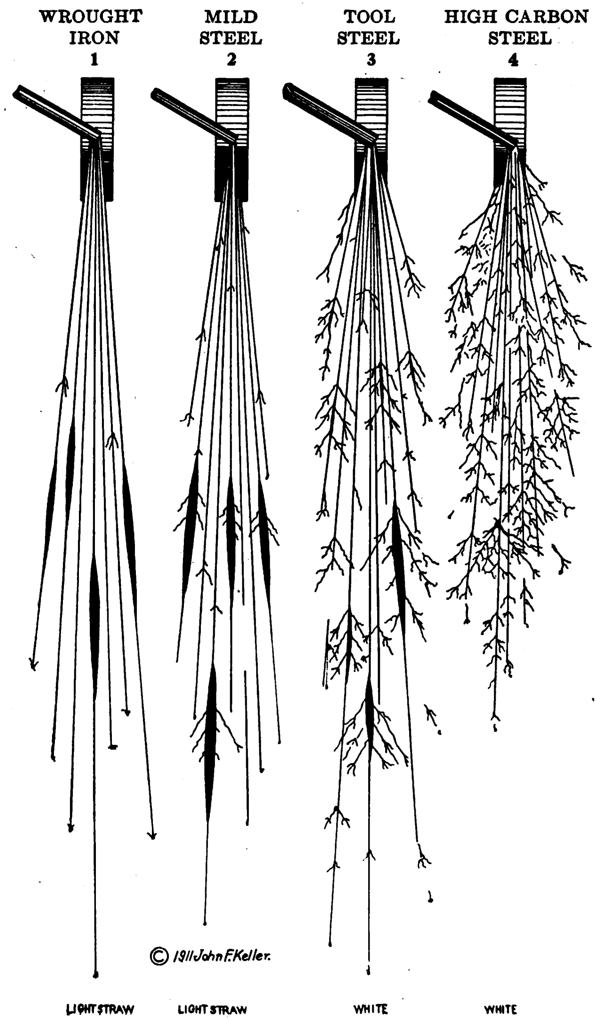
Figure 2. Mild steel which contains a small percentage of carbon. A division of forking of the luminous streak is at once noticeable; this is owing to the presence of carbon, which is acted upon by the maximum heat of the iron spark, which burns explosively, causing a break in the original heavy lines.

Figure 3. The lower grades of tool steel which contain from .50 to 1.00% carbon. The iron lines become less and less conspicuous, the forking of the luminous streak occurring very much more frequently, often subdividing; the lower the carbon content the less sparks and further they occur from the source of heat.

Figure 4. In the higher grades of carbon steels the iron lines are practically eliminated, with an increase of the star-like explosions which often divide and subdivide, causing a beautiful display of figures. This is probably due to the iron and carbon becoming so united that they are most easily attacked by the oxygen. Hence the great danger of burning the steel in the fire or when grinding. The higher the percentage of carbon the more profuse the explosions and the shorter the distance from the source of heat.

Figure 5. Chromium and tungsten high speed steels are very easily determined by the spark test. The particles seem to follow a

SPARK METHOD OF SELECTING IRON AND STEELS



SPARK METHOD OF SELECTING IRON AND STEELS

(Continued)

broken line with a very slight explosion; just before they disappear the color is of chrome yellow and shows no trace of a carbon spark. Note that while this class of steel contains .65% carbon, the particles show no trace of a carbon spark whatever and considerable pressure on the emery wheel is required to ignite the spark.

Figure 6. The characteristic difference of the manganese spark from that of the carbon spark is that it seems to shoot or explode at right angles to its line of force. Each dart is divided and subdivided into a number of white globules, the re-explosions being very distinct.

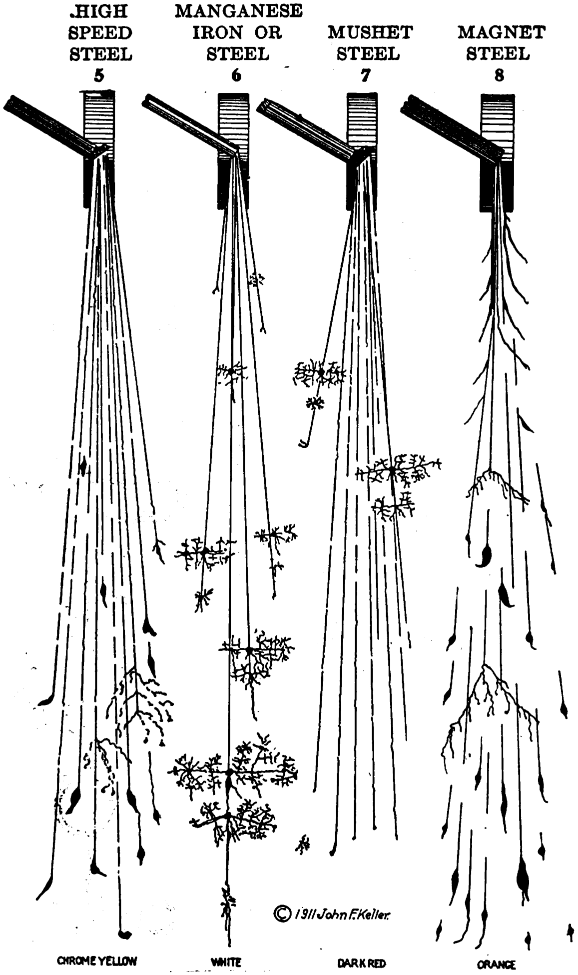
Figure 7. Mushet steel, air hardening or high speed steel. It is very easy to distinguish from other steels, as the particles follow a broken line and are a very, very dark red, with an occasional manganese spark. This is the old grade of Mushet, not the modern high speed steel, and requires considerable pressure on the wheel.

Figure 8. Represents a spark thrown from a special steel manufactured for use in magnet and known as magnet steel. The sparks are similar to those of high speed steel with the exception that they are of a lighter color with a more profuse quantity of abrupt luminous explosions and an occasional branching manganese spark. The explosions, however, occur at a shorter distance from the source of heat than those of high speed steel.

Cast iron is very difficult to determine by this method owing to the state and combination of the carbon present; the material being very seldom of standard quality, will often show scarcely any luminous sparks at all. If the carbon is in the combined state, the sparks will appear similar to those of steel proportional to the percentage of carbon so combined. Sometimes it is rich in manganese and the bright manganese darts appear at varying distances from the wheel.

The Spark Method may also be used to advantage to detect the decarbonizing of the surface of a piece of steel in an annealing or similar process. Such a surface is indicated by an iron spark, as in Fig. 1. The method also will show how much of the metal must be removed from the surface of annealed tool steel in order to reach metal containing sufficient carbon for hardening. In carbonizing or case hardening if the metal has been properly treated, the spark will be proportional to the percentage of carbon present and combined with the softer stock and will appear as Fig. 3 or 4. The depth of penetration of the slightly carbonized portion may also be determined. It may also be used to advantage in determining the quality of the metal in welded parts, the spark indicating whether an excess or deficiency of carbon is present. "Stelite," being composed of non-combustible elements, at grinding temperature throws no sparks and a very short red streak of fire is developed only when the sample is pressed with some considerable force against the emery wheel. This method of testing may also be used to advantage in the sorting out of mixed stocks and unmarked steel.

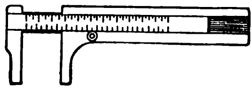
SPARK METHOD OF SELECTING IRON AND STEELS



STARRETT TOOLS FOR THE USE OF EXPERT MACHINISTS

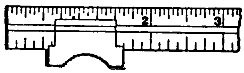
Slide Rule Caliper and Circumference Gage

Graduated to read the circumference as well as the diameter of the thing measured. Capacity 3½ inches in diameter, about 11 inches circumference. Jaws $1\frac{5}{16}$ inches deep. Graduated in 32ds of an inch standard and 16ths of an inch circumference.



Rules with Thumb Slide

The slide may be used on either edge of rule or removed and the rule used alone. Rules are furnished in different graduations.

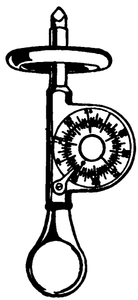


Inspectors' Gages

Graduated on two sides, one reading in 32ds and the other in 40ths of an inch. A knurled friction slide on the measuring rod slips down against the top, registering the measure, permitting the measuring rod to be withdrawn and the gage removed for easy reading. Width 1 inch. Also made $\frac{7}{16}$ inch wide.

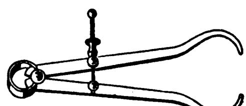
Improved Speed Indicator and Surface Speed Attachment

All working parts are enclosed. The graduations show every revolution, two rows of figures read right or left, as the shaft may revolve. The spindle is of hardened steel and is provided with rubber tips for both pointed and centered shafts. The Surface Speed Attachment registers on the dial.



Crank Shaft Calipers

Designed for use in turning automobile crank shafts and for reaching into difficult places. Made in 6 inch size only, either spring or solid nut.



For further information concerning Starrett Tools see other tool pages in this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

TABLE OF CHANGE GEARS, APPROXIMATE ANGLES AND LEADS FOR CUTTING SPIRALS

Twelve Change Gears are furnished with each Universal Miller as follows: 24, 24, 28, 32, 40, 44, 48, 56, 64, 72, 86, and 100 teeth

1st Intermediate Gear Drives the Gear on Worm.
2d Intermediate Gear drives the Gear for Screw.

DIAMETER OF WORK

Lead of Spiral, Inches	Gear on Worm	1st Intermediate Gear	2d Intermediate Gear	Gear for Screw	⅛ In.	¼ In.	⅜ In.	½ In.	⅝ In.	¾ In.	⅞ In.	1 In.	1¼ In.	1½ In.	1¾ In.	2 In.	2¼ In.	2½ In.	2¾ In.	3 In.	3¼ In.	3½ In.	3¾ In.	4 In.	4½ In.	5 In.	5½ In.	6 In.
	Driven	Driver	Driven	Driver																								
.67	24	86	24	100	30¼																							
.78	24	86	28	100	26	44½																						
.89	24	86	32	100	23½	41																						
1.12	24	86	40	100	19	34½																						
1.34	24	86	28	100	16	30¼	41½																					
1.46	24	64	48	72	14¾	28	38½																					
1.56	28	86	48	100	13¾	26½	37																					
1.67	24	64	32	72	12¾	25	34¾	43¼																				
1.94	28	64	32	72	11¼	21¾	31	39	45																			
2.08	24	64	40	72	10¼	20½	29½	37	43¼																			
2.22	32	56	28	72	9¾	19¼	27½	35	41¼																			
2.50	24	64	48	72	8¾	17	25	32	38	43¼																		
2.78	32	64	40	72	8	15½	23	29½	35¼	40½	44¾																	
2.92	32	56	44	86	7½	15	21¾	28¼	34	39	43¼																	
3.24	28	48	40	72	6¾	13¼	19¾	25¾	31¼	36	40½	44¼																
3.70	32	48	40	72	6	11¾	17½	23	28	32½	36½	40½																
3.89	32	64	56	72	5½	11¼	16¾	22	26¾	31¼	35¼	39																
4.17	40	64	48	72	5¼	10½	15¾	20½	25¼	29½	33½	37	43¼															
4.46	32	40	48	86	4¾	9¾	14¾	19¼	23¾	27¾	31½	35	41½															
4.86	40	64	56	72	4½	9	13½	17¾	22	25¾	29½	33	39	44¼														
5.33	32	40	48	72	4	8¼	12¼	16½	20¼	23¾	27¼	30½	36½	41½														
5.44	56	40	28	72	4	8	12	16	20	23½	26¾	30	36	41														
6.12	56	40	28	64	3½	7¼	11	14½	17¾	21	24¼	27	33	37¾	42													

Approximate Angle in Degrees for Setting Milling Machine Table.

These tables are of especial convenience for quickly setting the machine with proper change gears when the angle of spiral and the diameter of a piece of work are known. For example: To cut a spiral mill 4″ diameter, 25° angle: Follow down the 4″ column to the nearest angle, 25¼, and the change gears are 64, 28, 56, and 48.

$$\frac{\text{Lead}}{10} = \frac{\text{Driven}}{\text{Drivers}} = \frac{\text{2d} \times \text{Worm}}{\text{1st} \times \text{Screw}}$$

Courtesy of The Cincinnati Milling Machine Company

TABLE OF CHANGE GEARS, APPROXIMATE ANGLES AND LEADS FOR CUTTING SPIRALS—*Continued*

Twelve Change Gears are furnished with each Universal Miller as follows: 24, 24, 28, 32, 40, 44, 48, 56, 64, 72, 86 and 100 teeth

Lead of Spiral, Inches	Gear on Worm	1st Intermediate Gear	2d Intermediate Gear	Gear for Screw	1st Intermediate Gear Drives the Gear on Worm 2d Intermediate Gear Drives the Gear for Screw DIAMETER OF WORK																						
	Driven	Driver	Driven	Driver	⅛ In.	¼ In.	⅜ In.	½ In.	⅝ In.	¾ In.	⅞ In.	1 In.	1¼ In.	1½ In.	1¾ In.	2 In.	2¼ In.	2½ In.	2¾ In.	3 In.	3¼ In.	3½ In.	3¾ In.	4 In.	4½ In.	5 In.	5½ In.	6 In.
6.22	64	40	28	72	3½	7	10¾	14¼	17½	20¾	23¾	26¾	32½	37¼	41½													
6.48	40	48	56	72	3¼	6¾	10¼	13½	16¾	20	23	25¾	31½	36¼	40¼	44¼												
6.67	64	56	28	48	3¼	6½	10	13¼	16½	19½	22½	25¼	30¾	35¼	39½	43½												
7.29	56	64	40	48	3	6¼	9¼	12¼	15	18	20½	23½	28½	33	37	41	44¼											
7.41	40	48	64	72	3	6	9	12	14¾	17¾	20¼	22¾	28¼	32½	36½	40¼	43¾											
7.62	48	56	64	72	2¾	5¾	8¾	11½	14½	17¼	19¾	22¼	27½	32	36	39½	43											
8.33	48	32	40	72	2½	5¼	8	10½	13¼	15¾	18¼	20½	25½	29½	33½	37	40½	43½										
8.95	86	48	28	56	2½	5	7½	10	12½	14¾	17	19¼	24	28	31¾	35¼	38½	41¼	44									
9.33	48	40	56	72	2¼	4¾	7¼	9½	11¾	14	16¼	18½	23	27	30½	34	37½	40¼	43									
9.52	64	56	40	48	2¼	4½	7	9¼	11½	13¾	16	18¼	22½	26½	30	33½	36½	39½	42¼	45								
10.29	72	40	32	56	2	4¼	6½	8¾	10¾	12¾	15	17¼	21	24¾	28¼	31½	34½	37½	40	42½	45							
10.37	56	48	64	72	2	4¼	6½	8½	10½	12¾	14¾	17	20¾	24½	28	31¼	34¼	37¼	39¾	42¼	44¾							
10.50	56	64	48	40	2	4¼	6¼	8½	10½	12½	14½	16¾	20½	24¼	27¾	31	34	36¾	39½	42	44¼							
10.67	48	40	64	72	2	4	6¼	8¼	10¼	12¼	14¼	16½	20¼	24	27¼	30½	33½	36½	39	41½	43¾							
10.94	56	32	40	64	2	4	6	8¼	10¼	12	14	16¼	20	23½	26¾	30	33	35¾	38¼	43¾	43							
11.11	64	32	40	72	2	4	6	8	10	11¾	13¾	16	19¾	23	26½	29½	32½	35¼	38	40¼	42½	44¾						
11.66	56	32	48	72	1¾	3¾	5¾	7½	9½	11¼	13¼	15¾	18¾	22	25¼	28½	31¼	34	36½	39	41¼	43½						
12.00	72	40	32	48	1¾	3¾	5½	7¼	9¼	11	12¾	15	18¼	21½	24¾	27¾	30½	33¼	35¾	38	40¼	42½	44¾					
13.12	56	32	48	64	1½	3½	5¼	6¾	8½	10¼	11¾	13½	16¾	20	22¾	25¾	28¼	31	33¼	35¾	37¾	40	42	43¾				
13.33	64	32	48	72	1½	3¼	5	6½	8¼	10	11½	13¼	16½	19½	22½	25½	28	30½	33	35¼	37½	39½	41½	43¼	46¾	49¼	52¼	
13.71	64	56	48	40	1½	3¼	4¾	6½	8	9¾	11¼	13	16	19	22	24¾	27¼	30	32¼	34½	36½	38¾	40¾	42½	45¾	49	51½	
15.24	64	28	48	72	1½	3	4½	5¾	7¼	8¾	10¼	11¾	14½	17¼	20	22½	25	27¼	29½	31¾	34	35¾	37¾	39½	42¾	46	48½	51
15.56	64	32	56	72	1¼	2¾	4¼	5¾	7¼	8¾	10	11½	14¼	17	19½	22	24½	27	29	31¼	33¼	35¼	37	39	42¼	45¼	48	50¼

Courtesy of The Cincinnati Milling Machine Company

TABLE OF CHANGE GEARS, APPROXIMATE ANGLES AND LEADS FOR CUTTING SPIRALS—*Continued*

Twelve Change Gears are furnished with each Universal Miller as follows: 24, 24, 28, 32, 40, 44, 48, 56, 64, 72, 86 and 100 teeth

Lead of Spiral, Inches	Gear on Worm	1st Intermediate Gear	2d Intermediate Gear	Gear for Screw	1st Intermediate Gear Drives the Gear on Worm; 2d Intermediate Gear Drives the Gear for Screw — DIAMETER OF WORK																							
					⅛ In.	¼ In.	⅜ In.	½ In.	⅝ In.	¾ In.	⅞ In.	1 In.	1¼ In.	1½ In.	1¾ In.	2 In.	2¼ In.	2½ In.	2¾ In.	3 In.	3¼ In.	3½ In.	3¾ In.	4 In.	4½ In.	5 In.	5½ In.	6 In.
	Driven	Driver	Driven	Driver																								
15.75	72	64	56	40	1¼	2¾	4¼	5½	7	8½	9¾	11¼	14	16¾	19¼	21¾	24¼	26½	28¾	31	33	35	36¾	38½	42	45	47½	50
16.87	72	32	48	64	1¼	2½	4	5¼	6¾	7¾	9¼	10½	13¼	15¾	18¼	20½	22¾	25	27	29¼	31¼	33¼	35	36½	39¾	43	45¾	48¼
17.14	72	56	64	48	1¼	2½	4	5¼	6½	7¾	9	10¼	13	15½	17¾	20¼	22¼	24¾	26¾	29	30¾	32¾	34½	36	39½	42½	45¼	47¾
18.75	72	32	40	48	1	2¼	3½	4¾	6	7¼	8¼	9½	12	14¼	16¼	18½	20¾	22¾	25	26¾	28½	30¼	32	33¾	37	39¾	42¾	45
19.29	72	32	48	56	1	2¼	3½	4½	5¾	7	8	9¼	11½	13¾	16	18¼	20¼	22¼	24	26	28	29¾	31½	33	36¼	38¾	42	44½
19.59	64	28	48	56	1	2¼	3¼	4½	5¾	6¾	8	9¼	11½	13½	15¾	18	20	22	23¾	25¾	27½	29¼	31	32¾	35½	38¾	41½	44
19.69	72	32	56	64	1	2¼	3¼	4½	5¾	6¾	8	9	11½	13½	15¾	17¾	20	21¾	23¾	25½	27½	29¼	31	32½	35¾	38½	41¼	43¾
21.43	72	28	40	48	1	2	3¼	4¼	5¼	6¼	7½	8½	10½	12½	14½	16½	18½	20¼	22	23¾	25½	27¼	29	30¼	33½	36¼	38¾	41¼
22.50	72	28	56	64	1	2	3	4	5	6	7	8	10	12	13¾	15¾	17½	19¼	21	22¾	24½	27	27¾	29¼	32¼	35	37½	40
23.33	64	48	56	32	1	2	3	4	5	5¾	6¾	7¾	9¾	11½	13¼	15¼	17	18¾	20¼	22	23½	25¼	27	28¼	31¼	34	36¾	39
26.25	72	48	56	32	1	1¾	2¾	3½	4¼	5	6	7	8½	10¼	12	13½	15	16¾	18¼	19¾	21¼	22¾	24¼	25½	28¼	31	33¼	35¾
26.67	64	28	56	48	¾	1¾	2¾	3½	4¼	5	6	6¾	8½	10	11¾	13¼	14¾	16½	18	19½	21	22¼	23¾	25¼	28	30½	31¼	35¼
28.00	64	40	56	32	¾	1¾	2½	3¼	4	4¾	5¾	6½	8	9½	11¼	12¾	14¼	15¾	17¼	18¾	20	21½	22¾	24	26¾	29¼	31¾	34
30.86	72	28	48	40	¾	1½	2¼	3	3¾	4½	5	5¾	7¼	8¾	10	11½	13	14¼	15½	17	18½	19½	21	22	26	27	29¼	31½
31.50	72	40	56	32	¾	1½	2¼	3	3½	4¼	5	5¾	7¼	8½	10	11¼	12¾	14	15¼	16½	18	19¼	20½	21¾	24¼	26½	28¾	31
36.00	72	40	64	32	½	1¼	2	2½	3¼	3¾	4½	5	6¼	7½	8¾	10	11	12¼	13½	14¾	16	17	18¼	19¼	21½	23½	25¾	27¾
41.14	72	28	64	40	½	1	1¾	2¼	2¾	3¼	4	4½	5½	6½	7¾	8¾	9¾	10¾	11¾	13	14	15	16	17	19	21	22¾	24½
45.00	72	28	56	32	½	1	1½	2	2½	3	3½	4	5	6	7	8	9	10	11	11¾	12¾	13¾	14¾	15½	17½	19¼	21	22¾
48.00	72	24	64	40	½	1	1½	2	2½	3	3¼	3¾	4¾	5½	6½	7½	8½	9¼	10¼	11¼	12	13	13¾	14½	16½	18	19¾	21½
51.43	72	28	64	32	½	¾	1½	1¾	2¼	2¾	3	3½	4½	5¼	6	7	7¾	8¾	9½	10½	11¼	12	12¾	13¾	14¾	17	18½	20
60.00	72	24	64	32	½	¾	1¼	1½	2	2¼	2½	3	3¾	4½	5¼	6	6¾	7½	8¼	9	9½	10¼	11	11¾	13¼	14¾	16	17½

STANDARD INDEX TABLE

For the Standard Index Plate Used with Dividing Head

INDEXES ALL NUMBERS UP TO AND INCLUDING 60; ALL EVEN NUMBERS AND THOSE DIVISIBLE BY 5 UP TO 120, AND ALL DIVISIONS OBTAINABLE UP TO 400.

This Plate is drilled on both sides and has holes as follows:

FIRST SIDE — 24–25–28–30–34–37–38–39–41–42–43
SECOND SIDE — 46–47–49–51–53–54–57–58–59–62–66

No. of Divisions	Circle	Turns	Holes	No. of Divisions	Circle	Holes	No. of Divisions	Circle	Holes	No. of Divisions	Circle	Holes
2	ANY	20	..	44	66	60	104	39	15	205	41	8
3	24	13	8	45	54	48	105	42	16	210	42	8
4	ANY	10	..	46	46	40	106	53	20	212	53	10
5	ANY	8	..	47	47	40	108	54	20	215	43	8
6	24	6	16	48	24	20	110	66	24	216	54	10
7	28	5	20	49	49	40	112	28	10	220	66	12
8	ANY	5	..	50	25	20	114	57	20	224	28	5
9	54	4	24	51	51	40	115	46	16	228	57	10
10	ANY	4	..	52	39	30	116	58	20	230	46	8
11	66	3	42	53	53	40	118	59	20	232	58	10
12	24	3	8	54	54	40	120	66	22	235	47	8
13	39	3	3	55	66	48	124	62	20	236	59	10
14	49	2	42	56	28	20	125	25	8	240	66	11
15	24	2	16	57	57	40	130	39	12	245	49	8
16	24	2	12	58	58	40	132	66	20	248	62	10
17	34	2	12	59	59	40	135	54	16	250	25	4
18	54	2	12	60	42	28	136	34	10	255	51	8
19	38	2	4	62	62	40	140	28	8	260	39	6
20	ANY	2	..	64	24	15	144	54	15	264	66	10
21	42	1	38	65	39	24	145	58	16	270	54	8
22	66	1	54	66	66	40	148	37	10	272	34	5
23	46	1	34	68	34	20	150	30	8	280	28	4
24	24	1	16	70	28	16	152	38	10	290	58	8
25	25	1	15	72	54	30	155	62	16	296	37	5
26	39	1	21	74	37	20	156	39	10	300	30	4
27	54	1	26	75	30	16	160	28	7	304	38	5
28	42	1	18	76	38	20	164	41	10	310	62	8
29	58	1	22	78	39	20	165	66	16	312	39	5
30	24	1	8	80	34	17	168	42	10	320	24	3
31	62	1	18	82	41	20	170	34	8	328	41	5
32	28	1	7	84	42	20	172	43	10	330	66	8
33	66	1	14	85	34	16	176	66	15	336	42	5
34	34	1	6	86	43	20	180	54	12	340	34	4
35	28	1	4	88	66	30	184	46	10	344	43	5
36	54	1	6	90	54	24	185	37	8	360	54	6
37	37	1	3	92	46	20	188	47	10	368	46	5
38	38	1	2	94	47	20	190	38	8	370	37	4
39	39	1	1	95	38	16	192	24	5	376	47	5
40	ANY	1	..	96	24	10	195	39	8	380	38	4
41	41	..	40	98	49	20	196	49	10	390	39	4
42	42	..	40	100	25	10	200	30	6	392	49	5
43	43	..	40	102	51	20	204	51	10	400	30	3

Courtesy of The Cincinnati Milling Machine Company

CUTTING SPEEDS OF MILLING CUTTERS

Diam. Ins.	5	10	15	20	25	Diam. Ins.	5	10	15	20	25
	Feet per Minute / Revolutions per Minute						Feet per Minute / Revolutions per Minute				
½	38.2	76.4	114.6	152.9	191.1	8	2.4	4.8	7.2	9.6	11.9
⅝	30.6	61.2	91.8	122.5	153.1	9	2.1	4.2	6.4	8.5	10.6
¾	25.4	50.8	76.3	101.7	127.1	10	1.9	3.8	5.7	7.6	9.6
⅞	21.8	43.6	65.5	87.3	109.1	11	1.7	3.5	5.2	6.9	8.7
1	19.1	38.2	57.3	76.4	95.5	12	1.6	3.2	4.8	6.4	8.0
1⅛	17.0	34.0	51.0	68.0	85.0	13	1.5	2.9	4.4	5.9	7.3
1¼	15.3	30.6	45.8	61.2	76.3	14	1.4	2.7	4.1	5.5	6.8
1⅜	13.9	27.8	41.7	55.6	69.5	15	1.3	2.5	3.8	5.1	6.4
1½	12.7	25.4	38.2	50.8	63.7	16	1.2	2.4	3.6	4.8	6.0
1⅝	11.8	23.5	35.0	47.0	58.8	17	1.1	2.2	3.4	4.5	5.6
1¾	10.9	21.8	32.7	43.6	54.5	18	1.1	2.1	3.2	4.2	5.3
1⅞	10.2	20.4	30.6	40.7	50.9	19	1.0	2.0	3.0	4.0	5.0
2	9.6	19.1	28.7	38.2	47.8	20	1.0	1.9	2.9	3.8	4.8
2¼	8.5	17.0	25.4	34.0	42.4	21	.9	1.8	2.7	3.6	4.5
2½	7.6	15.3	22.9	30.6	38.2	22	.9	1.7	2.6	3.5	4.3
2¾	6.9	13.9	20.8	27.8	34.7	23	.8	1.7	2.5	3.3	4.1
3	6.4	12.7	19.1	25.5	31.8	24	.8	1.6	2.4	3.2	4.0
3½	5.5	10.9	16.4	21.8	27.3	25	.8	1.5	2.3	3.1	3.8
4	4.8	9.6	14.3	19.1	23.9	26	.7	1.5	2.2	2.9	3.7
4½	4.2	8.5	12.7	16.9	21.2	27	.7	1.4	2.1	2.8	3.5
5	3.8	7.6	11.5	15.3	19.1	28	.7	1.4	2.0	2.7	3.4
5½	3.5	6.9	10.4	13.9	17.4	29	.7	1.3	2.0	2.6	3.3
6	3.2	6.4	9.6	12.7	15.9	30	.6	1.3	1.9	2.5	3.2
7	2.7	5.5	8.1	10.9	13.6						

The above table will be convenient for finding the number of revolutions per minute required to give a periphery speed from 5 to 50 feet per minute of diameters from ½ to 30 inches.

Examples: A mill 2 inches in diameter, to have a periphery speed of 35 feet per minute, should make about 67 revolutions, while 1⅛ inch mill should make 119 revolutions to have the same periphery speed. If a ¾ inch mill makes 250 revolutions per minute, the periphery speed is about 50 feet.

(*Concluded on next page*)

Courtesy of Society of Automotive Engineers

CUTTING SPEEDS OF MILLING CUTTERS*—*Continued*

Diam. Ins.	Feet per Minute 30	35	40	45	50
	Revolutions per Minute				
½	229.3	267.5	305.7	344.0	382.2
⅝	183.7	214.3	244.9	275.5	306.1
¾	152.5	178.0	203.4	228.8	254.2
⅞	130.9	152.7	174.5	196.3	218.9
1	114.6	133.8	152.9	172.0	191.1
1⅛	102.0	119.0	136.0	153.0	170.0
1¼	91.8	106.9	122.5	137.4	153.1
1⅜	83.3	97.2	111.1	125.0	138.9
1½	76.3	89.2	101.7	114.6	127.1
1⅝	70.5	82.2	93.9	105.7	117.4
1¾	65.5	76.4	87.3	98.2	109.1
1⅞	61.1	71.3	81.5	91.9	101.9
2	57.3	66.9	76.4	86.0	95.5
2¼	51.0	59.4	68.0	76.2	85.0
2½	45.8	53.5	61.2	68.8	76.3
2¾	41.7	48.6	55.6	62.5	69.5
3	38.2	44.6	51.0	57.3	63.7
3½	32.7	38.2	43.6	49.1	54.5
4	28.7	33.4	38.2	43.0	47.8
4½	25.4	29.6	34.0	38.1	42.4
5	22.9	26.7	30.6	34.4	38.2
5½	20.8	24.3	27.8	31.3	34.7
6	19.1	22.3	25.5	28.7	31.8
7	16.4	19.1	21.8	24.6	27.3

Diam. Ins.	Feet per Minute 30	35	40	45	50
	Revolutions per Minute				
8	14.3	16.7	19.1	21.1	23.9
9	12.7	14.9	17.0	19.1	21.2
10	11.5	13.4	15.3	17.2	19.1
11	10.4	12.2	13.9	15.6	17.4
12	9.6	11.1	12.7	14.3	15.9
13	8.8	10.3	11.8	13.2	14.7
14	8.1	9.6	10.9	12.3	13.6
15	7.6	8.9	10.2	11.5	12.7
16	7.2	8.4	9.6	10.7	11.9
17	6.7	7.9	9.0	10.1	11.2
18	6.4	7.4	8.5	9.6	10.6
19	6.0	7.0	8.0	9.1	10.1
20	5.7	6.7	7.6	8.6	9.6
21	5.5	6.4	7.3	8.1	9.1
22	5.2	6.1	6.9	7.8	8.7
23	5.0	5.8	6.6	7.5	8.3
24	4.8	5.6	6.4	7.2	8.0
25	4.6	5.3	6.1	6.9	7.6
26	4.4	5.1	5.9	6.6	7.3
27	4.2	5.0	5.7	6.4	7.1
28	4.1	4.8	5.5	6.1	6.8
29	4.0	4.6	5.3	5.9	6.6
30	3.8	4.5	5.1	5.7	6.4

CUTTING SPEEDS OF SPIRAL AND FACE MILLS**

SPIRAL MILL		FACE MILL	
Cast Iron		**Cast Iron**	
Rough Milling	65–75 ft.	Rough Milling	65 ft.
Finish Milling	80–120 ft.	Finish Milling	80–110 ft.
Machine Steel		**Machine Steel**	
Rough Milling	70–75 ft.	Rough Milling	60–85 ft.
Finish Milling	100–140 ft.	Finish Milling	90–110 ft.
Tool Steel—Annealed			
Rough Milling	50 ft.		
Finish Millling	70–80 ft.		
Tobin Bronze — With Lubricant			
Rough Milling	90 ft.		
Finish Milling	125–150 ft.		

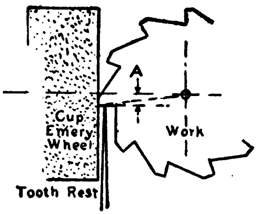
Chrome Nickel Steel 1.30 to .40 carbon drop forgings

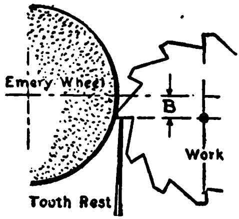
Brass.... 200 ft. Rough Milling.... 45 ft. Aluminum..... 600–1,000 ft.

*Courtesy of Society of Automotive Engineers

**Courtesy of The Cincinnati Milling Machine Company

EMERY WHEEL CLEARANCE TABLES





Cup Wheel Clearance Table

For setting tooth rest to obtain 5° or 7° clearance when grinding peripheral teeth of milling cutters with cup-shaped wheel. Tooth rest is set below work centers as at *A*, the distance being found in the table below.

Disk Wheel Clearance Table

Giving distance *B* for setting work centers and tooth rest below center of wheel spindle to obtain 5° or 7° clearance with wheels of different diameters when grinding with periphery of disk wheel.

Dia. Cutter inches	For 5° Clearance A =	For 7° Clearance A =	Dia. of Emery Wheel inches	For 5° Clearance B =	For 7° Clearance B =
¼	.011	.015	2	.0937	.125
⅜	.015	.022	2¼	.099	.141
½	.022	.030	2½	.110	.156
⅝	.028	.037	2¾	.125	.172
¾	.033	.045	3	.132	.187
⅞	.037	.052	3¼	.143	.203
1	.044	.060	3½	.154	.219
1¼	.055	.075	3¾	.165	.234
1½	.066	.090	4	.176	.250
1¾	.077	.105	4¼	.187	.265
2	.088	.120	4½	.198	.281
2¼	.099	.135	4¾	.209	.297
2½	.110	.150	5	.220	.312
2¾	.121	.165	5¼	.231	.328
3	.132	.180	5½	.242	.344
3½	.154	.210	5¾	.253	.359
4	.176	.240	6	.264	.375
4½	.198	.270	6¼	.275	.390
5	.220	.300	6½	.286	.406
5½	.242	.330	6¾	.297	.421
6	.264	.360	7	.308	.437

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

NUMBER OF TEETH IN PLAIN ROUGHING MILLING CUTTERS WITH COARSE PITCH

Diam. of Cutter	No. of Teeth	Diam. of Cutter	No. of Teeth	Diam. of Cutter	No. of Teeth	Diam. of Cutter	No. of Teeth	Diam. of Cutter	No. of Teeth
2	8	3	8	5	10	7	14	9	18
2¼	8	3½	9	5½	11	7½	14	9½	18
2½	8	4	9	6	12	8	16	10	20
2¾	8	4½	10	6½	12	8½	16	......	......

PLAIN AND SIDE MILLING CUTTERS

Diameter of Cutter	Plain Milling Cutter: Number of Teeth	Plain Milling Cutter: Radius of Point of Fluting Cutter	Side Milling Cutter: Number of Teeth	Side Milling Cutter: Angle of Cutter for Side Teeth	Width of Land on Teeth
2	14	5/64	22	For wide cutters, use 70- or 75-degree angle cutter. For thin cutters, use 80-, and in extreme cases 85-degree cutter.	1/32
2¼	14	5/64	22		1/32
2½	16	3/32	24		1/32
2¾	16	3/32	24		1/32
3	18	7/64	24		1/32
3½	18	7/64	24		3/64
4	20	⅛	26		3/64
4½	20	⅛	26		3/64
5	22	9/64	28		3/64

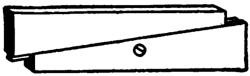
Diameter of Cutter	Plain Milling Cutter: Number of Teeth	Plain Milling Cutter: Radius of Point of Fluting Cutter	Side Milling Cutter: Number of Teeth	Side Milling Cutter: Angle of Cutter for Side Teeth	Width of Land on Teeth
5½	22	9/64	28	For wide cutters, use 70 or 75-degree angle cutter. For thin cutters, use 80-, and in extreme cases 85-degree cutter.	3/64
6	24	5/32	30		1/16
6½	24	5/32	30		1/16
7	26	3/16	30		1/16
7½	26	3/16	30		1/16
8	28	3/16	30		5/64
8½	28	3/16	32		5/64
9	30	3/16	32		5/64
10	30	3/16	32		5/64

STANDARD KEYWAYS FOR MILLING CUTTERS

Diameter of Hole	Width of Keyway	Depth of Keyway	Radius of Corners	Diameter of Hole	Width of Keyway	Depth of Keyway
⅜ to 9/16 inch	3/32	3/64	0.020	⅜ to ⅝ inch	⅛	1/16
⅝ to ⅞ inch	⅛	1/16	0.030	11/16 to 13/16 inch	3/16	3/32
15/16 to 1⅛ inch	5/32	5/64	0.035	⅞ to 1 3/16 inch	¼	⅛
1 3/16 to 1⅜ inch	3/16	3/32	0.040	1¼ to 1 7/16 inch	5/16	5/32
1 7/16 to 1¾ inch	¼	⅛	0.050	1½ to 2 inch	⅜	3/16
1 13/16 to 2 inch	5/16	5/32	0.060	2 1/16 to 2 7/16 inch	7/16	7/32
2 1/16 to 2½ inch	⅜	3/16	0.060	2½ to 3 inch	½	¼
2 9/16 to 3 inch	7/16	3/16	0.060	....	....	....

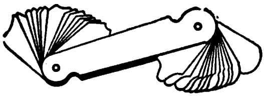
From "Machinery's" Handbook, The Industrial Press, New York

STARRETT TOOLS FOR USE IN CONNECTION WITH MILLING



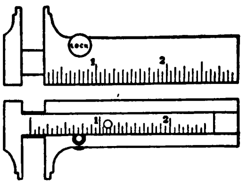
Adjustable Parallels

Made of good steel, carefully ground, dovetailed and adjusted by set screw inside. Have ranging height from $3/8$ in. to $2\frac{1}{4}$ in.



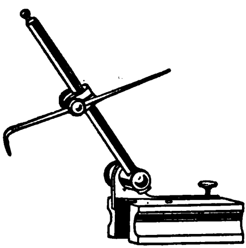
Fillet or Radius Gage

Made in two sizes. One has thirty leaves stamped to indicate radii by 64ths, from $\frac{1}{32}$ to $\frac{1}{4}$ in. (one half diametric size). Diameters are from $\frac{1}{16}$ to $\frac{1}{2}$ in., varying by 32ds. The other size has thirty-two leaves stamped to indicate radii by 64ths from $\frac{17}{64}$ to $\frac{1}{2}$ in. Diameters are from $\frac{17}{32}$ to 1 in., varying by 32ds



Pocket Slide Calipers

Accurate and convenient. Graduated in 32ds and 64ths; also made graduated in 32ds on the stock and 100ths on the slide and in the Metric system.

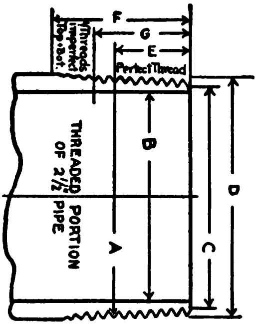


Toolmakers' Universal Surface Gage

Specially adapted to light work. Base of case-hardened steel with V-shaped groove in end and bottom, adapting it for use on cylindrical work. Spindle may be set rigidly in any position from vertical to horizontal and scriber placed so as to be used for depth gage or scribing gage.

For further information concerning these and other tools which may be used to advantage in Milling, see pages 34, 38, 61, 62, 63, 95, 96, and 158 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

STANDARD PIPE AND PIPE THREADS



A = Outside diameter of perfect thread
B = Inside diameter of pipe
C = Root diameter of thread at end of pipe
D = Outside diameter of thread at end of pipe
E = Length of perfect thread
F = Total length of thread
G = Length of perfect thread plus two threads

Briggs's Formula

E = Perfect thread = $(4.8+0.8A)$ P.

P = Pitch of thread = $\frac{1}{N}$

N = Number of threads
F = Length of taper at top
Taper ¾ inch to 1 foot

Height of thread = $8\frac{1}{N}$

G = Length of taper at bottom

Size	Thread	A	B	C	D	E	F	G
⅛	27	.405	.270	.334	.393	.19	.41	.264
¼	18	.540	.364	.433	.522	.29	.62	.402
⅜	18	.675	.494	.567	.656	.30	.63	.408
½	14	.840	.623	.702	.816	.39	.82	.534
¾	14	1.050	.824	.911	1.025	.40	.83	.546
1	11½	1.315	1.048	1.144	1.283	.51	1.03	.683
1¼	11½	1.660	1.380	1.488	1.627	.54	1.06	.707
1½	11½	1.900	1.611	1.727	1.866	.55	1.07	.724
2	11½	2.375	2.067	2.200	2.339	.58	1.10	.757
2½	8	2.875	2.468	2.618	2.818	.89	1.64	1.138
3	8	3.500	3.067	3.243	3.443	.95	1.70	1.200
3½	8	4.000	3.548	3.738	3.936	1.00	1.75	1.250
4	8	4.500	4.026	4.233	4.443	1.05	1.80	1.300
4	8	5.000	4.508	4.733	4.933	1.10	1.85	1.350
5	8	5.663	5.045	5.289	5.489	1.16	1.91	1.406
6	8	6.625	6.065	6.347	6.547	1.26	2.01	1.513
7	8	7.625	7.023	7.340	7.540	1.36	2.11	1.612
8	8	8.625	7.981	8.332	8.532	1.46	2.21	1.712
9	8	9.625	8.937	9.324	9.524	1.56	2.31	1.812
10	8	10.750	10.019	10.445	10.645	1.675	2.425	1.925
11	8	12.000	11.224	11.694	11.894	1.80	2.55	2.050
12	8	13.000	12.180	12.685	12.885	1.90	2.65	2.150

For dimensions which call for machine work, flanges, etc., see Vol. I of The Starrett Books.

DOUBLE EXTRA STRONG WROUGHT PIPE

Standard Dimensions

Diameter			Nominal Thickness	Circumference		Transverse Areas			Length of Pipe per Sq. Foot of		Length of Pipe Containing One Cubic Foot	Normal Weight per Foot Plain Ends
Nominal Internal	External	Approximate Internal		External	Internal	External	Internal	Metal	External Surface	Internal Surface		
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet	Feet	Feet	Lbs.
½	.840	.252	.294	2.639	.792	.554	.050	.504	4.547	15.157	2887.164	1.714
¾	1.050	.434	.308	3.299	1.363	.866	.148	.718	3.637	8.801	973.404	2.440
1	1.315	.599	.358	4.131	1.882	1.358	.282	1.076	2.904	6.376	510.998	3.659
1¼	1.660	.896	.382	5.215	2.815	2.164	.630	1.534	2.301	4.263	228.379	5.214
1½	1.900	1.100	.400	5.969	3.456	2.835	.950	1.885	2.010	3.472	151.526	6.408
2	2.375	1.503	.436	7.461	4.722	4.430	1.774	2.656	1.608	2.541	81.162	9.029
2½	2.875	1.771	.552	9.032	5.564	6.492	2.464	4.028	1.328	2.156	58.457	13.695
3	3.500	2.300	.600	10.996	7.226	9.621	4.155	5.466	1.091	1.660	34.659	18.583
3½	4.000	2.728	.636	12.566	8.570	12.566	5.845	6.721	.954	1.400	24.637	22.850
4	4.500	3.152	.674	14.137	9.902	15.904	7.803	8.101	.848	1.211	18.454	27.541
4½	5.000	3.580	.710	15.708	11.247	19.635	10.066	9.569	.763	1.066	14.306	32.530
5	5.563	4.063	.750	17.477	12.764	24.306	12.966	11.340	.686	.940	11.107	38.552
6	6.625	4.897	.864	20.813	15.384	34.472	18.835	15.637	.576	.780	7.646	53.160
7	7.625	5.875	.875	23.955	18.457	45.664	27.109	18.555	.500	.650	5.312	63.079
8	8.625	6.875	.875	27.096	21.598	58.426	37.122	21.304	.442	.555	3.879	72.424

Courtesy of the Greenfield Tap and Die Corporation

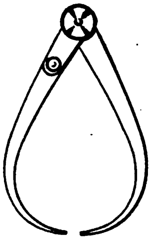
STANDARD WROUGHT STEAM, GAS, AND WATER PIPE

Standard Dimensions

Diameter: Nominal Internal	Diameter: External	Diameter: Approximate Internal	Nominal Thickness	Circumference: External	Circumference: Internal	Transverse Areas: External	Transverse Areas: Internal	Transverse Areas: Metal	Length of Pipe per sq. ft. of External Surface	Length of Pipe per sq. ft. of Internal Surface	Length of Pipe Containing One Cubic Foot	Nominal Weight per Foot, Iron: Plain End	Nominal Weight per Foot, Iron: Threaded and Coupled	Nominal Weight per Foot, Brass: Plain Ends	Nominal Weight per Foot, Copper: Plain Ends	Number of Threads per inch of Screw
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet	Feet	Feet					
1/8	.405	.269	.068	1.272	.845	.129	.057	.072	9.431	14.199	2533.775	.244	.245	.25	.26	27
1/4	.540	.364	.088	1.696	1.144	.229	.104	.125	7.073	10.493	1383.789	.424	.425	.43	.46	18
3/8	.675	.493	.091	2.121	1.549	.358	.191	.167	5.658	7.747	754.360	.567	.568	.62	.64	18
1/2	.840	.622	.109	2.639	1.954	.554	.304	.250	4.547	6.141	473.906	.850	.852	.90	.96	14
3/4	1.050	.824	.113	3.299	2.589	.866	.533	.333	3.637	4.635	270.034	1.130	1.134	1.25	1.30	14
1	1.315	1.049	.133	4.131	3.296	1.358	.864	.494	2.904	3.641	166.618	1.678	1.684	1.70	1.83	11½
1¼	1.660	1.380	.140	5.215	4.335	2.164	1.495	.669	2.301	2.767	96.275	2.272	2.281	2.50	2.69	11½
1½	1.900	1.610	.145	5.969	5.058	2.835	2.036	.799	2.010	2.372	70.733	2.717	2.731	3.00	3.20	11½
2	2.375	2.067	.154	7.461	6.494	4.430	3.355	1.075	1.608	1.847	42.913	3.652	3.678	4.00	4.23	11½
2½	2.875	2.469	.203	9.032	7.757	6.492	4.788	1.704	1.328	1.547	30.077	5.793	5.819	5.83	6.13	8
3	3.500	3.068	.216	10.996	9.638	9.621	7.393	2.228	1.091	1.245	19.479	7.575	7.616	8.32	8.75	8
3½	4.000	3.548	.226	12.566	11.146	12.566	9.886	2.680	.954	1.076	14.565	9.109	9.202	10.85	11.41	8
4	4.500	4.026	.237	14.137	12.648	15.904	12.730	3.174	.848	.948	11.312	10.790	10.889	12.30	12.94	8
4½	5.000	4.506	.247	15.708	14.156	19.635	15.947	3.688	.763	.847	9.030	12.538	12.642	13.74	14.46	8
5	5.563	5.047	.258	17.477	15.856	24.306	20.006	4.300	.686	.756	7.198	14.617	14.810	15.40	16.20	8
6	6.625	6.065	.280	20.813	19.054	34.472	28.891	5.581	.576	.629	4.984	18.974	19.185	18.44	19.41	8
7	7.625	7.023	.301	23.955	22.063	45.664	38.738	6.926	.500	.543	3.717	23.544	23.769	23.92	25.17	8
8	8.625	8.071	.277	27.096	25.356	58.426	51.161	7.265	.442	.473	2.815	24.696	25.000	30.06	31.63	8
8	8.625	7.981	.322	27.096	25.073	58.426	50.027	8.399	.442	.478	2.878	28.554	28.809			8
9	9.625	8.941	.342	30.238	28.089	72.760	62.786	9.974	.396	.427	2.294	33.907	34.188			8
10	10.750	10.192	.279	33.772	32.019	90.763	81.585	9.178	.355	.374	1.765	31.201	32.000			8
10	10.750	10.136	.307	33.772	31.843	90.763	80.691	10.072	.355	.376	1.785	34.240	35.000			8
10	10.750	10.020	.365	33.772	31.479	90.763	78.855	11.908	.355	.381	1.826	40.483	41.132			8

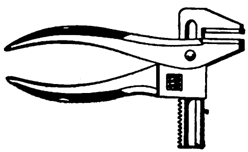
Courtesy of the Greenfield Tap and Die Corporation

STARRETT TOOLS FOR USE IN CONNECTION WITH PIPES AND FITTING



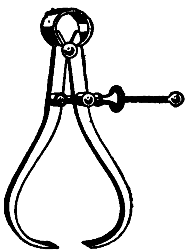
Lock Joint Transfer Calipers

Consists of the usual arms and an auxiliary leaf bound to the arm by a nut which when loosened permits the arm to be swung in or out to clear any obstruction, as a flange, etc., without losing the size calipered. Sensitive adjustment, light, stiff, large capacity, instantly opened, closed, or locked, points nicely tempered. Made in both inside and outside calipers, also lock-joint dividers.



Expansion Pliers

The jaws are adjustable from zero to 1¼ inches, the adjustment being made by a small worm screw. The device keeps the jaws parallel with the surface of the piece held and affords a strong grip on any object within the limits of the pliers. Made plain or nickeled.



Yankee Thread Calipers

Made with either spring or solid nut. Stiff bow. A light, well made tool.

For further information concerning these and other tools which may be used to advantage with Pipes and Fitting, see page 8 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

PRACTICAL CUTTING SPEEDS FOR PLANING

Cast iron, roughing	40 to 50 feet per minute
Cast iron, finishing	20 to 25 feet per minute
Steel castings, roughing	30 to 35 feet per minute
Wrought iron, roughing	30 to 45 feet per minute
Steel castings, finishing	20 feet per minute
Wrought iron, finishing	20 feet per minute
Bronze and brass	50 to 60 feet per minute
Machinery steel	30 to 35 feet per minute

NUMBER OF FEET TABLE TRAVELS PER HOUR ON CUT

Speed of Cut	Speed of return per minute							
Feet	50	60	70	80	90	100	120	150
20	857.14	900.	933.33	960.	981.81	1000.	1028.57	1058.82
25	1000.	1058.82	1105.26	1142.86	1173.91	1200.	1241.38	1285.71
30	1125.	1200.	1260.	1309.09	1350.	1384.6	1440.	1500.
35	1235.29	1321.31	1400.	1460.87	1512.	1555.55	1625.80	1702.702
40	1333.33	1440.	1527.27	1600.	1661.54	1714.28	1800.	1894.74
45	1421.05	1542.85	1643.47	1728.	1800.	1862.06	1863.63	2076.92
50	1500.	1636.36	1750.	1846.15	1928.57	2000.	2117.64	2250.

Divide by length of stroke to get number of strokes per hour.

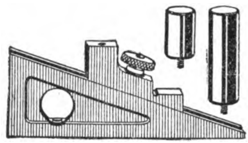
TIME OF PLANER TRAVEL PER FOOT

Travel feet per minute	Time one foot	Travel feet per minute	Time one foot
10	6. sec.	105	.571
15	4.	110	.545
20	3.	120	.5
25	2.4	130	.461
30	2.	140	.428
35	1.72	150	.4
40	1.5	160	.375
45	1.333	170	.353+
50	1.2	180	.333
55	1.09	190	.316
60	1.	200	.3
65	.923	220	.273
70	.857	240	.25
75	.8	260	.23
80	.75	280	.214
85	.705	300	.2
90	.666		
95	.631		
100	.6		

STARRETT TOOLS FOR USE IN CONNECTION WITH PLANING

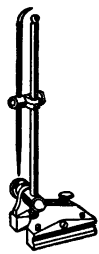
Planer and Shaper Gage

By setting the gage with a caliper, micrometer, or surface gage and bringing the planer tool in contact with it the accuracy of the first cut is assured. A level in the base of the gage makes it convenient for leveling pieces on the platen of a planer or the bed of a milling machine. The gage with extensions will give any height between ½ and 5½ inches.



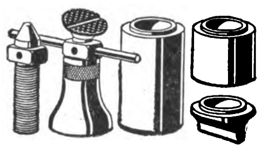
New Universal Surface Gage

Has a heavy base, grooved through the bottom and end, adapting it for use on or against circular work as well as flat surfaces. The spindle passes through a rotating head, jointed to a rocking bracket, pivoted in the base, the bracket being adjusted by a knurled screw in one end against a stiff spring in the other. The spindle may be set and sensitively adjusted to any position. By loosening the clamp nut the whole may be freely set in any position, being held by friction springs until locked by a slight turn of the clamp nut.



Little Giant Jackscrews

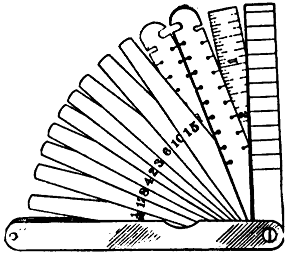
From 1 to 1¼ inches diameter at the base, with a lifting range from 1½ to 3⅝ inches. Extension bases increase the range to 6½ inches. An auxiliary pointed screw and base of special shape are also furnished. The lifting capacity is in excess of 1,000 pounds.



For further information concerning these and other tools which may be used to advantage in Planing, see pages 8, 89, 96 and 98 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

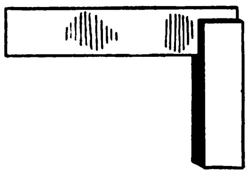
STARRETT TOOLS FOR USE IN CONNECTION WITH PLANING

Engineers' Taper, Wire and Thickness Gage



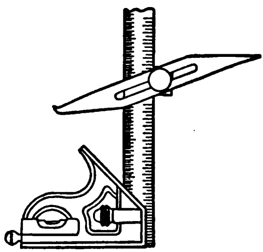
Shows thicknesses in 64ths to $\frac{3}{16}$ of an inch on one side, the reverse being graduated for 3 inches of its length as a rule, reading in 8ths and 16ths of an inch. The wire gage, English Standard, shows on one side sizes numbered from 19 to 36, with two extra slots, one $\frac{1}{16}$, the other $\frac{1}{8}$ of an inch, and on the reverse side the decimal equivalents in thousandths.

Steel Square



Hardened edge, solid steel square, not graduated, made in sizes from 1 inch to 24 inches inside beam. The 18 and 24 inch sizes are equipped with a stock support which projects beyond the side of the stock, or, when not in use, is contained wholly within the stock and may be clamped firmly in either position. Also special squares for fine tool and die makers, these being fitted with sliding scale, extra bevel blade, and special narrow blade for squaring small holes, etc.

Attachment for Combination Squares



Clamps to a 12 inch blade of any of The Starrett Combination Squares. Can be used on a height gage, for scribing lines, leveling planer work, etc.

For further information concerning these and other tools which may be used to advantage in Planing, see pages 8, 89, 93 and 95 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

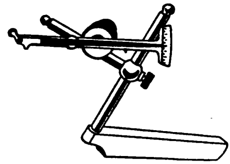
Precision Measurements

"Interchangeability," "Duplication of Parts," and similar expressions, mean to the machinist a definite thing, that of being able to machine and finish the separate parts of a mechanism so closely to the figured dimensions that they can be assembled into a complete unit without further fitting. This is the exact ideal always before the modern constructor.

The assembling machinist soon realizes that a minute error in dimension may make it necessary for him to do a certain amount of fitting as he assembles the various parts into a complete machine unit. If such fitting is necessary, the parts cannot be said to be truly interchangeable. In general practice certain error allowances, minute or otherwise, are tolerated, and these allowed errors in measurements are for this reason termed "tolerances." Where the given measurement needs to be exact to the one-thousandth part of an inch or to a fraction thereof, it is known as a precision measurement and the tools used to determine such a measurement to the required accuracy are known as precision tools. Precision tools are designed and constructed in such manner that *direct readings* may be made of errors in dimension as minute as a thousandth part of an inch or a fraction of a thousandth thereof. Such tools are sold under the names of micrometers, verniers, etc., for the direct reading of minute measurements, of lengths, of diameters, of depths, and of heights; when the measurement is one of angles, direct reading of such is provided for by precision protractors, usually termed "Universal Bevel Protractors with Vernier." All the above-mentioned tools are tested to an exactness much less than a ten-thousandth part of an inch and are sold to read directly to one ten-thousandth part of an inch. It will assist the machinist in using precision tools if he clearly understands that his work must be exact within a certain limiting error of dimension and that he is using his precision tool,— for example, a micrometer caliper, — to learn by a direct reading tool how small an error of dimension he has in his work at the time the measurement is made. In certain classes of work, as, for example, precision holes, solid or fixed gages may be provided having the tolerated error an inherent part of their construction. These are often termed Limiting Gages, built so that a certain part of the gage will go into the hole, while another part of the gage will not go into the hole. The machinist usually knows such tools as "go" and "not go" gages. In all precision measurements, the direct reading micrometer and the direct reading vernier tools are at the head in the machinist's kit of tools.

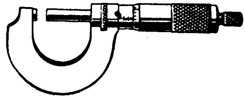
STARRETT INSTRUMENTS FOR PRECISION MEASUREMENTS

Universal Test Indicator



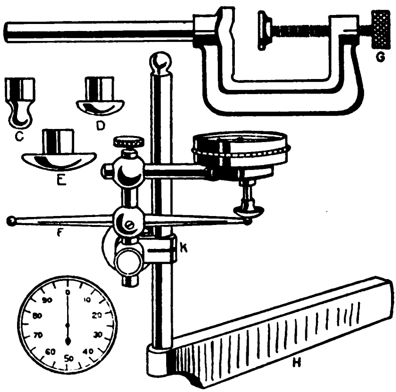
Clamps on any flat or round support up to three eighths inch. A special holder is designed to go in the tool post of a lathe. The head of the needle has three working points, equally distant from its fulcrum, so that the telltale needle will vibrate, reading in thousandths, when the work is in contact with any point. The working parts of the head are hardened.

Half Inch .0001 Micrometer Caliper



Has lock nut and ratchet stop, measuring by ten thousandths of an inch up to one half inch. Made, as are all Starrett Micrometers, with a solid anvil and a thin, graduated sleeve over the barrel, carrying the base or zero line. The anvil and spindle are hardened, ground, and lapped.

Universal Dial Test Indicators



Simple, reliable, easily read, and very sensitive. Slightest pressure upon contact point produces a movement of the hand on the dial. Circumference of dial divided into one hundred equal spaces, each representing a movement of the contact point of one thousandth of an inch. One revolution of the hand indicates one tenth inch, the capacity of the instrument being two tenths. Each indicator is fitted with three hardened contact points for different classes of work. The special tool post and sleeve are useful in lathe work.

The clamp G permits attaching the indicator to large lathe and planer tools, milling arbors, etc. The attachment F adapts it for use inside of holes, to reach over blockings on faceplates, etc.

For further information concerning these and other tools which may be used to advantage in Precision Measurements, see especially pages 18, 34, 40, 61, 62, 63, and 158 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

TAPER REAMERS FOR MORSE, JARNO, AND BROWN & SHARPE STANDARD TAPER SOCKETS

Number of Taper	Diameter at Small End	Diameter at Large End	Diameter of Shank	Size of Square	Length of Square	Length of Flute	Total Length	Width at Bottom of Groove	Depth of Groove	Taper per Foot	Number of Nicks per Inch	Number of Flutes Fin. Reamer	No. of Flutes Roughing Reamer
0	0.252	0.369	11/32	1/4	5/16	2 1/4	3 3/4	1/32	0.025	0.625	3 1/2	6	4
1	0.369	0.510	15/32	23/64	1/2	2 13/16	4 11/16	3/64	0.025	0.600	3 1/2	6	4
2	0.572	0.741	21/32	1/2	5/8	3 3/8	5 5/8	1/16	1/32	0.602	3	8	5
3	0.778	0.979	7/8	21/32	13/16	4	6 5/8	5/64	1/32	0.602	3	8	5
4	1.020	1.280	1 1/8	27/32	1	5	8	3/32	3/64	0.623	2 1/2	8	6
5	1.475	1.790	1 1/2	1 1/8	1 1/8	6	9 3/8	7/64	3/64	0.630	2 1/2	10	6
6	2.116	2.559	2	1 1/2	1 5/16	8 1/2	12 1/4	1/8	1/16	0.626	2 1/2	14	8
7	2.750	3.375	2 5/8	1 31/32	1 1/2	12	16 1/8	9/64	1/16	0.625	2 1/2	14	8

JARNO

1	0.100	0.144	1/8	3/32	3/16	7/8	1 3/4	1/32	0.025	0.600	3 1/2	6	4
2	0.200	0.269	15/64	11/64	9/32	1 3/8	2 5/8	1/32	0.025	0.600	3 1/2	6	4
3	0.300	0.400	3/8	9/32	3/8	2	3 1/2	1/32	0.025	0.600	3 1/2	6	4
4	0.400	0.531	15/32	23/64	1/2	2 5/8	4 3/8	3/64	0.025	0.600	3 1/2	6	4
5	0.500	0.659	19/32	29/64	5/8	3 3/16	5 1/8	3/64	0.025	0.600	3	6	4
6	0.600	0.787	11/16	33/64	5/8	3 3/4	5 7/8	1/16	1/32	0.600	3	8	5
7	0.700	0.916	13/16	39/64	3/4	4 5/16	6 5/8	1/16	1/32	0.600	3	8	5
8	0.800	1.044	15/16	45/64	7/8	4 7/8	7 3/8	5/64	1/32	0.600	3	8	5
9	0.900	1.169	1 1/16	51/64	7/8	5 3/8	8 1/8	5/64	1/32	0.600	3	8	5
10	1.000	1.297	1 1/8	27/32	1	5 15/16	8 7/8	3/32	3/64	0.600	2 1/2	8	6
11	1.100	1.422	1 3/16	57/64	1	6 7/16	9 1/2	3/32	3/64	0.600	2 1/2	8	6
12	1.200	1.550	1 5/16	63/64	1 1/16	7	10 1/8	3/32	3/64	0.600	2 1/2	8	6
13	1.300	1.675	1 7/16	1 5/64	1 1/16	7 1/2	10 3/4	7/64	3/64	0.600	2 1/2	10	6
14	1.400	1.800	1 1/2	1 1/8	1 1/8	8	11 3/8	7/64	3/64	0.600	2 1/2	10	6
15	1.500	1.928	1 5/8	1 7/32	1 1/8	8 9/16	12	7/64	3/64	0.600	2 1/2	10	6
16	1.600	2.053	1 3/4	1 3/16	1 1/8	9 1/16	12 5/8	7/64	3/64	0.600	2 1/2	10	6
17	1.700	2.181	1 13/16	1 23/64	1 1/4	9 5/8	13 3/8	7/64	3/64	0.600	2 1/2	10	6
18	1.800	2.306	1 7/8	1 13/32	1 1/4	10 1/8	14	1/8	1/16	0.600	2 1/2	12	6
19	1.900	2.431	1 15/16	1 29/64	1 1/4	10 5/8	14 5/8	1/8	1/16	0.600	2 1/2	12	6
20	2.000	2.556	2	1 1/2	1 3/8	11 1/8	15 1/4	1/8	1/16	0.600	2 1/2	12	6

BROWN & SHARPE

1	0.200	0.252	7/32	5/32	1/4	1 1/4	2 1/4	1/32	0.025	1/2	3 1/2	6	4
2	0.250	0.318	9/32	7/32	5/16	1 5/8	3	1/32	0.025	1/2	3 1/2	6	4
3	0.312	0.416	3/8	9/32	3/8	2 1/2	4 1/4	1/32	0.025	1/2	3 1/2	6	4
4	0.350	0.444	13/32	5/16	7/16	2 1/4	3 3/4	1/32	0.025	1/2	3 1/2	6	4
5	0.450	0.564	1/2	3/8	1/2	2 3/4	4 3/4	3/64	0.025	1/2	3	6	4
6	0.500	0.667	19/32	7/16	5/8	4	6 1/2	3/64	0.025	1/2	3	6	4
7	0.600	0.803	23/32	17/32	3/4	4 7/8	8	1/16	1/32	1/2	3	8	5
8	0.750	0.958	27/32	5/8	13/16	5	8 1/4	5/64	1/32	1/2	3	8	5
9	0.900	1.119	1	3/4	7/8	5 1/4	8 5/8	5/64	1/32	1/2	3	8	5
10	1.045	1.346	1 7/32	29/32	1	7 1/4	10 3/4	3/32	3/64	0.5161	2 1/2	8	6
11	1.250	1.573	1 7/16	1 1/16	1 1/16	7 3/4	11 1/2	3/32	3/64	1/2	2 1/2	8	6
12	1.500	1.838	1 11/16	1 1/4	1 1/8	8 1/8	12	7/64	3/64	1/2	2 1/2	10	6
13	1.750	2.114	1 15/16	1 7/16	1 1/4	8 3/4	12 3/4	7/64	3/64	1/2	2 1/2	10	6
14	2.000	2.385	2 1/8	1 19/32	1 3/8	9 1/4	13 3/8	1/8	1/16	1/2	2 1/2	10	6
15	2.250	2.656	2 3/8	1 25/32	1 1/2	9 3/4	14	1/8	1/16	1/2	2 1/2	14	8
16	2.500	2.927	2 5/8	1 31/32	1 5/8	10 1/4	14 1/2	9/64	1/16	1/2	2 1/2	14	8
17	2.750	3.198	2 7/8	2 5/32	1 3/4	10 3/4	15 1/4	9/64	1/16	1/2	2 1/2	14	8
18	3.000	3.469	3 1/8	2 11/32	1 7/8	11 1/4	15 3/4	9/64	1/16	1/2	2 1/2	14	8

REAMER CLEARANCES

Ground with Cup Wheel 3 in. Dia.—Tooth rest to be set central with emery wheel spindle. Set work holding centers above emery wheel center by amount given below in Tables No. 1, 2 and 3

Set tooth rest below work holding centers. Amount given below in Table No. 4

Size of Reamer	Table 1 Hand Reamer for Steel Cutting Clearance Land .006 Wide — For Cutting Clearance	Table 1 — For Second Clearance	Table 2 Hand Reamer for Cast Iron and Bronze Cut'g Clearance Land .025 Wide — For Cutting Clearance	Table 2 — For Second Clearance	Table 3 Chucking Reamer for Cast Iron and Bronze Cut'g Clearance Land .025 Wide — For Cutting Clearance	Table 3 — For Second Clearance	Table 4 Chucking Reamers for Steel Circular Round — Angle on End of Blade	Table 4 — For Cutting Clearance on Angle
Inches								
1/2	.012	.052	.032	.072	.040	.080	45 degrees	.080
9/16	.012	.057	.032	.072	.040	.080	45 "	.080
5/8	.012	.062	.032	.072	.040	.090	45 "	.090
11/16	.012	.067	.035	.095	.040	.100	45 "	.100
3/4	.012	.072	.035	.095	.040	.100	45 "	.100
13/16	.012	.077	.037	.095	.045	.125	45 "	.125
7/8	.012	.082	.040	.120	.045	.125	45 "	.125
15/16	.012	.087	.040	.120	.045	.125	45 "	.125
1	.012	.092	.040	.120	.045	.125	45 "	.125
1 1/16	.012	.097	.040	.120	.045	.125	45 "	.125
1 1/8	.012	.102	.040	.120	.045	.125	45 "	.125
1 3/16	.012	.106	.042	.122	.045	.125	45 "	.125
1 1/4	.012	.112	.045	.145	.050	.160	45 "	.160
1 5/16	.012	.118	.045	.145	.050	.160	45 "	.160
1 3/8	.012	.122	.045	.145	.050	.160	45 "	.175
1 7/16	.012	.127	.045	.145	.055	.175	45 "	.175
1 1/2	.012	.132	.048	.168	.055	.175	45 "	.175
1 9/16	.012	.137	.050	.170	.055	.175	45 "	.175
1 5/8	.012	.142	.050	.170	.060	.200	45 "	.200
1 11/16	.012	.147	.050	.170	.060	.200	45 "	.200
1 3/4	.012	.152	.052	.192	.060	.200	45 "	.200
1 13/16	.012	.157	.052	.192	.060	.200	45 "	.200
1 7/8	.012	.162	.056	.196	.060	.200	45 "	.200
1 15/16	.012	.167	.056	.196	.064	.200	45 "	.200
2	.012	.172	.056	.216	.064	.224	45 "	.225
2 1/16	.012	.172	.056	.216	.064	.224	45 "	.225
2 1/8	.012	.172	.059	.219	.064	.224	45 "	.225
2 3/16	.012	.172	.059	.219	.064	.224	45 "	.225
2 1/4	.012	.172	.063	.223	.064	.224	45 "	.225
2 5/16	.012	.172	.063	.223	.064	.224	45 "	.225
2 3/8	.012	.172	.063	.223	.068	.228	45 "	.230
2 7/16	.012	.172	.063	.223	.068	.228	45 "	.230
2 1/2	.012	.172	.065	.225	.072	.232	45 "	.230
2 9/16	.012	.172	.065	.225	.072	.232	45 "	.230
2 5/8	.012	.172	.065	.225	.075	.235	45 "	.235
2 11/16	.012	.172	.065	.225	.075	.235	45 "	.235
2 3/4	.012	.172	.065	.225	.077	.237	45 "	.240
Mount tooth rest on emery wheel head							Mount tooth rest on table of machine	

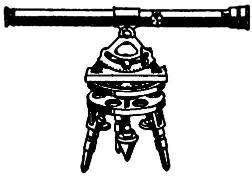
From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

REAMER CLEARANCES — *Continued*

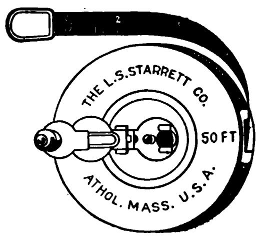
Ground with Cup Wheel 3 in. Dia.—Tooth rest to be set central with emery wheel spindle. Set work holding centers above emery wheel center by amount given below in Tables No. 1, 2 and 3							Set tooth rest below work holding centers. Amount given below in Table No. 4	
	Table 1 Hand Reamer for Steel Cutting Clearance Land .006 Wide		Table 2 Hand Reamer for Cast Iron and Bronze Cutting Clearance Land .025 Wide		Table 3 Chucking Reamer for Cast Iron and Bronze Cut'g Clearance Land .025 Wide		Table 4 Chucking Reamers for Steel Circular Ground	
Size of Reamer	For Cutting Clearance	For Second Clearance	For Cutting Clearance	For Second Clearance	For Cutting Clearance	For Second Clearance	Angle on End of Blade	For Cutting Clearance on Angle
Inches								
2 13/16	.012	.172	.065	.225	.077	.237	45 degrees	.240
2 7/8	.012	.172	.070	.230	.080	.240	45 "	.240
2 15/16	.012	.172	.070	.230	.080	.240	45 "	.240
3	.012	.172	.072	.232	.080	.240	45 "	.240
3 1/16	.012	.172	.072	.232	.080	.240	45 "	.240
3 1/8	.012	.172	.075	.235	.083	.240	45 "	.240
3 3/16	.012	.172	.075	.235	.083	.243	45 "	.240
3 1/4	.012	.172	.078	.238	.083	.243	45 "	.245
3 5/16	.012	.172	.078	.238	.087	.243	45 "	.245
3 3/8	.012	.172	.081	.241	.087	.247	45 "	.245
3 7/16	.012	.172	.081	.241	.090	.247	45 "	.245
3 1/2	.012	.172	.084	.244	.090	.250	45 "	.250
3 9/16	.012	.172	.084	.244	.090	.250	45 "	.250
3 5/8	.012	.172	.087	.247	.093	.253	45 "	.250
3 11/16	.012	.172	.087	.247	.093	.253	45 "	.250
3 3/4	.012	.172	.090	.250	.097	.257	45 "	.255
3 13/16	.012	.172	.090	.250	.097	.257	45 "	.255
3 7/8	.012	.172	.093	.253	.100	.260	45 "	.255
3 15/16	.012	.172	.093	.253	.100	.260	45 "	.255
4	.012	.172	.096	.256	.104	.264	45 "	.260
4 1/16	.012	.172	.096	.256	.104	.264	45 "	.260
4 1/8	.012	.172	.096	.256	.104	.264	45 "	.260
4 3/16	.012	.172	.096	.256	.106	.266	45 "	.260
4 1/4	.012	.172	.096	.256	.106	.266	45 "	.265
4 5/16	.012	.172	.096	.256	.106	.266	45 "	.265
4 3/8	.012	.172	.096	.256	.108	.268	45 "	.265
4 7/16	.012	.172	.096	.256	.108	.268	45 "	.265
4 1/2	.012	.172	.100	.260	.108	.268	45 "	.265
4 9/16	.012	.172	.100	.260	.108	.268	45 "	.265
4 5/8	.012	.172	.100	.260	.110	.270	45 "	.270
4 11/16	.012	.172	.100	.260	.110	.270	45 "	.270
4 3/4	.012	.172	.104	.264	.114	.274	45 "	.275
4 13/16	.012	.172	.104	.264	.114	.274	45 "	.275
4 7/8	.012	.172	.106	.266	.116	.276	45 "	.275
4 15/16	.012	.172	.106	.266	.116	.276	45 "	.275
5	.012	.172	.110	.270	.118	.278	45 "	.275
5 1/8	.012	.172	.118	.278	...	...	.....	...
Mount tooth rest on emery wheel head							Mount tooth rest on table of machine	

STARRETT TOOLS FOR THE USE OF ENGINEERS

Simplified Transit



The upper plate, which can be leveled by the leveling screws, contains a graduated arc for taking angles. On the plate rests a triangular frame to which are attached a level, graduated arc for vertical angles, and sight tube or telescope fitted with cross lines. Free from complicated and confusing adjustments found on the regular engineer's transit.



Steel Measuring Tape

Tape is ⅜ inch wide in metal-lined leather case, with extension push button handle which is flush with case when closed. Quick reading graduations. Black finish with bright figures or vice versa, as desired.

Engineers' Level

Instrument consists of adjustable incline level, a fixed level, and a plumb. The hinged tube working inside the frame, carrying a level, is adjustable to graduated scale, showing incline by 32ds (or less) to 2 inches to the foot. Longitudinal groove in seat of frame adapts tool to use on cylindrical surfaces.

For further information concerning these and other tools of interest to engineers see pages 8 and 113 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

STARRETT HACK SAW CHART

FOR MOST SATISFACTORY RESULTS USE SAWS REFERRED TO BELOW

Numbers refer to the blade numbers in The Starrett Catalogue

Material to be Cut	No. of Blade for Hand Frame		No. of Blade for Power Machine			
	All Hard	Flexible or Soft Back	Light Machine	Medium Machine	Heavy Machine	Extra Heavy Machine
Light Angles Light Channels Light Tee Iron Light Ornamental	102	252	115	262		
Heavy Angles Heavy Channels Heavy Tee Iron	103 112	250	115–B	255		
Light Structural	112–B			255	254	256
Heavy Structural	112–B			255–B	254–B	256–B
Iron Pipe Conduit Pipe Brass Pipe	102	252	115	262	259	
Solid Stock Cold Rolled Machine Steel	103–B 112–B	250 250–B	114	255–B 255–C	254–B 254–C	256–B 256–C
Tool Steel Cast Iron	103 112		114	255	254	256
Brass	103 112		115	262	259	
Sheet Metal Less than 18 gage Over 18 gage	 253 102	 258 252				

SUGGESTIONS AS TO SPEED

The speed of saws varies largely according to the material being cut. Saws used in machines can be run to good advantage on soft steel about 100 strokes per minute; on annealed tool steel, about 65 strokes per minute; on unannealed tool steel, about 60 strokes per minute; that is, when compound or water is used; when not used, run about 50 strokes per minute.

SAWS USED IN HAND FRAMES

Strain the blade well in frame with the rake of teeth forward. Bear down on forward stroke so that blade will not slip, and ease the pressure on the return stroke. Do not bend sidewise. Use at about 50 strokes per minute.

HACK SAW DON'TS

Don't use a coarse blade on light sheet metal, tubing, or very hard steel.

Don't use a coarse blade on solid brass, copper, or gas pipe.

Don't let blades slip or slide without cutting.

Don't run blades too fast in power machines. We suggest that for dry cutting about 50 strokes per minute will give the best results, whereas if a compound is used, 65 to 100 strokes may be applied, according to conditions.

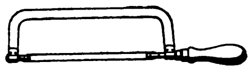
Don't put too much weight on a new saw. Nothing is gained in trying to force the saw. Too much weight dulls the saw quickly.

HACK SAW THRIFT

CUTS PER HOUR CORRESPONDING TO GROSS TIME PER CUT

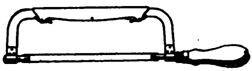
Minutes per Cut	Seconds per Cut												
	0	5	10	15	20	25	30	35	40	45	50	55	60
	Number of Cuts per Hour												
1	60.	55.	52.6	48.	45.	42.2	40.	38.2	36.1	34.3	32.8	31.4	30.
2	30.	28.8	27.6	26.6	25.8	24.8	24.	23.3	22.5	21.9	20.8	20.5	20.
3	20.	19.4	18.9	18.6	18.	17.6	17.	16.7	16.3	16.	15.7	15.3	15.
4	15.	14.7	14.4	14.1	13.85	13.37	13.3	13.	12.8	12.6	12.4	12.2	12.
5	12.	11.8	11.6	11.4	11.25	11.	10.9	10.7	10.6	10.4	10.3	10.2	10.
6	10.	9.87	9.7	9.5	9.47	9.36	9.2	9.12	9.	8.88	8.81	8.76	8.6
7	8.6	8.47	8.38	8.3	8.19	8.09	8.	7.9	7.83	7.74	7.68	7.59	7.5
8	7.5	7.42	7.35	7.27	7.2	7.13	7.1	7.	6.92	6.9	6.8	6.75	6.7
9	6.7	6.6	6.55	6.48	6.43	6.36	6.3	6.26	6.21	6.2	6.1	6.07	6.
10	6.	5.95	5.87	5.85	5.8	5.76	5.7	5.67	5.62	5.6	5.56	5.55	5.5
11	5.5	5.41	5.37	5.36	5.29	5.25	5.2	5.18	5.14	5.1	5.08	5.04	5.
12	5.	4.96	4.94	4.93	4.86	4.83	4.8	4.76	4.73	4.7	4.68	4.64	4.6
13	4.6	4.58	4.57	4.56	4.5	4.47	4.4	4.41	4.38	4.36	4.34	4.32	4.3
14	4.3	4.26	4.24	4.23	4.18	4.16	4.14	4.11	4.08	4.07	4.05	4.02	4.
15	4.	3.9	3.96	3.95	3.92	3.9	3.89	3.86	3.83	3.81	3.79	3.76	3.73

STARRETT TOOLS FOR USE IN CONNECTION WITH SAWING



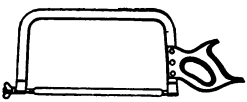
Solid Saw Frame

This solid steel frame is very stiff. The stock is wider than that commonly used and cannot be cramped by straining the blade. The saw may be set to cut in any one of four directions and tightened by turning the handle.



Hack Saw Frame

On this type of frame, spring plungers overlap the ends of the saw, automatically holding it home. By slightly pushing them back the saw may be instantly removed. A nut within the tool handle, turning with it, gives the desired tension to the blade. The adjustable or extension back frames have improved spring pawls, adapting the frame to blades of different lengths. Frames are nickeled.



Heavy Hack Saw Frame

Takes 12 inch blade only. Depth of frame from teeth of saw to inside edge of frame, 5¼ inches. A nut within the hardwood tool handle gives the required tension to the blade. Frame is nickel plated. Made also 7¼ and 10¼ inches in depth.

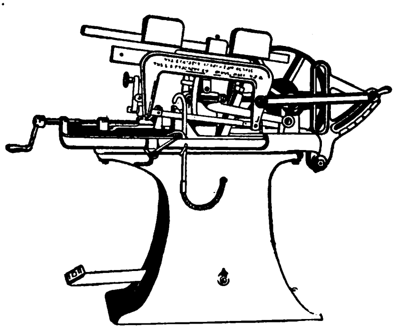
Starrett Hack Saws

Made of the finest grade steel. Teeth are sharp, with square cutting points, and set so that every tooth cuts. The set is just enough to insure free, smooth, and rapid cut.

For further information concerning these and other tools which may be used to advantage in connection with Sawing, see Vol. I of The Starrett Books, and the Starrett Catalogue.

STARRETT TOOLS FOR USE IN CONNECTION WITH SAWING

Starrett Hack Saw Machine



Has a capacity of from 0 to 6 inch stock. Designed for 14 inch blades, 12 or 13 inch saws may be used if desired. Belt driven by 16 inch pulley with 3 inch face. Dimensions 14 by 32 on floor, by 48 inches high. Weight 470 pounds. Cuts on draw stroke with quick return. Automatic locking device prevents saw dragging on return stroke and holds saw frame at any height when the machine is stopped for setting work. Saw frame mounted on rectangular slide with 11½ inch bearing. Quick acting Saw Tightener holds blades square. Stroke adjustable for stock from 1 inch to 6 inches diameter. Oil Dash Pot allows machine to be started when frame is up without dropping and breaking the saw. Also protects saw teeth from stripping. Frame is lifted by operator's weight on foot treadle. Pump and Lubricant Tank are inside base and easily accessible. Main shaft is 1¼ inch diameter, running in special hard cast iron 7 inch bushing. Crank is keyed and taper pinned to shaft. Drive is through a positive clutch, automatically released and stopping saw when stock is cut off. Vise is made exceptionally strong. Studs and Rolls are hardened, ground, and accurately fitted.

Starrett Hack Saw Blades

Tempered by our improved process, the blades are hard, tough, and uniform in temper and will not "shell off." With the exception of the flexible back saws all blades are hardened throughout. Each saw is guaranteed for the work for which it is intended.

For further information concerning these and other tools which may be used to advantage in connection with Hack Saws, see Vol. I of The Starrett Books, and the Starrett Catalogue.

SCREW MACHINE FEEDS AND SPEEDS

The first three of the following tables are taken from data furnished by a prominent manufacturer of high-class screw machines, and in common with the other tables refer to good general practice. It must, however, be recognized that no table is applicable to all conditions. The speeds given should, as a rule, be easily maintained.

SURFACE SPEEDS FOR EXTERNAL CUTTING TOOLS

Table 1

Material	Surface Speed in Feet per Min.	
	Carbon Steel	High Speed Steel
Brass	170–200	225–300
Gun Screw Iron	80– 90	105–120
Drill Rod	50– 60	65– 80
Soft Machinery Steel	75– 80	100–120
Zinc	170–200	225–300

SURFACE SPEEDS FOR THREADING

Table 2

Material	Surface Speed in Feet per Min. Carbon Steel Tools
Gun Screw Iron	25–30
Drill Rod	12–15
Soft Machinery Steel	20–30

FEED PER REVOLUTION IN INCHES

Table 3

Tool	Brass	Gun Screw Iron	Machine Steel	Drill Rod
Hollow Mills	.006 –.015	.004 –.012	.004 –.012	....
Cutting off Tools	.0015–.002	.0012–.00176	.0012–.00176	....
Box Tools	.010	.010 –.012	.010 –.012	From .003–.007
Forming Tools	.0018–.0015	.0002–.001	.0002–.001	....
Drills	¼ in. to ⅛ in. .003 –.006	.001 –.002	.001 –.002	....
	Less ⅛ in. .0015–.003	.0005–.001	.0005–.001	....

BOX TURNING TOOLS AND HOLLOW MILLS

Where cold drawn stock and brass are to be rough turned, using a single tool roughing box, Tables 4 and 5 may be used. These are adaptable for rough turning with hollow mills. Using hollow mills the feed per revolution may be increased from 20 to 30 per cent. Table 6 indicates good practice when the finish box tool is used.

CUTTING SPEEDS AND FEEDS FOR ROUGHING COLD ROLLED STOCK

Table 4

If using high speed steel tools increase speed 25 to 50%. Increase feed 15%.

1/32 Inch Chip				1/16 Inch Chip				1/8 Inch Chip				1/4 Inch Chip			
Diam. of Stock	Feet Surface Speed	Rev. per Min.	Feed per Rev.	Diam. of Stock	Feet Surface Speed	Rev. per Min.	Feed per Rev.	Diam. of Stock	Feet Surface Speed	Rev. per Min.	Feed per Rev.	Diam. of Stock	Feet Surface Speed	Rev. per Min.	Feed per Rev.
1/8	80	2445	.002	1/4	60	916	.0035	3/8	55	560	.004	3/4	50	254	.004
3/16	70	1426	.003	3/8	60	611	.004	1/2	55	420	.005	1	50	191	.005
1/4	70	1069	.004	1/2	60	458	.005	3/4	55	280	.006	1 1/4	45	137	.005
3/8	70	713	.005	3/4	55	280	.006	1	50	191	.007	1 1/2	45	114	.006
1/2	60	458	.006	1	55	210	.007	1 1/4	50	152	.007	1 3/4	45	98	.006
3/4	60	305	.007	1 1/4	55	168	.007	1 1/2	45	114	.007	2	40	76	.006
1	60	229	.008	1 1/2	50	127	.008	1 3/4	45	98	.007	2 1/4	40	68	.007
1 1/4	60	183	.008	1 3/4	50	109	.008	2	40	76	.008	2 1/2	40	61	.007

CUTTING SPEEDS AND FEEDS FOR ROUGHING BRASS SCREW STOCK

Table 5

If using high speed steel tools increase speed 25 to 50%. Increase speed 15%.

1/32 Inch Chip				1/16 Inch Chip				1/8 Inch Chip				1/4 Inch Chip			
Diam. of Stock	Feet Surface Speed	Rev. per Min.	Feed per Rev.	Diam. of Stock	Feet Surface Speed	Rev. per Min.	Feed per Rev.	Diam. of Stock	Feet Surface Speed	Rev. per Min.	Feed per Rev.	Diam. of Stock	Feet Surface Speed	Rev. per Min.	Feed per Rev.
1/8	180	5500	.003	1/4	180	2748	.004	3/8	165	1680	.004	3/4	150	762	.005
3/16	180	3668	.004	3/8	180	1833	.005	1/2	165	1260	.006	1	150	573	.006
1/4	180	2748	.005	1/2	180	1374	.0065	3/4	165	840	.007	1 1/4	135	411	.007
3/8	180	1833	.006	3/4	165	840	.0075	1	150	573	.008	1 1/2	135	342	.008
1/2	180	1374	.008	1	165	630	.0085	1 1/4	150	456	.009	1 3/4	135	294	.008
3/4	180	915	.010	1 1/4	165	504	.010	1 1/2	135	342	.010	2	120	228	.009
1	180	687	.011	1 1/2	150	381	.012	1 3/4	135	294	.010	2 1/4	120	204	.009
1 1/4	180	549	.012	1 3/4	150	327	.012	2	120	228	.011	2 1/2	120	183	.010

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

SPEEDS AND FEEDS FOR FINISH BOX TOOL

Table 6

If using high speed tools increase speed 25 to 50%.

Finished Diameter of Work	Screw Stock			Brass Rod			Amount Advisable to Remove on a Side
	Feet Surface Speed	Rev. per Min.	Feed per Rev.	Feet Surface Speed	Rev. per Min.	Feed per Rev.	
1/8	80	2445	.0045	180	5500	.0045	.0025
3/16	70	1426	.0055	180	3668	.0055	.0025
1/4	65	993	.0075	180	2750	.0075	.0045
1/2	60	458	.011	180	1375	.011	.006
3/4	60	305	.012	180	917	.012	.006
1	60	229	.012	175	668	.012	.0065
1 1/2	55	140	.014	170	433	.014	.007
2	50	95	.014	170	325	.014	.008

SPEEDS FOR FORMING

Table 7

25 to 50% increase for high speed tools.

Diam. of Work	Screw Stock		Brass Rod		Diam. of Work	Screw Stock		Brass Rod	
	Feet Surface Speed	Rev. per Min.	Feet Surface Speed	Rev. per Min.		Feet Surface Speed	Rev. per Min.	Feet Surface Speed	Rev. per Min.
1/8	75	2292	200	6112	5/8	60	360	175	1050
3/16	75	1528	200	4074	3/4	60	305	175	882
1/4	70	1069	185	2827	1	60	229	175	667
3/8	65	662	185	1885	1 1/2	60	153	170	432
1/2	65	497	185	1414	2	50	96	170	324

FEEDS FOR FORMING TOOLS

Table 8

15% increase of feed for high speed tools.

Width of Form	Smallest Diameter of Form							
	1/16	1/8	3/16	1/4	3/8	1/2	3/4	1 1/2
1/16	.0007	.0008	.001	.0012	.0012	.0012	.0012	.0012
1/8	.0005	.0008	.001	.0012	.0015	.0020	.0025	.0025
1/4	....	.0007	.001	.001	.0015	.0015	.0018	.0018
3/8	....	....	.0009	.001	.001	.0012	.0015	.0015
1/2	....	....	.0008	.0009	.001	.001	.0015	.0015
3/4	....	....	....	.0008	.0009	.001	.0011	.0012
1	....	....	....	....	.0008	.0009	.001	.0012
1 1/2	....	....	....	....	.0007	.0007	.0009	.0011
2	....	....	....	....	....	....	.0007	.001

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

SPEEDS FOR DIES AND TAPS

Table 9

Run high speed steel tools 25% faster.

Diam. of Thread	Screw Stock		Brass Rod		Diam. of Thread	Screw Stock		Brass Rod	
	Feet Surface Speed	Rev. per Min.	Feet Surface Speed	Rev. per Min.		Feet Surface Speed	Rev. per Min.	Feet Surface Speed	Rev. per Min.
1/8	25	764	100	3056	3/4	20	102	80	408
1/4	25	382	90	1376	1	20	76	80	306
3/8	20	204	80	815	1 1/4	20	67	80	245
1/2	20	153	80	611	1 1/2	15	38	70	178
5/8	20	123	80	489	2	15	29	70	134

FEEDS AND SPEEDS FOR REAMING

Table 10

Run high speed tools 25% faster.

Diam. of Reamer	Feed per Rev.	Amt. to Re-move on Diam.	Rev. per Min.		Diam. of Reamer	Feed per Rev.	Amt. to Re-move on Diam.	Rev. per Min.	
			Screw Stock at 40 Ft.	Brass Rod at 130 Ft.				Screw Stock at 40 Ft.	Brass Rod at 130 Ft.
1/8	.005	.0045	1222	3972	1 1/4	.018	.010	122	397
3/16	.006	.0045	815	2648	1 1/2	.020	.010	102	331
1/4	.007	.006	611	1986	1 3/4	.022	.010	87	284
3/8	.0085	.006	407	1324	2	.024	.013	76	248
1/2	.0105	.008	306	993	2 1/4	.026	.013	68	220
5/8	.012	.008	245	795	2 1/2	.028	.013	61	199
3/4	.014	.008	204	662	2 3/4	.030	.013	56	181
1	.016	.010	153	497	3	.032	.013	51	165

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

FEEDS AND SPEEDS FOR DRILLS

Table 11

25 to 50% increase of speed for high speed tools. Some operators allow a 25% clearance on all work where the wall diameter is not an important consideration.

Diam. of Drill	Screw Stock: Feed per Drill	Screw Stock: R.P.M at 60 Ft. Peripheral Speed	Brass Rod: Feed per Rev.	Brass Rod: R.P.M. at 175 Ft. Peripheral Speed	Diam. of Drill	Screw Stock: Feed per Rev.	Screw Stock: R.P.M. at 55 Ft. Peripheral Speed	Brass Rod: Feed per Rev.	Brass Rod: R.P.M. at 165 Ft. Peripheral Speed
1/16	.0013	3667	.0017	10696	1/2	.005	420	.0065	1260
5/64	.0016	2093	.002	8555	9/16	.0057	373	.0074	1120
3/32	.0018	2445	.0023	7130	5/8	.0059	336	.0077	1008
1/8	.0025	1833	.0033	5348	11/16	.006	305	.0078	917
5/32	.003	1421	.0039	4144	3/4	.0065	280	.0084	84
3/16	.004	1222	.0052	3565	7/8	.0075	240	.0097	702
7/32	.004	1043	.0052	3050	..	....	50 Ft.	....	150 Ft.
1/4	.0045	916	.0055	2674	1	.0085	191	.0110	573
9/32	.0045	815	.0058	2377	1 1/4	.0095	152	.0123	458
5/16	.0045	733	.0058	2139	1 1/2	.011	127	.0143	382
3/8	.0045	611	.0061	1783	1 3/4	.013	109	.0169	327
7/16	.005	524	.0065	1528	2	.014	96	.0182	294

CLEARANCES FOR THREADING IN THE SCREW MACHINE

Threads per Inch	External Work Turn Undersize	Internal Work Increase Over Theoretical Bottom of Thread
28	0.002	0.004
24	0.002	0.0045
22	0.0025	0.005
20	0.0025	0.0055
16	0.003	0.006
14	0.003	0.0065
13	0.0035	0.007
12	0.0035	0.007
11	0.0035	0.0075
10	0.004	0.008
9	0.004	0.0085
8	0.0045	0.009
7	0.0045	0.0095
6	0.005	0.010

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company Inc.

TABLE OF FEEDS AND SPEEDS FOR SCREW MACHINE

Feed per Revolution

Outside Diameter of Stock	Radial Depth of Chip $\frac{1}{16}$ Inch					Radial Depth of Chip ⅛ Inch					Radial Depth of Chip $\frac{3}{16}$ Inch					Radial Depth of Chip ¼ Inch					Radial Depth of Chip ⅜ Inch					Radial Depth of Chip ½ Inch				
	Feet Peripheral Speed				Rev. per Min.	Feet Peripheral Speed				Rev. per Min.	Feet Peripheral Speed				Rev. per Min.	Feet Peripheral Speed				Rev. per Min.	Feet Peripheral Speed				Rev. per Min.	Feet Peripheral Speed				Rev. per Min.
In.	90	85	80	75		85	80	75	70		85	80	75	70		85	80	75	70		80	75	70	65		80	75	70	65	
¼	.004	...	...	...	1375	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
⅜	.005	...	...	...	917	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
½	.006	...	...	...	687	.005	...	...	...	649	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
⅝	...	.007	...	...	519	.006	...	...	...	519	.006	...	...	...	519	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
¾	...	.008	...	...	433	.007	...	...	...	433	.007	...	...	...	433	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
⅞	...	.009	...	...	371	.008	...	...	...	371	.008	...	...	...	371	.007	...	...	...	371	...	...	...	...	...	...	...	...	...	...
1	...	.010	...	...	325	.009	...	...	...	325	.009	...	...	...	325	.007	...	...	...	325	...	...	...	...	...	...	...	...	...	...
1⅛	...	.011	...	...	289	.010	...	...	...	289	.010	...	...	...	289	.009	...	...	...	289	.008	...	...	...	272	...	...	...	...	...
1¼	...	...	.012	...	244	...	.011	...	...	244	...	.011	...	...	244	...	.010	...	...	244	.009	...	...	...	244	...	...	...	...	...
1½	...	...	.012	...	204	...	.011	...	...	204	...	.011	...	...	204	...	.010	...	...	204	.009	...	...	...	204	.009	...	...	...	204
1¾	...	...	.012	...	175	...	.011	...	...	175	...	.011	...	...	175	...	.010	...	...	175	...	.009	...	...	164	...	.009	...	...	164
2	...	...	.012	...	153	...	.011	...	...	153	...	.011	...	...	153	...	.010	...	...	153	...	.009	...	...	143	...	.009	...	...	143
2¼	...	...	...	.013	127	...	...	.012	...	127	...	...	.012	...	127	...	...	.011	...	127	...	...	.010	...	119	...	...	.009	...	119
2½	...	...	...	.013	115	...	...	.012	...	115	...	...	.012	...	115	...	...	.011	...	115	...	...	.010	...	107	...	...	.009	...	107
2¾	...	...	...	.013	104	...	...	.012	...	104	...	...	.012	...	104	...	...	.011	...	104	...	...	.010	...	97	...	...	.009	...	97
3	...	...	...	.013	95	...	...	.012	...	95	...	...	.012	...	95	...	...	.011	...	95	...	...	.010	...	89	...	...	...	.010	83
3½	...	...	...	.014	82	...	...	...	.014	76	...	...	...	.014	76	...	...	...	.013	76	...	...	...	.012	71	...	...	...	.011	71
4	...	...	...	.014	72	...	...	...	.014	67	...	...	...	.014	67	...	...	...	.013	67	...	...	...	.012	62	...	...	...	.011	62
4½	...	...	...	.014	64	...	...	...	.014	59	...	...	...	.014	59	...	...	...	.013	59	...	...	...	.012	55	...	...	...	.011	55

Above Table is for Turret Lathe Work, Turning Bright Drawn Machinery Steel. Stock with scale should use same feeds but 20 per cent lower speeds.

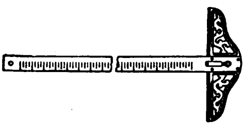
STARRETT INSTRUMENTS FOR USE OF DRAFTSMEN

Draftsmen's Scales

This scale has tilting studs so placed that each of its four corners, with different graduations, will come in contact with the paper by its own weight when resting on the studs, with the back edge raised at an angle of 30°. Graduated on corners in 10ths, 40ths, 50ths, 100ths, or in 8ths, 16ths, 32ds, and 64ths. Also made in Metric system.

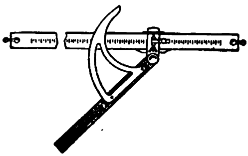
Combination Straightedges

The needle carriers at each end swing on taper studs carrying needle-pointed brads. A turn of the nut brads the straightedge to the paper. The straightedge may be had either graduated or plain.



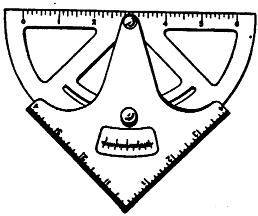
T Square

Made either graduated or plain. Nickel plated with spring-tempered blade and aluminum head; weight about 5 oz. Automatic clasping device holds it by spring pressure against metal straightedge of a drafting board or table and can be locked firm.



Section Liner

Can be set at any angle either way and the joint leveled by slight turn of knurled disc. Button-head screen may be adjusted to fine or coarse movement.

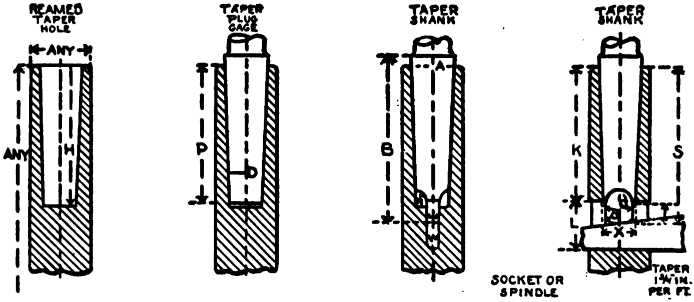


Draftsmen's Protractor

Made of sheet steel, nickel plated, graduated in degrees to read from either right or left with vernier to read in five minutes. The three straightedges are graduated in 16ths. Will lie flat on paper. Provided with locking nut.

For further information concerning these and other tools of interest to the draftsman see page 102 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

MORSE STANDARD TAPER SHANKS



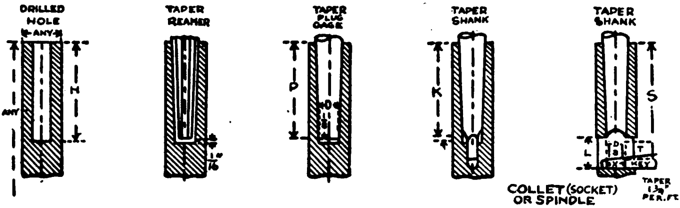
Number of Taper	Diameter of Plug at Small End	Diameter at End of Socket	Standard Plug Depth	Whole Length of Shank	Depth of Hole	End of Socket to Keyway	Length of Keyway	Length of Tongue	Thickness of Tongue	Width of Keyway	Shank Depth	Taper per Foot
	D	A	P	B	H	K	L	T	t	W	S	
0	0.252	0.356	2	2 11/32	2 1/32	1 15/16	9/16	1/4	5/32	0.160	2 7/32	.625
1	0.369	0.475	2 1/8	2 9/16	2 3/16	2 1/16	3/4	5/16	1 3/64	0.213	2 3/8	.600
2	0.572	0.700	2 9/16	3 1/16	2 5/8	2 1/2	7/8	3/8	1/4	0.260	2 7/8	.602
3	0.778	0.938	3 3/16	3 3/4	3 1/4	3 1/16	1 1/16	7/16	5/16	0.322	3 9/16	.602
4	1.020	1.231	4 1/16	4 3/4	4 1/8	3 7/8	1 1/4	1/2	15/32	0.478	4 1/2	.623
5	1.475	1.748	5 3/16	6	5 1/4	4 15/16	1 1/2	5/8	5/8	0.635	5 3/4	.630
6	2.116	2.494	7 1/4	8 5/16	7 3/8	7	1 3/4	7/8	3/4	0.760	8	.626
7	2.750	3.270	10	11 5/8	10 1/8	9 1/2	2 5/8	1 3/8	1 1/8	1.135	11 1/4	.625

Short Shanks

0	0.271	0.356	1 5/8	1 21/32	1 21/32	1 17/32	5/8	1/4	3/16	0.195	1 27/32	.625
1	0.388	0.475	1 3/4	2 3/16	1 13/16	1 21/32	13/16	3/16	1/4	0.260	2	.600
2	0.600	0.700	2	2 9/16	2 1/16	1 27/32	1 3/16	7/16	3/8	0.387	2 3/8	.602
3	0.816	0.938	2 7/16	3 1/8	2 1/2	2 7/32	1 5/16	3/16	1/2	0.514	2 15/16	.602
4	1.062	1.231	3 1/4	4 1/16	3 9/16	2 31/32	1 1/2	5/8	5/8	0.639	3 13/16	.623
5	1.532	1.748	4 1/8	5 1/16	4 3/16	3 21/32	2	3/4	1	1.014	4 13/16	.630
6	2.201	2.494	5 5/8	7 1/16	5 3/4	5 1/16	2 3/4	1 1/8	1 1/4	1.266	6 3/4	.626
7	2.857	3.270	7 15/16	9 11/16	8 1/16	7 1/8	3 5/8	1 1/2	1 5/8	1.642	9 5/16	.625

The dimensions given above for regular (full length) Morse taper shanks are those which have been accepted as standard and are used by most manufacturers. In a recent catalogue of the Morse Twist Drill & Machine Co., however, a table is given in which the length of the tang and, consequently, the whole length of the shank is slightly increased. The increase in length, however, is so slight that it does not prevent the shank from fitting into the ordinary standard taper socket.

BROWN & SHARPE TAPER SHANKS

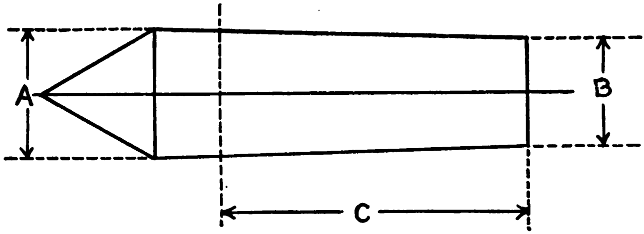


Taper per ft. is ½ in., except for No. 10 shank, where the taper is 0.5161 in. per ft.

Number of Taper	Diameter at End of Socket	Whole Length of Shank	Shank Depth	Diameter of Plug at Small End	Standard Plug Depth	Depth of Hole	End of Socket to Keyway	Length of Keyway	Width of Keyway	Length of Tongue	Thickness of Tongue
	A	B	C	D	E	F	G	H	K	L	M
1	0.239	1 9/32	1 3/16	0.200	15/16	1 1/16	15/16	3/8	0.135	3/16	1/8
2	0.299	1 19/32	1 1/2	0.250	1 3/16	1 5/16	1 11/64	1/2	0.166	1/4	5/32
3	0.375	1 31/32	1 7/8	0.312	1 1/2	1 5/8	1 15/32	5/8	0.197	5/16	3/16
3	0.385	2 7/32	2 1/8	0.312	1 3/4	1 7/8	1 23/32	5/8	0.197	5/16	3/16
3	0.395	2 15/32	2 3/8	0.312	2	2 1/8	1 31/32	5/8	0.197	5/16	3/16
4	0.402	1 3/4	1 21/32	0.350	1 1/4	1 3/8	1 13/64	11/16	0.228	11/32	7/32
4	0.420	2 3/16	2 3/32	0.350	1 11/16	1 13/16	1 41/64	11/16	0.228	11/32	7/32
5	0.523	2 9/32	2 3/16	0.450	1 3/4	1 7/8	1 11/16	3/4	0.260	3/8	1/4
5	0.533	2 17/32	2 7/16	0.450	2	2 1/8	1 15/16	3/4	0.260	3/8	1/4
5	0.539	2 21/32	2 9/16	0.450	2 1/8	2 1/4	2 1/16	3/4	0.260	3/8	1/4
6	0.599	2 31/32	2 7/8	0.500	2 3/8	2 1/2	2 19/64	7/8	0.291	7/16	9/32
6	0.635	3 27/32	3 3/4	0.500	3 1/4	3 3/8	3 11/64	7/8	0.291	7/16	9/32
7	0.704	3 1/8	3 1/32	0.600	2 1/2	2 5/8	2 13/32	15/16	0.322	15/32	5/16
7	0.720	3 1/2	3 13/32	0.600	2 7/8	3	2 25/32	15/16	0.322	15/32	5/16
7	0.725	3 5/8	3 17/32	0.600	3	3 1/8	2 29/32	15/16	0.322	15/32	5/16
7	0.767	4 5/8	4 17/32	0.600	4	4 1/8	3 29/32	15/16	0.322	15/32	5/16
8	0.898	4 1/4	4 1/8	0.750	3 9/16	3 11/16	3 29/64	1	0.353	1/2	11/32
8	0.917	4 11/16	4 9/16	0.750	4	4 1/8	3 57/64	1	0.353	1/2	11/32
9	1.067	4 3/4	4 5/8	0.900	4	4 1/8	3 7/8	1 1/8	0.385	9/16	3/8
9	1.077	5	4 7/8	0.900	4 1/4	4 3/8	4 1/8	1 1/8	0.385	9/16	3/8
10	1.260	5 27/32	6 23/32	1.0446	5	5 1/8	4 27/32	1 5/16	0.447	21/32	7/16
10	1.289	6 17/32	6 13/32	1.0446	5 11/16	5 13/16	5 17/32	1 5/16	0.447	21/32	7/16
10	1.312	7 1/16	6 15/16	1.0446	6 7/32	6 11/32	6 1/16	1 3/16	0.447	21/32	7/16
11	1.498	6 25/32	6 21/32	1.250	5 15/16	6 1/16	5 25/32	1 5/16	0.447	21/32	7/16
11	1.531	7 19/32	7 15/32	1.250	6 3/4	6 7/8	6 19/32	1 5/16	0.447	21/32	7/16
12	1.797	8 1/16	7 15/16	1.500	7 1/8	7 1/4	6 15/16	1 1/2	0.510	3/4	1/2
13	2.073	8 11/16	8 9/16	1.750	7 3/4	7 7/8	7 9/16	1 1/2	0.510	3/4	1/2
14	2.344	9 9/32	9 5/32	2.000	8 1/4	8 3/8	8 1/32	1 11/16	0.572	27/32	9/16
15	2.615	9 25/32	9 21/32	2.250	8 3/4	8 7/8	8 17/32	1 11/16	0.572	27/32	9/16
16	2.885	10 3/8	10 1/4	2.500	9 1/4	9 3/8	9	1 7/8	0.635	15/16	5/8
17	3.156	...	...	2.750	9 3/4	9 7/8	...	...	.....	...	...
18	3.427	...	...	3.000	10 1/4	10 3/8	...	...	.....	...	...

JARNO TAPERS

Used on Norton Grinding Machines, Pratt & Whitney, etc.



Taper per foot = 0.6 inch. Taper per inch = 0.05 inch, or 1 in 20

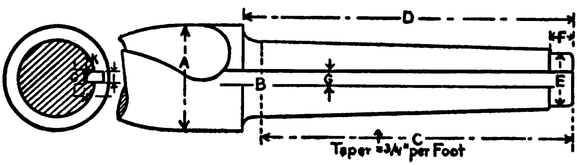
Number of Taper	Diam. of Large End A	Diam. of Small End B	Length of Taper C	Number of Taper	Diam. of Large End A	Diam. of Small End B	Length of Taper C
1	.125	.10	.5	11	1.375	1.10	5.5
2	.250	.20	1.0	12	1.500	1.20	6.0
3	.375	.30	1.5	13	1.625	1.30	6.5
4	.500	.40	2.0	14	1.750	1.40	7.0
5	.625	.50	2.5	15	1.875	1.50	7.5
6	.750	.60	3.0	16	2.000	1.60	8.0
7	.875	.70	3.5	17	2.125	1.70	8.5
8	1.000	.80	4.0	18	2.250	1.80	9.0
9	1.125	.90	4.5	19	2.375	1.90	9.5
10	1.250	1.00	5.0	20	2.500	2.00	10.0

REED TAPERS

The taper is the same per foot as that of the Jarno, but the diameters are different and in most cases the lengths are somewhat less.

THE SELLERS TAPER

The system of tapers used by William Sellers & Co., Inc., of Philadelphia, Pa., in lathes, drilling, and boring machines, is given in the following table. The taper is ¾ inch per foot and each size of taper is splined as shown for a key the dimensions of which are included in the table. The pitch of the spiral for the drills used by the company is also included.



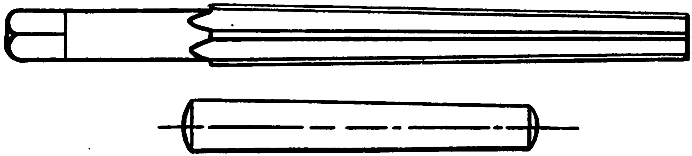
SELLERS TAPERS

Diameter of Drill	Diameter of Shank at Gage Point B	Length of Shank from Point B	Length of Drill Body from Point B	Total Length of Drill	Length of Shank Over All	Diameter at Reduced Portion of Shank	Length of Reduced Portion of Shank	Approximate Pitch of Spiral Grooves	Width of Spline in Shank	Depth of Spline in Shank	Width of Key	Height of Key
A	B	C			D	E	F		G	H	I	K
1/4	1/2	2 1/4	4 1/4	6 1/2	2 5/16	11/32	3/16	3.70	3/32	5/64	5/64	9/64
5/16	1/2	2 1/4	4 1/4	6 1/2	2 5/16	11/32	3/16	3.70	3/32	5/64	5/64	9/64
3/8	1/2	2 1/4	4 3/4	7	2 5/16	11/32	3/16	3.70	3/32	5/64	5/64	9/64
7/16	1/2	2 1/4	5 1/4	7 1/2	2 5/16	11/32	3/16	3.70	3/32	5/64	5/64	9/64
1/2	1/2	2 1/4	5 3/4	8	2 5/16	11/32	3/16	5.32	3/32	5/64	5/64	9/64
9/16	11/16	2 3/4	6 1/4	8	2 7/8	1/2	1/4	5.32	1/8	3/32	7/64	11/64
5/8	11/16	2 3/4	6 3/4	9 1/2	2 7/8	1/2	1/4	5.32	1/8	3/32	7/64	11/64
11/16	11/16	2 3/4	6 3/4	9 1/2	2 7/8	1/2	1/4	6.24	1/8	3/32	7/64	11/64
3/4	11/16	2 3/4	7 1/4	10	2 7/8	1/2	1/4	6.24	1/8	3/32	7/64	11/64
13/16	11/16	2 3/4	7 1/4	10	2 7/8	1/2	1/4	6.24	1/8	3/32	7/64	11/64
7/8	7/8	3 1/2	8	11 1/2	3 11/16	5/8	5/16	7.28	1/8	3/32	7/64	11/64
15/16	7/8	3 1/2	8	11 1/2	3 11/16	5/8	5/16	7.28	1/8	3/32	7/64	11/64
1	7/8	3 1/2	8 1/2	12	3 11/16	5/8	5/16	9.50	1/8	3/32	7/64	11/64
1 1/16	7/8	3 1/2	8 1/2	12	3 11/16	5/8	5/16	9.50	1/8	3/32	7/64	11/64
1 1/8	1 1/8	4 1/2	9	13 1/2	4 3/4	25/32	3/8	9.50	3/16	1/8	11/64	15/64
1 3/16	1 1/8	4 1/2	9	13 1/2	4 3/4	25/32	3/8	9.50	3/16	1/8	11/64	15/64
1 1/4	1 1/8	4 1/2	9	13 1/2	4 3/4	25/32	3/8	9.50	3/16	1/8	11/64	15/64
1 5/16	1 1/8	4 1/2	9	13 1/2	4 3/4	25/32	3/8	9.50	3/16	1/8	11/64	15/64
1 3/8	1 1/8	4 1/2	9 1/2	14	4 3/4	25/32	3/8	9.50	3/16	1/8	11/64	15/64
1 7/16	1 1/8	4 1/2	9 1/2	14	4 3/4	25/32	3/8	9.50	3/16	1/8	11/64	15/64
1 1/2	1 1/8	4 1/2	10	14 1/2	4 3/4	25/32	3/8	9.50	3/16	1/8	11/64	15/64
1 9/16	1 1/8	4 1/2	10	14 1/2	4 3/4	25/32	3/8	9.50	3/16	1/8	11/64	15/64
1 5/8	1 5/8	6 1/2	10	16 1/2	6 3/4	1 1/8	7/16	13.72	1/4	5/32	15/64	21/64
1 11/16	1 5/8	6 1/2	10	16 1/2	6 3/4	1 1/8	7/16	13.72	1/4	5/32	15/64	21/64
1 3/4	1 5/8	6 1/2	10 1/2	17	6 3/4	1 1/8	7/16	13.72	1/4	5/32	15/64	21/64
1 13/16	1 5/8	6 1/2	10 1/2	17	6 3/4	1 1/8	7/16	13.72	1/4	5/32	15/64	21/64
1 7/8	1 5/8	6 1/2	11	17 1/2	6 3/4	1 1/8	7/16	13.72	1/4	5/32	15/64	21/64
1 15/16	1 5/8	6 1/2	11	17 1/2	6 3/4	1 1/8	7/16	13.72	1/4	5/32	15/64	21/64
2	1 5/8	6 1/2	11 1/2	18	6 3/4	1 1/8	7/16	13.72	1/4	5/32	15/64	21/64

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

TAPER REAMERS AND PINS

(Pratt & Whitney Co.)



Taper = ¼ inch per foot or .0208 inch per inch.

Size No.	Diam. Sml. End Reamer	Diam. Lge. End Reamer	Length Flute	Length Reamer	Drill for Reamer	Longest Limit Length Pin	Diam. Lge. End Pin	Approx. Fractional Size Lge. End Pin
	Inch	Inch	Inch	Inch		Inch	Inch	Inch
0	0.135	.162	1 5/16	2	28	1	.156	5/32
1	.146	.179	1 9/16	2⅜	25	1¼	.156	11/64
2	.162	.200	1 11/16	2 11/16	19	1½	.193	3/16
3	.183	.226	2 1/16	3	12	1¾	.219	7/32
4	.208	.257	2⅜	3 7/16	3	2	.250	¼
5	.240	.300	2⅞	4⅛	¼	2¼	.289	19/64
6	.279	.354	3⅝	5	9/32	3¼	.341	11/32
7	.331	.423	4 7/16	6 1/16	11/32	3¾	.409	13/32
8	.398	.507	5¼	7 1/16	13/32	4½	.492	½
9	.482	.609	6⅛	8⅛	31/64	5¼	.591	19/32
10	.581	.727	7	9½	19/32	6	.706	23/32
11	.706	.878	8¼	11¼	23/32	7¼	.857	55/64
12	.842	1.050	10	13⅜	55/64	8¾	1.013	1 1/64
13	1.009	1.259	12	16	1 1/64	10¾	1.233	1 15/64

These reamer sizes are so proportioned that each overlaps the size smaller about ½ inch.

RULES FOR FIGURING TAPERS*

Given	To Find	Rule
The taper per foot.	The taper per inch.	Divide the taper per foot by 12.
The taper per inch.	The taper per foot.	Multiply the taper per inch by 12.
End diameters and length of taper in inches.	The taper per foot.	Subtract small diameter from large; divide by length of taper, and multiply quotient by 12.
Large diameter and length of taper in inches, and taper per foot	Diameter at small end in inches.	Divide taper per foot by 12; multiply by length of taper, and subtract result from large diameter.
Small diameter and length of taper in inches, and taper per foot.	Diameter at large end in inches.	Divide taper per foot by 12; multiply by length of taper, and add result to small diameter.
The taper per foot and two diameters in inches.	Distance between two given diameters in inches.	Subtract small diameter from large; divide remainder by taper per foot, and multiply quotient by 12.
The taper per foot.	Amount of taper in a certain length given in inches.	Divide taper per foot by 12; multiply by given length of tapered part.

*From "Machinery's" Handbook, The Industrial Press, New York

AMOUNT OF TAPER IN A GIVEN LENGTH

When the Taper per foot is known

Length of Taper	Taper per Foot										
	1/16	3/32	1/8	1/4	3/8	1/2	0.600	5/8	3/4	1	1 1/4
1/32	.0002	.0002	.0003	.0007	.0010	.0013	.0016	.0016	.0020	0.0026	0.0033
1/16	.0003	.0005	.0007	.0013	.0020	.0026	.0031	.0033	.0039	0.0052	0.0065
1/8	.0007	.0010	.0013	.0026	.0039	.0052	.0062	.0065	.0078	0.0104	0.0130
3/16	.0010	.0015	.0020	.0039	.0059	.0078	.0094	.0098	.0117	0.0156	0.0195
1/4	.0013	.0020	.0026	.0052	.0078	.0104	.0125	.0130	.0156	0.0208	0.0260
5/16	.0016	.0024	.0033	.0065	.0098	.0130	.0156	.0163	.0195	0.0260	0.0326
3/8	.0020	.0029	.0039	.0078	.0117	.0156	.0187	.0195	.0234	0.0312	0.0391
7/16	.0023	.0034	.0046	.0091	.0137	.0182	.0219	.0228	.0273	0.0365	0.0456
1/2	.0026	.0039	.0052	.0104	.0156	.0208	.0250	.0260	.0312	0.0417	0.0521
9/16	.0029	.0044	.0059	.0117	.0176	.0234	.0281	.0293	.0352	0.0469	0.0586
5/8	.0033	.0049	.0065	.0130	.0195	.0260	.0312	.0326	.0391	0.0521	0.0651
11/16	.0036	.0054	.0072	.0143	.0215	.0286	.0344	.0358	.0430	0.0573	0.0716
3/4	.0039	.0059	.0078	.0 56	.0234	.0312	.0375	.0391	.0469	0.0625	0.0781
13/16	.0042	.0063	.0085	.0169	.0254	.0339	.0406	.0423	.0508	0.0677	0.0846
7/8	.0046	.0068	.0091	.0182	.0273	.0365	.0437	.0456	.0547	0.0729	0.0911
15/16	.0049	.0073	.0098	.0195	.0293	.0391	.0469	.0488	.0586	0.0781	0.0977
1	.0052	.0078	.0104	.0208	.0312	.0417	.0500	.0521	.0625	0.0833	0.1042
2	.0104	.0156	.0208	.0417	.0625	.0833	.1000	.1042	.1250	0.1667	0.2083
3	.0156	.0234	.0312	.0625	.0937	.1250	.1500	.1562	.1875	0.2500	0.3125
4	.0208	.0312	.0417	.0833	.1250	.1667	.2000	.2083	.2500	0.3333	0.4167
5	.0260	.0391	.0521	.1042	.1562	.2083	.2500	.2604	.3125	0.4167	0.5208
6	.0312	.0469	.0625	.1250	.1875	.2500	.3000	.3125	.3750	0.5000	0.6250
7	.0365	.0547	.0729	.1458	.2187	.2917	.3500	.3646	.4375	0.5833	0.7292
8	.0417	.0625	.0833	.1667	.2500	.3333	.4000	.4167	.5000	0.6667	0.8333
9	.0469	.0703	.0937	.1875	.2812	.3750	.4500	.4687	.5625	0.7500	0.9375
10	.0521	.0781	.1042	.2083	.3125	.4167	.5000	.5208	.6250	0.8333	1.0417
11	.0573	.0859	.1146	.2292	.3437	.4583	.5500	.5729	.6875	0.9167	1.1458
12	.0625	.0937	.1250	.2500	.3750	.5000	.6000	.6250	.7500	1.0000	1.2500

TAPERS AND ANGLES

Taper per Foot	Included Angle			Angle with Center Line			Taper per Inch	Taper per Inch from Center Line
	Deg.	Min.	Sec.	Deg.	Min.	Sec.		
1/8	0	35	48	0	17	54	.010416	.005203
3/16	0	53	44	0	26	52	.015625	.007812
1/4	1	11	36	0	35	48	.020833	.010416
5/16	1	29	30	0	44	45	.026042	.013021
3/8	1	47	24	0	53	42	.031250	.015625
7/16	2	5	18	1	2	39	.036458	.018229
1/2	2	23	10	1	11	35	.041667	.020833
9/16	2	41	4	1	20	32	.046875	.023438
5/8	2	59	42	1	29	51	.052084	.026042
11/16	3	16	54	1	38	27	.057292	.028646
3/4	3	34	44	1	47	22	.062500	.031250
13/16	3	52	38	1	56	19	.067708	.033854
7/8	4	10	32	2	5	16	.072917	.036456
15/16	4	28	24	2	14	12	.078125	.039063
1	4	46	18	2	23	9	.083330	.041667
1¼	5	57	48	2	58	54	.104666	.052084
1½	7	9	10	3	34	35	.125000	.062500
1¾	8	20	26	4	10	13	.145833	.072917
2	9	31	36	4	45	48	.166666	.083332
2½	11	53	36	5	56	48	.208333	.104166
3	14	15	0	7	7	30	.250000	.125000
3½	16	35	40	8	17	50	.291666	.145833
4	18	55	28	9	27	44	.333333	.166666
4½	21	14	2	10	37	1	.375000	.187500
5	23	32	12	11	46	6	.416666	.208333
6	28	4	2	14	2	1	.500000	.250000

TAPERS PER FOOT AND CORRESPONDING ANGLES

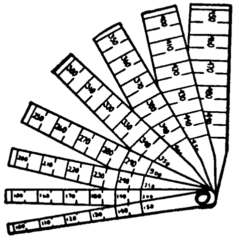
Taper per Foot	Included Angle			Angle with Center Line			Taper per Foot	Included Angle			Angle with Center Line		
	Deg.	Min.	Sec.	Deg.	Min.	Sec.		Deg.	Min.	Sec.	Deg.	Min.	Sec.
1/64	0	4	28	0	2	14	1 7/8	8	56	2	4	28	1
1/32	0	8	58	0	4	29	1 15/16	9	13	50	4	36	55
1/16	0	17	54	0	8	57	2	9	31	36	4	45	48
3/32	0	26	52	0	13	26	2 1/8	10	7	10	5	3	35
1/8	0	35	48	0	17	54	2 1/4	10	42	42	5	21	21
5/32	0	44	44	0	22	22	2 3/8	11	18	10	5	39	5
3/16	0	53	44	0	26	52	2 1/2	11	53	36	5	56	48
7/32	1	2	34	0	31	17	2 5/8	12	29	2	6	14	31
1/4	1	11	36	0	35	48	2 3/4	13	4	24	6	32	12
9/32	1	20	30	0	40	15	2 7/8	13	39	42	6	49	51
5/16	1	29	30	0	44	45	3	14	15	0	7	7	30
11/32	1	38	22	0	49	11	3 1/8	14	50	14	7	25	7
3/8	1	47	24	0	53	42	3 1/4	15	25	24	7	42	42
13/32	1	56	24	0	58	12	3 3/8	16	0	34	8	0	17
7/16	2	5	18	1	2	39	3 1/2	16	35	40	8	17	50
15/32	2	14	16	1	7	8	3 5/8	17	10	40	8	35	20
1/2	2	23	10	1	11	35	3 3/4	17	45	40	8	52	50
17/32	2	32	4	1	16	2	3 7/8	18	20	34	9	10	17
9/16	2	41	4	1	20	32	4	18	55	28	9	27	44
19/32	2	50	2	1	25	1	4 1/8	19	30	18	9	45	9
5/8	2	59	42	1	29	51	4 1/4	20	5	2	10	2	31
21/32	3	7	56	1	33	58	4 3/8	20	39	44	10	19	52
11/16	3	16	54	1	38	27	4 1/2	21	14	2	10	37	1
23/32	3	25	50	1	42	55	4 5/8	21	48	54	10	54	27
3/4	3	34	44	1	47	22	4 3/4	22	23	22	11	11	41
25/32	3	43	44	1	51	52	4 7/8	22	57	48	11	28	54
13/16	3	52	38	1	56	19	5	23	32	12	11	46	6
27/32	4	1	36	2	0	48	5 1/8	24	6	28	12	3	14
7/8	4	10	32	2	5	16	5 1/4	24	40	42	12	20	21
29/32	4	19	34	2	9	47	5 3/8	25	14	48	12	37	24
15/16	4	28	24	2	14	12	5 1/2	25	48	48	12	54	24
31/32	4	37	20	2	18	40	5 5/8	26	22	52	13	11	26
1	4	46	18	2	23	9	5 3/4	26	56	46	13	28	23
1 1/16	5	4	12	2	32	6	5 7/8	27	30	34	13	45	17
1 1/8	5	21	44	2	40	52	6	28	4	2	14	2	1
1 3/16	5	39	54	2	49	57	6 1/8	28	37	58	14	18	59
1 1/4	5	57	48	2	58	54	6 1/4	29	11	34	14	35	47
1 5/16	6	15	38	3	7	49	6 3/8	29	45	18	14	52	39
1 3/8	6	33	26	3	16	43	6 1/2	30	18	26	15	9	13
1 7/16	6	51	20	3	25	40	6 5/8	30	51	48	15	25	54
1 1/2	7	9	10	3	34	35	6 3/4	31	25	2	15	42	31
1 9/16	7	26	58	3	43	29	6 7/8	31	58	10	15	59	5
1 5/8	7	44	48	3	52	24	7	32	31	12	16	15	36
1 11/16	8	2	38	4	1	19	7 1/8	33	4	8	16	32	4
1 3/4	8	20	26	4	10	13	7 1/4	33	36	40	16	48	20
1 13/16	8	38	16	4	19	8	7 3/8	34	9	50	17	4	55

From "Machinery's" Handbook,
The Industrial Press, New York

STARRETT TOOLS FOR USE IN CONNECTION WITH TAPERS

Taper Gages

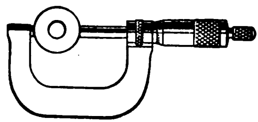
Of wide scope and general utility. Made from spring tempered stock .012 inch thick. From 2½ to 2¾ inches long and reading from $\frac{1}{10}$ to 1 inch in thousandths of an inch. Eight and ten leaves. Gages are also made to read in Metric as well as English measure.



Two Inch Micrometer Calipers

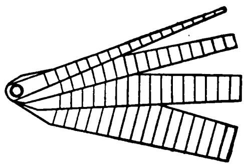
Measure by thousandths from an inch to two inches with lock nut, ratchet stop and one inch test gage. Is also made with lock nut at end of frame. Decimal equivalents of thirty seconds, sixteenths and eighths of an inch are stamped on the frame. This micrometer may also be obtained for measurements in ten thousandths from one inch to two inches.

An attachment may be had by means of which a two inch Micrometer may be converted into a one inch tool.



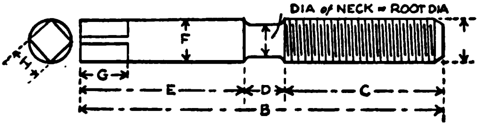
Taper Gage

The thin leaves of this gage taper by $\frac{1}{64}$ inch to every ¼ inch of their length. Graduated in ¼ and figured to read in fractions of an inch from $\frac{1}{16}$ inch to $1\frac{1}{16}$ inch.



For further information concerning these and other tools which may be used to advantage in connection with Tapers, see pages 18 and 34 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

DIMENSIONS OF MACHINE SCREW TAPS

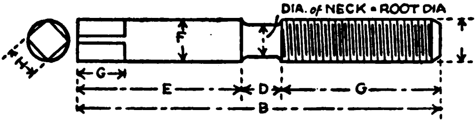


These are for the American Screw Company's Standard screws that have been in use for many years.

Number of Tap	Diameter of Tap	Number of Threads per Inch	Total Length	Length of Thread	Length of Neck	Length of Shank	Diameter of Shank	Length of Square	Size of Square	No. of Flutes
	A		B	C	D	E	F	G	H	
1	.071	64	1¾	9/16	No neck used on these	1 3/16	.125	3/16	3/32	3
1½	.081	56	1¾	9/16		1 3/16	.125	3/16	3/32	3
2	.089	56	1¾	9/16		1 3/16	.125	3/16	3/32	3
3	.101	48	1⅞	⅝		1¼	.125	3/16	3/32	3
4	.113	36	2	11/16		1 5/16	.125	3/16	3/32	3
5	.125	36	2⅛	¾		1⅜	.125	7/32	3/32	3
6	.141	32	2⅛	¾		1⅜	.141	7/32	7/64	3
7	.154	32	2⅛	¾		1⅜	.154	7/32	7/64	3
8	.166	32	2¼	13/16	⅛	1 5/16	.166	7/32	⅛	4
9	.180	30	2¼	⅞	⅛	1¼	.180	¼	⅛	4
10	.194	24	2¼	⅞	⅛	1¼	.194	¼	5/32	4
11	.206	24	2⅜	⅞	⅛	1¼	.206	¼	5/32	4
12	.221	24	2⅜	15/16	⅛	1 5/16	.221	9/32	5/32	4
13	.234	22	2½	1	3/16	1 5/16	.234	9/32	3/16	4
14	.246	20	2⅝	1 1/16	3/16	1⅜	.246	9/32	3/16	4
15	.261	20	2¾	1⅛	3/16	1 7/16	.261	5/16	3/16	4
16	.272	18	2¾	1⅛	3/16	1 7/16	.272	5/16	7/32	4
18	.298	18	2¾	1⅛	3/16	1 7/16	.298	5/16	7/32	4
20	.325	16	3	1¼	¼	1½	.325	11/32	¼	4
22	.350	16	3	1¼	¼	1½	.350	11/32	¼	4
24	.378	16	3¼	1¼	5/16	1 11/16	.378	⅜	9/32	4
26	.404	16	3¼	1¼	5/16	1 11/16	.404	⅜	5/16	4
28	.430	14	3½	1⅜	5/16	1 13/16	.430	13/32	5/16	4
30	.456	14	3½	1⅜	5/16	1 13/16	.456	7/16	11/32	4

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

DIMENSIONS OF MACHINE SCREW TAPS

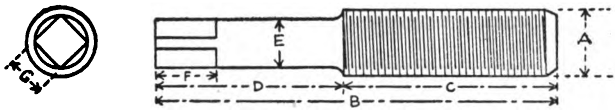


This table covers the sizes adopted by the American Society of Mechanical Engineers in June, 1907, and now known as the A.S.M.E. Standard for machine screw sizes.

No. of Tap	Dia. of Tap	Threads per Inch	Total Length	Length of Thread	Length of Neck	Length of Shank	Diameter of Shank	Length of Square	Size of Square	No. of Flutes
	A		B	C	D	E	F	G	H	
0	.060	80	1 3/4	9/16	No Neck used on these	1 3/16	.125	3/16	3/32	3
1	.073	72	1 3/4	9/16		1 3/16	.125	3/16	3/32	3
2	.086	64	1 3/4	9/16		1 3/16	.125	3/16	3/32	3
3	.099	56	1 7/8	5/8		1 1/4	.125	3/16	3/32	3
4	.112	48	2	11/16		1 5/16	.125	3/16	3/32	3
5	.125	44	2 1/8	3/4		1 3/8	.125	7/32	3/32	3
6	.138	40	2 1/8	3/4		1 3/8	.138	7/32	7/64	3
7	.151	36	2 1/8	3/4		1 3/8	.151	7/32	7/64	3
8	.164	36	2 1/4	13/16	1/8	1 5/16	.164	7/32	1/8	4
9	.177	32	2 1/4	7/8	1/8	1 1/4	.177	1/4	1/8	4
10	.190	30	2 1/4	7/8	1/8	1 1/4	.190	1/4	5/32	4
12	.216	28	2 3/8	7/8	1/8	1 1/4	.216	1/4	5/32	4
14	.242	24	2 3/8	15/16	1/8	1 5/16	.242	9/32	5/32	4
16	.268	22	2 1/2	1	3/16	1 5/16	.268	9/32	3/16	4
18	.294	20	2 5/8	1 1/16	3/16	1 3/8	.294	9/32	3/16	4
20	.320	20	2 3/4	1 1/8	3/16	1 7/16	.320	5/16	3/16	4
22	.346	18	2 3/4	1 1/8	3/16	1 7/16	.346	5/16	7/32	4
24	.372	16	3	1 1/4	1/4	1 1/2	.372	11/32	1/4	4
26	.398	16	3 1/4	1 1/4	5/16	1 11/16	.398	3/8	9/32	4
28	.424	14	3 1/2	1 3/8	5/16	1 13/16	.424	13/32	5/16	4
30	.450	14	3 1/2	1 3/8	5/16	1 13/16	.450	7/16	11/32	4

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

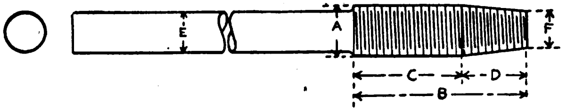
DIMENSIONS OF HAND TAPS



Diameter of Tap	Number of Threads per Inch		Total Length	Length of Thread	Length of Shank	Diameter of Shank E		Length of Square	Size of Square	No. of Flutes
A	U.S. St'd	V. St'd	B	C	D	U.S. St'd	V. St'd	F	G	
3/16	32	24	2 1/4	13/16	1 7/16	0.187	0.187	3/16	9/64	4
1/4	20	20	2 3/4	1 1/8	1 5/8	0.250	0.250	1/4	3/16	4
5/16	18	18	3	1 1/4	1 3/4	0.225	0.200	5/16	5/32	4
3/8	16	16	3 1/4	1 3/8	1 7/8	0.280	0.250	3/8	3/16	4
7/16	14	14	3 1/2	1 1/2	2	0.330	0.300	3/8	1/4	4
1/2	13	12	3 3/4	1 9/16	2 3/16	0.385	0.340	7/16	9/32	4
9/16	12	12	4	1 11/16	2 5/16	0.440	0.400	1/2	5/16	4
5/8	11	11	4 1/4	1 13/16	2 7/16	0.490	0.455	9/16	11/32	4
11/16	11	11	4 1/2	1 15/16	2 9/16	0.555	0.515	9/16	13/32	4
3/4	10	10	4 3/4	2	2 3/4	0.605	0.560	5/8	7/16	4
13/16	10	10	4 7/8	2 1/8	2 3/4	0.670	0.625	11/16	1/2	4
7/8	9	9	5 1/8	2 3/16	2 15/16	0.715	0.675	3/4	1/2	4
15/16	9	9	5 1/4	2 5/16	2 15/16	0.780	0.730	3/4	9/16	4
1	8	8	5 1/2	2 3/8	3 1/8	0.825	0.770	13/16	5/8	4
1 1/16	7	8	5 3/4	2 1/2	3 1/4	0.860	0.830	7/8	5/8	4
1 1/8	7	7	5 7/8	2 9/16	3 5/16	0.925	0.860	7/8	11/16	4
1 3/16	7	7	5 7/8	2 9/16	3 5/16	0.980	0.920	7/8	11/16	4
1 1/4	7	7	6 1/4	2 3/4	3 1/2	1.050	0.985	15/16	3/4	4
1 5/16	6	7	6 1/4	2 3/4	3 1/2	1.080	1.050	15/16	13/16	4
1 3/8	6	6	6 5/8	2 7/8	3 3/4	1.145	1.070	15/16	13/16	4
1 7/16	6	6	6 5/8	2 7/8	3 3/4	1.20	1.130	1	7/8	4
1 1/2	6	6	7	3	4	1.270	1.200	1	15/16	4
1 5/8	5 1/2	5	7 1/4	3 3/16	4 1/16	1.375	1.265	1 1/16	1	4
1 3/4	5	5	7 5/8	3 5/16	4 5/16	1.475	1.390	1 1/16	1 1/16	4
1 7/8	5	4 1/2	7 7/8	3 7/16	4 7/16	1.600	1.475	1 1/8	1 1/8	6
2	4 1/2	4 1/2	8 1/4	3 5/8	4 5/8	1.700	1.600	1 3/16	1 1/4	6
2 1/8	4 1/2	4 1/2	8 1/2	3 3/4	4 3/4	1.810	1.710	1 3/16	1 5/16	6
2 1/4	4 1/2	4 1/2	8 3/4	3 7/8	4 7/8	1.945	1.845	1 1/4	1 7/16	6
2 3/8	4	4 1/2	9	4	5	2.030	1.975	1 5/16	1 1/2	6
2 1/2	4	4	9 1/4	4 1/8	5 1/8	2.160	2.040	1 5/16	1 9/16	6
2 5/8	4	4	9 1/2	4 1/4	5 1/4	2.285	2.175	1 3/8	1 11/16	6
2 3/4	4	4	9 3/4	4 5/16	5 7/16	2.400	2.290	1 7/16	1 3/4	6
2 7/8	3 1/2	4	10	4 7/16	5 9/16	2.485	2.425	1 7/16	1 13/16	6
3	3 1/2	3 1/2	10 1/8	4 9/16	5 9/16	2.600	2.480	1 1/2	1 7/8	8

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

DIMENSIONS OF TAPPER TAPS



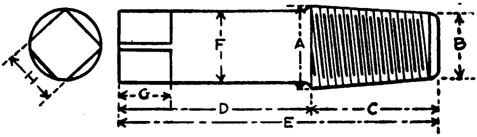
Regular Lengths over all
are 11, 12, 14 and 15 inches.

NOTE: Tapper taps differ from machine taps in not having a square on the end of the shank. They are used in nut tapping machines, the nuts being run over the tap on to the shank and when full the tap is removed and the nuts slid off. The tap is then replaced for another lot of nuts.

Diameter of Tap	Number of Threads per Inch		Length of Thread	Length of Straight Part	Length of Chamfered Part	Diameter of Shank E		Diameter of Point F		No. of Flutes
A	U. S. St'd	V. St'd	B	C	D	U. S. St'd	V. St'd	U. S. St'd	V. St'd	
1/4	20	20	1 3/4	1 1/8	5/8	0.170	0.150	0.179	0.158	4
5/16	18	18	2	1 1/4	3/4	0.225	0.200	0.234	0.210	4
3/8	16	16	2	1 1/4	3/4	0.280	0.250	0.287	0.261	4
7/16	14	14	2 1/4	1 3/8	7/8	0.330	0.300	0.338	0.307	4
1/2	13	12	2 1/4	1 3/8	7/8	0.385	0.340	0.393	0.348	4
9/16	12	12	2 1/2	1 1/2	1	0.440	0.400	0.446	0.411	4
5/8	11	11	2 1/2	1 1/2	1	0.490	0.455	0.499	0.462	4
11/16	11	11	2 1/2	1 1/2	1	0.555	0.515	0.561	0.523	4
3/4	10	10	2 3/4	1 5/8	1 1/8	0.605	0.560	0.611	0.570	4
13/16	10	10	2 3/4	1 5/8	1 1/8	0.670	0.625	0.673	0.631	4
7/8	9	9	3	1 3/4	1 1/4	0.720	0.675	0.722	0.675	4
15/16	9	9	3	1 3/4	1 1/4	0.780	0.730	0.783	0.736	4
1	8	8	3 1/2	2	1 1/2	0.820	0.770	0.828	0.775	4
1 1/8	7	7	3 1/2	2	1 1/2	0.925	0.860	0.928	0.869	4
1 1/4	7	7	3 1/2	2	1 1/2	1.050	0.985	1.053	0.993	4
1 3/8	6	6	4	2 3/8	1 5/8	1.145	1.070	1.147	1.075	4
1 1/2	6	6	4	2 3/8	1 5/8	1.270	1.195	1.272	1.200	4

 From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

BRIGGS'S STANDARD PIPE TAPS



Taper per Foot = 3/4 Inch
Taper per Inch = 1/16 Inch

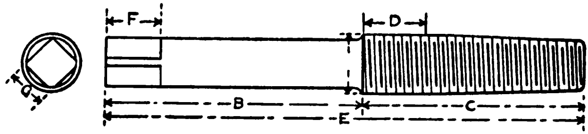
Nominal Dia. of Tap	Threads per Inch	Dia. Large End	Dia. of Small End before Chamfering	Length of Thread	Length of Shank	Total Length	Diameter of Shank	Length of Square	Size of Square	Number of Flutes
		A	B	C	D	E	F	G	H	
1/8	27	.443	.381	1	1 1/2	2 1/2	7/16	9/16	5/16	4
1/4	18	.575	.505	1 1/8	1 5/8	2 3/4	1/2	9/16	3/8	4
3/8	18	.718	.640	1 1/4	1 3/4	3	9/16	5/8	7/16	4
1/2	14	.887	.793	1 1/2	1 7/8	3 3/8	3/4	11/16	9/16	4
3/4	14	1.104	.993	1 5/8	2 1/8	3 3/4	15/16	3/4	11/16	4
1	11 1/2	1.366	1.257	1 3/4	2 3/8	4 1/8	1 1/8	13/16	13/16	5
1 1/4	11 1/2	1.717	1.599	1 7/8	2 5/8	4 1/2	1 5/16	15/16	1	5
1 1/2	11 1/2	1.963	1.838	2	2 7/8	4 7/8	1 1/2	1	1 1/8	5
2	11 1/2	2.453	2.312	2 1/4	3 1/2	5 3/4	1 7/8	1 3/16	1 3/8	7
2 1/2	8	2.961	2.781	2 7/8	4	6 7/8	2 1/4	1 3/8	1 11/16	8
3	8	3.605	3.402	3 1/4	4 1/2	7 3/4	2 5/8	1 1/2	1 15/16	9
3 1/2	8	4.125	3.899	3 5/8	4 9/16	8 3/16	2 13/16	1 9/16	2 1/8	11
4	8	4.629	4.395	3 3/4	4 5/8	8 3/8	3	1 5/8	2 1/4	11

STOVE BOLT TAPS

These have no fixed standard form of thread, being usually something like an Acme thread in general appearance.

	Diameters					
Threads per Inch	5/32	3/16	7/32	1/4	5/16	3/8
Present Standard	28	24	22	18	18	16
Old Standard	30	24	24	18	18	18

DIMENSIONS OF TAPER DIE TAPS

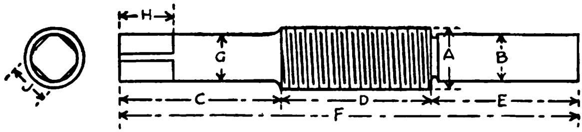


Diam. of Shank Root Diam. less 0.015 in.

Diameter of Tap	Length of Shank	Length of Thread	Length of Straight Thread	Total Length	Length of Square	Size of Square	Number of Flutes
A	B	C	D	E	F	G	
1/4	1 1/2	2	1/4	3 1/2	9/16	1/8	5
5/16	1 1/2	2 1/2	5/16	4	5/8	5/32	5
3/8	1 1/2	3	3/8	4 1/2	11/16	3/16	5
7/16	1 3/4	3 1/4	7/16	5	11/16	1/4	5
1/2	2	3 1/2	1/2	5 1/2	3/4	9/32	5
9/16	2 1/4	3 3/4	9/16	6	13/16	5/16	5
5/8	2 1/2	4	5/8	6 1/2	13/16	11/32	5
11/16	2 3/4	4 1/4	11/16	7	7/8	13/32	6
3/4	3	4 1/2	3/4	7 1/2	7/8	7/16	6
13/16	3 1/4	4 3/4	13/16	8	15/16	1/2	6
7/8	3 1/2	5	7/8	8 1/2	1	1/2	6
15/16	3 1/2	5 1/4	15/16	8 3/4	1	9/16	6
1	3 1/2	5 1/2	1	9	1 1/16	5/8	6
1 1/8	3 1/2	5 3/4	1 1/8	9 1/4	1 1/8	11/16	6
1 1/4	3 1/2	6	1 1/4	9 1/2	1 3/16	3/4	7
1 3/8	3 5/8	6 1/8	1 3/8	9 3/4	1 5/16	13/16	7
1 1/2	3 5/8	6 3/8	1 1/2	10	1 3/8	15/16	7
1 5/8	3 5/8	6 5/8	1 5/8	10 1/4	1 7/16	1	7
1 3/4	3 5/8	6 7/8	1 3/4	10 1/2	1 1/2	1 1/16	8
1 7/8	3 5/8	7 1/8	1 7/8	10 3/4	1 5/8	1 1/8	8
2	3 5/8	7 3/8	2	11	1 11/16	1 1/4	8

 From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

DIMENSIONS OF SELLERS HOBS

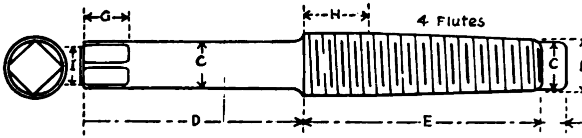


The Sellers hob is designed to be run on centers, the work, such as hand or die chasers, being held against it and fed along by the lathe carriage.

Diameter of Hob	Number of Threads per Inch		Diameter of Pilot B		Length of Shank	Length of Thread	Length of Pilot	Total Length	Diameter of Shank G		Length of Square	Size of Square	No. of Flutes
A	U. S. St'd	V. St'd	U.S. St'd	V. St'd	C	D	E	F	U. S. St'd	V St'd	H	J	
1/4	20	20	3/16	5/32	2	1 1/8	1 1/8	4 1/4	0.170	0.150	3/4	1/8	6
5/16	18	18	3/16	3/16	2	1 1/4	1 1/4	4 1/2	0.225	0.200	3/4	5/32	6
3/8	16	16	1/4	1/4	2 1/8	1 7/16	1 7/16	5	0.280	0.250	3/4	3/16	6
7/16	14	14	5/16	1/4	2 1/8	1 9/16	1 9/16	5 1/4	0.330	0.300	13/16	1/4	6
1/2	13	12	3/8	5/16	2 1/8	1 13/16	1 13/16	5 3/4	0.385	0.340	13/16	9/32	8
9/16	12	12	3/8	3/8	2 1/4	1 7/8	1 7/8	6	0.440	0.400	13/16	5/16	8
5/8	11	11	1/2	3/8	2 1/4	2 1/8	2 1/8	6 1/2	0.490	0.455	7/8	11/32	8
11/16	11	11	1/2	1/2	2 1/4	2 3/8	2 3/8	7	0.555	0.515	7/8	13/32	8
3/4	10	10	1/2	1/2	2 1/2	2 1/2	2 1/2	7 1/2	0.605	0.560	7/8	7/16	8
13/16	10	10	1/2	1/2	2 1/2	2 3/4	2 3/4	8	0.670	0.625	15/16	1/2	8
7/8	9	9	11/16	1/2	2 1/2	3	3	8 1/2	0.715	0.675	15/16	1/2	8
15/16	9	9	11/16	11/16	2 1/2	3 1/4	3 1/4	9	0.780	0.730	1	9/16	10
1	8	8	11/16	11/16	2 5/8	3 7/16	3 7/16	9 1/2	0.825	0.770	1	5/8	10
1 1/8	7	7	7/8	11/16	2 5/8	3 9/16	3 9/16	9 3/4	0.925	0.860	1 1/16	11/16	10
1 1/4	7	7	7/8	7/8	2 5/8	3 11/16	3 11/16	10	1.050	0.985	1 1/16	3/4	10
1 3/8	6	6	1 1/16	7/8	2 5/8	3 15/16	3 15/16	10 1/2	1.145	1.070	1 1/8	13/16	10
1 1/2	6	6	1 1/16	1 1/16	2 5/8	4 3/16	4 3/16	11	1.270	1.200	1 3/16	15/16	10
1 5/8	5 1/2	5	1 5/16	1 1/8	2 3/4	4 3/8	4 3/8	11 1/2	1.375	1.265	1 1/4	1	12
1 3/4	5	5	1 5/16	1 5/16	2 3/4	4 5/8	4 5/8	12	1.475	1.390	1 1/4	1 1/16	12
1 7/8	5	4 1/2	1 1/2	1 5/16	2 3/4	4 7/8	4 7/8	12 1/2	1.600	1.475	1 5/16	1 1/8	12
2	4 1/2	4 1/2	1 1/2	1 1/2	2 3/4	5 1/8	5 1/8	13	1.700	1.600	1 3/8	1 1/4	12

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

STANDARD SQUARE THREAD TAPS

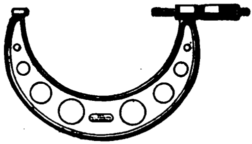


Note: While in theory the thread and the space are both one half the pitch, in practice it is necessary to make the thread a little more than half in order to allow clearance for the screw that goes into the threaded hole. The amount of this clearance depends on the character of the work and varies from .001 inch up. Some also make the tap so that the screw will bear only on the top or bottom and the sides.

Size	A	B	C	D	E	F	G	H	I
Diameter 5/8" ..... (1)	35/64	1/2	1/2	3 5/8	3 1/4	1/2	9/16	5/8	7/16
(2)	19/32	17/32	1/2	3 5/8	3 1/4	1/2	9/16	5/8	7/16
Pitch 8 .... (3)	5/8	37/64	1/2	3 5/8	3 1/4	1/2	9/16	5/8	7/16
Diameter 3/4" ..... (1)	41/64	37/64	37/64	3 3/4	3 3/8	1/2	3/4	3/4	7/16
(2)	45/64	5/8	37/64	3 3/4	3 3/8	1/2	3/4	3/4	7/16
Pitch 6 .... (3)	3/4	11/16	37/64	3 3/4	3 3/8	1/2	3/4	3/4	7/16
Diameter 7/8" ..... (1)	3/4	21/32	21/32	4	3 3/4	1/2	13/16	7/8	1/2
(2)	13/16	47/64	21/32	4	3 3/4	1/2	13/16	7/8	1/2
Pitch 4 1/2 .... (3)	7/8	51/64	21/32	4	3 3/4	1/2	13/16	7/8	1/2
Diameter 1" ...... (1)	57/64	51/64	51/64	4 1/2	4 1/4	1/2	15/16	1	5/8
(2)	61/64	7/8	51/64	4 1/2	4 1/4	1/2	15/16	1	5/8
Lead D'BL 2/5" .... (3)	1	15/16	51/64	4 1/2	4 1/4	1/2	15/16	1	5/8
Diameter 1 1/8" ... (1)	61/64	55/64	55/64	4 3/4	4 3/8	1/2	1	1 1/8	11/16
(2)	1 1/32	15/16	55/64	4 3/4	4 3/8	1/2	1	1 1/8	11/16
(3)	1 5/64	1 1/64	55/64	4 3/4	4 3/8	1/2	1	1 1/8	11/16
Pitch 3 1/2 .... (4)	1 1/8	1 1/16	55/64	4 3/4	4 3/8	1/2	1	1 1/8	11/16
Diameter 1 3/8".... (1)	1 13/64	1 1/8	1 1/8	5 1/4	4 5/8	5/8	1 1/8	1 3/8	7/8
(2)	1 9/32	1 3/16	1 1/8	5 1/4	4 5/8	5/8	1 1/8	1 3/8	7/8
(3)	1 21/64	1 17/64	1 1/8	5 1/4	4 5/8	5/8	1 1/8	1 3/8	7/8
Lead D'BL 1/2"... (4)	1 3/8	1 5/16	1 1/8	5 1/4	4 5/8	5/8	1 1/8	1 3/8	7/8

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company Inc.

STARRETT MICROMETERS FOR SPECIAL PURPOSES

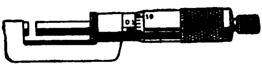


Heavy Micrometer Calipers

The spindle and screw portion is of larger area than in the regular micrometer. Those from 2 inch to 6 inch are made from drop forgings and those from 7 to 12 inch from steel castings. Bearing parts and measuring surface are hardened. Made with lock nut and ratchet stop.

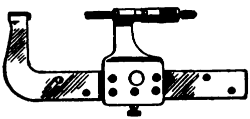
Micrometer Caliper Heads

Length from shoulder to lock nut ¾ inch, ½ inch diameter. Easily attached to tools or machines. Ratchet stop and lock nut, unless desired without. Graduated to read to thousandths of an inch. Also made to read in ten thousandths and in the Metric system.



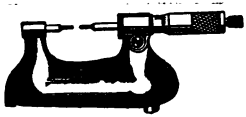
Hub Micrometer Caliper

The frame will easily pass through a ¾ inch hole. Graduated to read by thousandths up to 1 inch. Also made in Metric system. Has lock nut and ratchet stop.



Six-Inch Micrometer Caliper

Measures round work to 4¼ inches and flat work to 6 inches. Six independent holes through both movable part and the beam. Each hole bushed with hardened steel bushings ground and lapped to fit the plug which locates to exactness the various inch settings. Made also in Metric system.

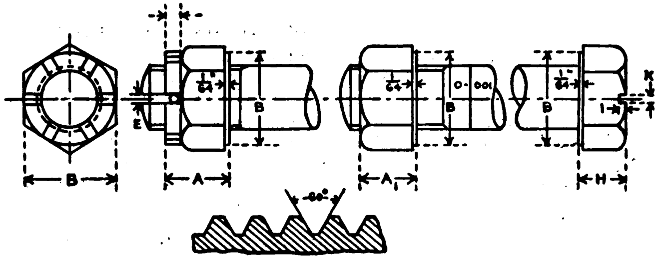


Bench Micrometer Caliper

Measure by thousandths or ten thousandths of an inch up to 1 inch. Heavy base makes tool very rigid and accurate. Made with lock nut and ratchet stop. Also made in Metric system.

For other Starrett Micrometer Calipers see pages 18, 21, 40, 80, 122, and 155 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

S. A. E. SCREW STANDARD



B = Refers to all Nuts and Screw Heads

D = Diameter of Screw

d = Diameter of Cotter Pin

D × 1.5 = Length of Threaded Portion

P = Pitch of Thread

$\frac{P}{R}$ = Flat Top

D	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
P	28	24	24	20	20	18	18	16	16	14	14	12	12	12	12
A	9/32	21/64	13/32	29/64	9/16	39/64	23/32	49/64	13/16	29/32	1	1 5/32	1 1/4	1 13/32	1 1/2
A1	7/32	17/64	21/64	3/8	7/16	31/64	35/64	19/32	21/32	49/64	7/8	63/64	1 3/32	1 13/64	1 5/16
B	7/16	1/2	9/16	5/8	3/4	7/8	15/16	1	1 1/16	1 1/4	1 7/16	1 5/8	1 13/16	2	2 3/16
C	3/32	3/32	1/8	1/8	3/16	3/16	1/4	1/4	1/4	1/4	1/4	5/16	5/16	3/8	3/8
E	5/64	5/64	1/8	1/8	1/8	5/32	5/32	5/32	5/32	5/32	5/32	7/32	7/32	1/4	1/4
H	3/16	15/64	9/32	21/64	3/8	27/64	15/32	33/64	9/16	21/32	3/4	27/32	15/16	1 1/32	1 1/8
I	3/32	7/64	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	7/32	7/32	1/4	1/4
K	1/16	1/16	3/32	3/32	3/32	3/32	3/32	3/32	3/32	3/32	3/32	5/32	5/32	3/16	3/16
d	1/16	1/16	3/32	3/32	3/32	1/8	1/8	1/8	1/8	1/8	1/8	11/64	11/64	13/64	13/64

All castle nuts are to be case hardened.

It is assumed that where screws are to be used in soft material such as cast iron, brass, bronze, or aluminum, the United States standard pitches will be used.

Tolerance. The body diameter of the screws shall be one-thousandth (.001) inch less than the nominal diameter, with a plus tolerance of zero and a minus tolerance of two-thousandths (.002) inch.

The nuts shall be a good fit without perceptible shake.

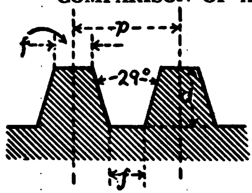
CLEARANCE BETWEEN TOPS AND BOTTOMS OF THREADS

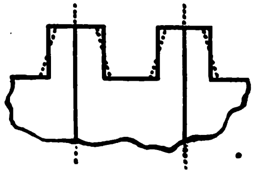
The tap shall be between two-thousandths (.002) inch and three-thousandths (.003) inch large.

Sizes of Taps: Inch	Sizes of Taps: Threads	Drill Sizes	Sizes of Taps: Inch	Sizes of Taps: Threads	Drill Sizes
1/4	28	7/32*	11/16	16	[illegible]
5/16	24	[illegible]	3/4	16	[illegible]
3/8	24	[illegible]	7/8	14	[illegible]
7/16	20	3/8	1	14	[illegible]
1/2	20	7/16	1 1/8	12	1 [illegible]
9/16	18	1/2	1 1/4	12	1 [illegible]
5/8	18	[illegible]	1 3/8	12	1 [illegible]
			1 1/2	12	1 [illegible]

*No. 5 Drill Gauge

COMPARISON OF ACME AND SQUARE THREADS





The various parts of the Acme Standard Thread are obtained as follows:

Width of Point of Tool for Screw or Tap Thread $= \dfrac{.3707}{\text{No. of Threads per in}} - .0052$

Width of Screw or Nut Thread $= \dfrac{.3707}{\text{No. of Threads per in.}}$

Diameter of Tap = Diameter of Screw + .020.

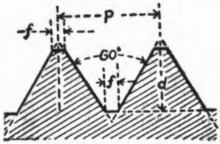
Diameter of Tap or Screw at Root = Diameter of Screw $- \left(\dfrac{1}{\text{No. of Linear Threads per in.}} + .020\right)$

Depth of Thread $= \dfrac{1}{2 \times \text{No. of Threads per in.}} + .010$

TABLE OF THREAD PART

No. of Threads per inch	Depth of Thread	Width at Top of Thread	Width at Bottom of Thread	Space at Top of Thread	Thickness at Root of Thread
1	.5100	.3707	.3655	.6293	.6345
1 1/3	.3850	.2780	.2728	.4720	.4772
2	.2600	.1853	.1801	.3147	.3199
3	.1767	.1235	.1183	.2098	.2150
4	.1350	.0927	.0875	.1573	.1625
5	.1100	.0741	.0689	.1259	.1311
6	.0933	.0618	.0566	.1049	.1101
7	.0814	.0529	.0478	.0899	.0951
8	.0725	.0463	.0411	.0787	.0839
9	.0655	.0413	.0361	.0699	.0751
10	.0600	.0371	.0319	.0629	.0681

METRIC STANDARD SCREW THREADS



Formula

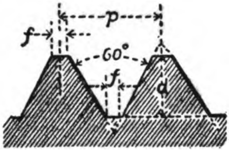
p = pitch

d = depth = pitch × .64952

f = flat = $\frac{\text{pitch}}{8}$

Diam. Screw, mm.	Pitch, mm.	Diam. at Root, mm	Width of Flat mm.
3	0.5	2.35	.06
4	0.75	3.03	.09
5	0.75	4.03	.09
6	1.0	4.70	.13
7	1.0	5.70	.13
8	1.0	6.70	.13
8	1.25	6.38	.16
9	1.0	7.70	.13
9	1.25	7.38	.16
10	1.5	8.05	.19
11	1.5	9.05	.19
12	1.5	10.05	.19
12	1.75	9.73	.22
14	2.0	11.40	.25
16	2.0	13.40	.25
18	2.5	14.75	.31
20	2.5	16.75	.31
22	2.5	18.75	.31
24	3.0	20.10	.38
26	3.0	22.10	.38
27	3.0	23.10	.38
28	3.0	24.10	.38
30	3.5	25.45	.44
32	3.5	27.45	.44
33	3.5	28.45	.44
34	3.5	29.45	.44
36	4.0	30.80	.5
38	4.0	32.80	.5
39	4.0	33.80	.5
40	4.0	34.80	.5
42	4.5	36.15	.56
44	4.5	38.15	.56
45	4.5	39.15	.56
46	4.5	40.15	.56
48	5.0	41.51	.63
50	5.0	43.51	.63
52	5.0	45.51	.63
56	5.5	48.86	.69
60	5.5	52.86	.69
64	6.0	56.21	.75
68	6.0	60.21	.75
72	6.5	63.56	.81
76	6.5	67.56	.81
80	7.0	70.91	.88

UNITED STATES STANDARD SCREW THREAD



Formula

$p = \text{pitch} = \dfrac{1}{\text{No. of threads per inch}}$

$d = \text{depth} = \text{pitch} \times .6495 \text{ or } \dfrac{.6495}{n}$

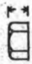
$f = \text{flat} = \dfrac{\text{pitch}}{8}$

$n = \text{threads}$

Fractional Size	Decimal Equivalent Outside Diameter	Threads per Inch	Basic Pitch Diameter	Root Diameter	(d) Depth of Thread $\frac{.6495}{n}$
¼	.2500	20	.2175	.850	.0325
5/16	.3125	18	.2764	.2403	.0361
⅜	.3750	16	.3344	.2938	.0406
7/16	.4375	14	.3911	.3447	.0464
½	.5000	13	.4501	.4001	.0499
9/16	.5625	12	.5084	.4542	.0541
⅝	.6250	11	.5660	.5069	.0591
11/16	.6875	11	.6290	.5694	.0591
¾	.7500	10	.6851	.6201	.0649
13/16	.8125	10	.7480	.6826	.0649
⅞	.8750	9	.8029	.7307	.0721
15/16	.9375	9	.8650	.7932	.0721
1	1.0000	8	.9188	.8376	.0812
1⅛	1.1250	7	1.0322	.9394	.0928
1¼	1.2500	7	1.1572	1.0644	.0928
1⅜	1.3750	6	1.2668	1.1585	.1082
1½	1.5000	6	1.3918	1.2835	.1082
1⅝	1.6250	5½	1.5070	1.3888	.1181
1¾	1.7500	5	1.6201	1.4902	.1299
1⅞	1.8750	5	1.7451	1.6152	.1299
2	2.0000	4½	1.8557	1.7113	.1444

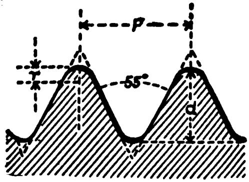
Courtesy of the Greenfield
Tap and Die Corporation

UNITED STATES STANDARD SCREW THREADS

Diameter	No. of Threads per Inch	Diameter at Root of Thread	Diameter of Tap Drill	Area in Sq. Inches		Dimensions of Nuts and Bolt Heads				
				Of Bolt	At Root of Thread					
1/4	20	0.185	13/64	0.049	0.026	1/2	0.578	0.707	1/4	1/4
5/16	18	0.240	1/4	0.076	0.045	19/32	0.686	0.840	5/16	19/64
3/8	16	0.294	5/16	0.110	0.068	11/16	0.794	0.972	3/8	11/32
7/16	14	0.345	23/64	0.150	0.093	25/32	0.902	1.105	7/16	25/64
1/2	13	0.400	27/64	0.196	0.126	7/8	1.011	1.237	1/2	7/16
9/16	12	0.454	15/32	0.248	0.162	31/32	1.119	1.370	9/16	31/64
5/8	11	0.507	17/32	0.307	0.202	1 1/16	1.227	1.502	5/8	17/32
3/4	10	0.620	41/64	0.442	0.302	1 1/4	1.444	1.768	3/4	5/8
7/8	9	0.731	3/4	0.601	0.419	1 7/16	1.660	2.033	7/8	23/32
1	8	0.838	55/64	0.785	0.551	1 5/8	1.877	2.298	1	1 3/16
1 1/8	7	0.939	31/32	0.994	0.694	1 13/16	2.093	2.563	1 1/8	29/32
1 1/4	7	1.064	1 3/32	1.227	0.893	2	2.310	2.828	1 1/4	1
1 3/8	6	1.158	1 7/32	1.485	1.057	2 3/16	2.527	3.093	1 3/8	1 3/32
1 1/2	6	1.283	1 11/32	1.767	1.295	2 3/8	2.743	3.358	1 1/2	1 3/16
1 5/8	5 1/2	1.389	1 27/64	2.074	1.515	2 9/16	2.960	3.623	1 5/8	1 9/32
1 3/4	5	1.490	1 17/32	2.405	1.746	2 3/4	3.176	3.889	1 3/4	1 3/8
1 7/8	5	1.615	1 21/32	2.761	2.051	2 15/16	3.393	4.154	1 7/8	1 15/32
2	4 1/2	1.711	1 49/64	3.142	2.302	3 1/8	3.609	4.419	2	1 9/16
2 1/4	4 1/2	1.961	2 1/64	3.976	3.023	3 1/2	4.043	4.949	2 1/4	1 3/4
2 1/2	4	2.175	2 15/64	4.909	3.719	3 7/8	4.476	5.479	2 1/2	1 15/16
2 3/4	4	2.425	2 31/64	5.940	4.620	4 1/4	4.909	6.010	2 3/4	2 1/8
3	3 1/2	2.629	2 11/16	7.069	5.428	4 5/8	5.342	6.540	3	2 5/16
3 1/4	3 1/2	2.879	2 15/16	8.296	6.510	5	5.775	7.070	3 1/4	2 1/2
3 1/2	3 1/4	3.100	3 11/64	9.621	7.548	5 3/8	6.208	7.600	3 1/2	2 11/16
3 3/4	3	3.317	3 3/8	11.045	8.641	5 3/4	6.641	8.131	3 3/4	2 7/8
4	3	3.567	3 5/8	12.566	9.963	6 1/8	7.074	8.661	4	3 1/16
4 1/4	2 7/8	3.798	3 27/32	14.186	11.340	6 1/2	7.508	9.191	4 1/4	3 1/4
4 1/2	2 3/4	4.028	4 3/32	15.904	12.750	6 7/8	7.941	9.721	4 1/2	3 7/16
4 3/4	2 5/8	4.255	4 5/16	17.721	14.215	7 1/4	8.374	10.252	4 3/4	3 5/8
5	2 1/2	4.480	4 9/16	19.635	15.760	7 5/8	8.807	10.782	5	3 13/16
5 1/4	2 1/2	4.730	4 13/16	21.648	17.570	8	9.240	11.312	5 1/4	4
5 1/2	2 3/8	4.953	5 1/32	23.758	19.260	8 3/8	9.673	11.842	5 1/2	4 3/16
5 3/4	2 3/8	5.203	5 9/32	25.967	21.250	8 3/4	10.106	12.373	5 3/4	4 3/8
6	2 1/4	5.423	5 1/2	28.274	23.090	9 1/8	10.539	12.903	6	4 9/16

From "Machinery's" Handbook
The Industrial Press, New York

WHITWORTH STANDARD THREAD



Formula

$$p = \text{pitch} = \frac{1}{\text{No. threads per inch}}$$

$$d = \text{depth} = \text{pitch} \times .64033$$

$$r = \text{radius} = \text{pitch} \times .1373$$

Full Diameter	Decimal Equivalent Outside Diameter	No. of Thds. per Inch	Pitch	Standard Depth of Thread	Effective Diameter	Core Diameter	Cross Sectional Area at Bottom of Thread
1/4	.25	20	.0500	.0320	.2180	.1860	.0272
5/16	.3125	18	.0556	.0356	.2769	.2414	.0458
3/8	.375	16	.0625	.0400	.3350	.2950	.0683
7/16	.4375	14	.0714	.0457	.3918	.3460	.0940
1/2	.5	12	.0833	.0534	.4466	.3933	.1215
9/16	.5625	12	.0833	.0534	.5091	.4558	.1632
5/8	.625	11	.0909	.0582	.5668	.5086	.2032
11/16	.6875	11	.0909	.0582	.6293	.5711	.2562
3/4	.75	10	.1000	.0640	.6860	.6219	.3038
13/16	.8125	10	.1000	.0640	.7485	.6844	.3679
7/8	.875	9	.1111	.0711	.8039	.7327	.4216
1	1.000	8	.1250	.0800	.9200	.8399	.5540
1 1/8	1.125	7	.1429	.0915	1.0335	.9420	.6969
1 1/4	1.25	7	.1429	.0915	1.1585	1.0670	.8942
1 3/8	1.375	6	.1667	.1067	1.2683	1.1616	1.0597
1 1/2	1.5	6	.1667	.1067	1.3933	1.2866	1.3001
1 5/8	1.625	5	.2000	.1281	1.4969	1.3689	1.4718
1 3/4	1.75	5	.2000	.1281	1.6219	1.4939	1.7528
2	2.000	4 1/2	.2222	.1423	1.8577	1.7154	2.3111
2 1/4	2.25	4	.2500	.1601	2.0899	1.9298	2.9249
2 1/2	2.5	4	.2500	.1601	2.3399	2.1798	3.7318
2 3/4	2.75	3 1/2	.2857	.1830	2.5670	2.3841	4.4641
3	3.000	3 1/2	.2857	.1830	2.8170	2.6341	5.4496
3 1/4	3.25	3 1/4	.3077	.1970	3.0530	2.8560	6.4063
3 1/2	3.5	3 1/4	.3077	.1970	3.3030	3.1060	7.5769
3 3/4	3.75	3	.3333	.2134	3.5366	3.3231	8.6732
4	4.000	3	.3333	.2134	3.7866	3.5731	10.0272

Courtesy of the Greenfield Tap and Die Corporation

TABLE OF DIAMETERS WITH CORRESPONDING PITCH

Diam. in.	Pitch U.S. Stan.	Pitch "V"	Pitch Whitworth	Diam. in.	Pitch U.S. Stan.	Pitch "V"	Pitch Whitworth	Diam. in.	Pitch U.S. Stan.	Pitch "V"	Pitch Whitworth
1/4	20	20	20	1 1/8	7	7	7	2 3/4	4	4	3 1/2
5/16	18	18	18	1 1/4	7	7	7	2 7/8	3 1/2	4	3 1/2
3/8	16	16	16	1 3/8	6	6	6	3	3 1/2	3 1/2	3 1/2
7/16	14	14	14	1 1/2	6	6	6	3 1/8	3 1/2	3 1/2	3 1/2
1/2	13	12	12	1 5/8	5 1/2	5	5	3 1/4	3 1/2	3 1/2	3 1/4
9/16	12	12	12	1 3/4	5	5	5	3 3/8	3 1/4	3 1/4	3 1/4
5/8	11	11	11	1 7/8	5	4 1/2	4 1/2	3 1/2	3 1/4	3 1/4	3 1/4
11/16	11	11	11	2	4 1/2	4 1/2	4 1/2	3 5/8	3 1/4	3 1/4	3 1/4
3/4	10	10	10	2 1/8	4 1/2	4 1/2	4 1/2	3 3/4	3	3	3
13/16	10	10	10	2 1/4	4 1/2	4 1/2	4	3 7/8	3	3	3
7/8	9	9	9	2 3/8	4	4 1/2	4	4	3	3	3
15/16	9	9	9	2 1/2	4	4	4				
1	8	8	8	2 5/8	4	4	4				

CONSTANTS FOR FINDING DIAMETER AT BOTTOM OF THREAD

Threads per inch	U.S. Standard Constant	"V" Thread Constant	Threads per inch	U.S. Standard Constant	"V" Thread Constant
64	.02030	.02706	16	.08119	.10825
60	.02165	.02887	14	.09279	.12372
56	.02320	.03093	13	.09993	.13323
50	.02598	.03464	12	.10825	.14434
48	.02706	.03608	11	.11809	.15746
44	.02952	.03936	10	.12990	.17321
40	.03248	.04330	9	.14434	.19245
36	.03608	.04811	8	.16238	.21651
32	.04059	.05413	7	.18558	.24744
30	.04330	.05773	6	.21651	.28868
28	.04639	.06186	5 1/2	.23619	.31492
26	.04996	.06662	5	.25981	.34641
24	.05413	.07217	4 1/2	.28868	.38490
22	.05905	.07873	4	.32476	.43301
20	.06495	.08660	3 1/2	.37115	.49487
18	.07217	.09623	3	.43301	.57733

C = Constant for number of threads per inch.
D = Outside diameter.
D^1 = Diameter at bottom of thread.

$$D^1 = D - C.$$

EXAMPLE

Given outside diameter of U. S. S. screw thread, 2 inches. 4½ threads per inch; find diameter at bottom of thread; $D = 2$ inches; for 4½ threads U. S. S., constant, $C = .2886$; then diameter at bottom of thread, $D^1 = 2 - .2886 = 1.7114$ inches.

Courtesy of The Geometric Tool Co.

DOUBLE DEPTH OF THREADS

Threads per in.	V Threads D D	U.S. St'd D D	Whit.St'd D D	Threads per in.	VThreads D D	U.S. St'd D D	Whit. St'd D D
2	.86650	.64950	.64000	28	.06185	.04639	.04571
2¼	.77022	.57733	.56888	30	.05773	.04330	.04266
2⅜	.72960	.54694	.53894	32	.05412	.04059	.04000
2½	.69320	.51960	.51200	34	.05097	.03820	.03764
2⅝	.66015	.49485	.48761	36	.04811	.03608	.03555
2¾	.63019	.47236	.46545	38	.04560	.03418	.03368
2⅞	.60278	.45182	.44521	40	.04330	.03247	.03200
3	.57733	.43300	.42666	42	.04126	.03093	.03047
3¼	.53323	.39966	.39384	44	.03936	.02952	.03136
3½	.49485	.37114	.36571	46	.03767	.02823	.02782
4	.43300	.32475	.32000	48	.03608	.02706	.02666
4½	.38488	.28869	.28444	50	.03464	.02598	.02560
5	.34660	.25980	.25600	52	.03332	.02498	.02461
5½	.31490	.23618	.23272	54	.03209	.02405	.02370
6	.28866	.21650	.21333	56	.03093	.02319	.02285
7	.24742	.18557	.18285	58	.02987	.02239	.02206
8	.21650	.16237	.16000	60	.02887	.02165	.02133
9	.19244	.14433	.14222	62	.02795	.02095	.02064
10	.17320	.12990	.12800	64	.02706	.02029	.02000
11	.15745	.11809	.11636	66	.02625	.01968	.01939
11½	.15069	.11295	.11121	68	.02548	.01910	.01882
12	.14433	.10825	.10666	70	.02475	.01855	.01728
13	.13323	.09992	.09846	72	.02407	.01804	.01782
14	.12357	.09278	.09142	74	.02341	.01752	.01729
15	.11555	.08660	.08533	76	.02280	.01714	.01673
16	.10825	.08118	.08000	78	.02221	.01665	.01641
18	.09622	.07216	.07111	80	.02166	.01623	.01600
20	.08660	.06495	.06400	82	.02113	.01584	.01560
22	.07872	.05904	.05818	84	.02063	.01546	.01523
24	.07216	.05412	.05333	86	.02015	.01510	.01476
26	.06661	.04996	.04923	88	.01957	.01476	.01454
27	.06418	.04811	.04740	90	.01925	.01443	.01422

$D^2 \frac{1.733}{N}$ For V Thread. $D^2 \frac{1.299}{N}$ For U.S. Standard.

$D^2 \frac{1.28}{N}$ For Whitworth Standard.

TAP DRILLS FOR A. S. M. E. STANDARD AND SPECIAL MACHINE SCREW TAPS

The diameter given for each hole to be tapped allows for a practical clearance at the root of the thread of the screw and will not impose undue strain upon the tap in service.

Size of Tap	No. of Threads	Size of Drill	Size of Tap	No. of Threads	Size of Drill
0	80	.0465	9	32	.1405
1	**64**	**.055**	**10**	**24**	**.140**
1	72	.0595	10	30	.152
2	**56**	**.0670**	**10**	**32**	**.154**
2	64	.070	**12**	**24**	**.166**
3	**48**	**.076**	12	28	.173
3	56	.0785	**14**	**20**	**.182**
4	**36**	**.080**	14	24	.1935
4	**40**	**.082**	**16**	**20**	**.209**
4	48	.089	16	22	.213
5	**36**	**.0935**	**18**	**18**	**.228**
5	**40**	**.098**	18	20	.234
5	44	.0995	**20**	**18**	**.257**
6	**32**	**.1015**	20	20	.261
6	**36**	**.1065**	**22**	**16**	**.272**
6	40	.110	22	18	.281
7	**30**	**.113**	24	16	.295
7	**32**	**.116**	**24**	**18**	**.302**
7	36	.120	**26**	**14**	**.316**
8	**30**	**.1285**	26	16	.323
8	**32**	**.1285**	28	14	.339
8	36	.136	**28**	**16**	**.348**
9	**24**	**.1285**	30	14	.368
9	**30**	**.136**	**30**	**16**	**.377**

NOTE: Special Taps are in Boldface Type.

TAP DRILLS FOR MACHINE SCREWS

Size of Tap	American Standard Diam. in inches	Size of Drill for Outside Diam. of Screw Number	Size of Drill for Tapping Hole Number
2 x 48 2 x 56 2 x 64	.25763	44	50 49 48
3 x 40 3 x 48 3 x 56	.22942	39	49 47 45
4 x 32 4 x 36 4 x 40	.20431	33	46 44 43
5 x 30 5 x 32 5 x 36 5 x 40	.18194	1/8	43 42 41 38
6 x 30 6 x 32 6 x 36 6 x 40	.16202	28	38 37 36 35
7 x 28 7 x 30 7 x 32	.14428	24	34 33 32
8 x 24 8 x 30 8 x 32	.12849	19	31 31 30
9 x 24 9 x 28 9 x 30 9 x 32	.11443	16	30 28 28 26
10 x 24 10 x 30 10 x 32	.10189	11	26 24 24
11 x 24 11 x 28 11 x 30	.090742	6	21 20 19
12 x 20 12 x 22 12 x 24 12 x 28	.080808	7/32	24 20 19 18

Size of Tap	American Standard Diam. in inches	Size of Drill for Outside Diam. of Screw Number	Size of Drill for Tapping Hole Number
13 x 20 13 x 22 13 x 24	.071961	15/64	17 17 15
14 x 20 14 x 22 14 x 24	.064084	1/4	15 11 10
15 x 18 15 x 20 15 x 22 15 x 24	.057068	F	12 10 8 7
16 x 16 16 x 18 16 x 20	.05082	I	12 8 7
17 x 16 17 x 18 17 x 20	.045257	L	8 4 3
18 x 16 18 x 18 18 x 20	.040303	19/64	2 2 1
19 x 16 19 x 18 19 x 20	.03589	5/16	1 B C
20 x 16 20 x 18 20 x 20	.031961	P	C E F
22 x 16 22 x 18	.025347	S	H J
24 x 14 24 x 16 24 x 18	.0201	3/8	L M N
26 x 14 26 x 16	.01594	13/32	O P
28 x 14 28 x 16	.012641	7/16	R S
30 x 14 30 x 16	.010025	29/64	U V

TABLE OF TAPPED HOLE LIMITS FOR U. S. S. TAPS

CLOSE FIT LIMITS

Size in Inches	P	Basic or P. D. of Max. Sc.	Min. Sc. P. D. Proposed	Max. Sc. over Min. Sc.	Min. Tap over Basic	Tapped Hole Pitch Diams.		Tapped Hole Diff.	GAGE Pitch Diams.		Gage P. D. Diff.	Min. Gage over Max. Sc.
						Min.	Max.		Min.	Max.		
1/4	20	.2175	.2160	.0015	.0005	.2180	.2190	.0010	.21775	.21925	.0015	.00025
5/16	18	.2764	.2745	.0019	.0006	.2770	.2780	.0010	.27675	.27825	.0015	.00035
3/8	16	.3344	.3325	.0019	.0006	.3350	.3365	.0015	.33475	.33675	.0020	.00035
7/16	14	.3911	.38915	.00195	.0009	.3920	.3935	.0015	.39175	.39375	.0020	.00065
1/2	13	.4501	.4481	.0020	.0009	.4510	.4525	.0015	.45075	.45275	.0020	.00075
9/16	12	.5084	.5064	.0020	.0011	.5095	.5115	.0020	.50925	.51175	.0025	.00085
5/8	11	.5660	.5635	.0025	.0010	.5670	.5690	.0020	.56675	.56925	.0025	.00075
11/16	11	.6285	.6260	.0025	.0010	.6295	.6315	.0020	.62925	.63175	.0025	.00075
3/4	10	.6851	.6821	.0030	.0009	.6860	.6880	.0020	.68575	.68825	.0025	.00075
13/16	10	.7475	.7445	.0030	.0009	.7484	.7509	.0025	.74815	.75115	.0030	.00065
7/8	9	.8028	.7996	.0032	.0011	.8039	.8064	.0025	.80365	.80665	.0030	.00085
1 5/16	9	.8653	.8621	.0032	.0011	.8664	.8689	.0025	.86615	.86915	.0030	.00085
1	8	.9188	.9155	.0033	.0012	.9200	.9225	.0025	.91975	.92275	.0030	.00095
1 1/8	7	1.0322	1.0280	.0042	.0013	1.0335	1.0360	.0025	1.03325	1.03625	.0030	.00105
1 1/4	7	1.1572	1.1530	.0042	.0013	1.1585	1.1610	.0025	1.15825	1.16125	.0030	.00105
1 3/8	6	1.2668	1.2625	.0043	.0012	1.2680	1.2710	.0030	1.26775	1.27125	.0035	.00095
1 1/2	6	1.3918	1.3875	.0043	.0012	1.3930	1.3960	.0030	1.39275	1.39625	.0035	.00095

Table for Loose Fit Limits, page 143; for S. A. E. Taps, page 145; for Machine Screw Taps, page 141.

Courtesy of the Greenfield Tap and Die Corporation

TABLE OF TAPPED HOLE LIMITS FOR U. S. S. TAPS

LOOSE FIT LIMITS

Size in Inches	P	Basic or P. D. of Max. Sc.	Min. Sc. P. D. Proposed	Max. Sc. over Min. Sc.	Min. Tap over Basic	Tapped Hole Pitch Diams.		Tapped Hole Diff.	GAGE Pitch Diams.		Gage P. D. Diff.	Min. Gage over Max. Sc.
						Min.	Max.		Min.	Max.		
1/4	20	.2175	.2160	.0015	.0005	.2180	.2200	.0020	.21775	.22025	.0025	.00025
5/16	18	.2764	.2745	.0019	.0006	.2770	.2790	.0020	.27675	.27925	.0025	.00035
3/8	16	.3344	.3325	.0019	.0006	.3350	.3380	.0030	.33475	.33825	.0035	.00035
7/16	14	.3911	.38915	.00195	.0009	.3920	.3950	.0030	.39175	.39525	.0035	.00065
1/2	13	.4501	.4481	.0020	.0009	.4510	.4540	.0030	.45075	.45425	.0035	.00075
9/16	12	.5084	.5064	.0020	.0011	.5095	.5135	.0040	.50925	.51375	.0045	.00085
5/8	11	.5660	.5635	.0025	.0010	.5670	.5710	.0040	.56675	.57125	.0045	.00075
11/16	11	.6285	.6260	.0025	.0010	.6295	.6335	.0040	.62925	.63675	.0045	.00075
3/4	10	.6851	.6821	.0030	.0009	.6860	.6900	.0040	.68575	.69025	.0045	.00075
13/16	10	.7475	.7445	.0030	.0009	.7484	.7534	.0050	.74815	.75375	.0055	.00065
7/8	9	.8028	.7996	.0032	.0011	.8039	.8089	.0050	.80365	.80915	.0055	.00085
15/16	9	.8653	.8621	.0032	.0011	.8664	.8714	.0050	.86615	.87165	.0055	.00085
1	8	.9188	.9155	.0033	.0012	.9200	.9250	.0050	.91975	.92525	.0055	.00095
1 1/8	7	1.0322	1.0280	.0042	.0013	1.0335	1.0385	.0050	1.03325	1.03875	.0055	.00105
1 1/4	7	1.1572	1.1530	.0042	.0013	1.1585	1.1635	.0050	1.15525	1.16375	.0055	.00105
1 3/8	6	1.2668	1.2625	.0043	.0012	1.2680	1.2740	.0050	1.26775	1.27425	.0065	.00085
1 1/2	6	1.3918	1.3875	.0043	.0012	1.3930	1.3990	.0060	1.39275	1.39925	.0065	.00085

Table of Close Fit Limits will be found on page 142.

Courtesy of the Greenfield Tap and Die Corporation

BRITISH ASSOCIATION SCREW THREADS*

Size of Tap	Outside Diameter mm.	Core Diameter mm.	Nearest Commercial Drill to produce 75% depth of thread	
			Inch Decimals	Commercial Designation
0	6.0	4.80	.201	No. 7
1	5.3	4.22	.177	16
2	4.7	3.73	.156	22
3	4.1	3.22	.135	29
4	3.6	2.81	.118	31
5	3.2	2.49	.105	37
6	2.8	2.16	.091	43
7	2.5	1.92	.081	46
8	2.2	1.68	.075	48
9	1.9	1.43	.061	$\frac{1}{16}$ in.
10	1.7	1.28	.055	No. 54
11	1.5	1.13	.048	56
12	1.3	.96	.041	59

NOTE: A common nut drilled out so that it contains only 50% of a full depth thread will break the bolt before it will strip.

A 75% depth of thread yields an ample margin of safety (2 to 1) and is economical in tapping.

A full depth of thread in a common nut is only about 5% stronger than a 75% depth of thread, yet it requires three times the power to tap.

ADAPTING LATHE TO CUT SCREW THREADS IN METRIC SYSTEM

Metric screw threads are usually expressed in a certain number of threads per centimeter. Metric threads may be cut on any engine lathe that is arranged for compound gearing as follows:

For example: To cut 10 threads per centimeter, gear up the lathe to cut 10 threads per inch, using the gears prescribed on the index plate in the usual manner for cutting 10 threads per inch, but instead of using the usual intermediate gears on the lathe, use two gears, one of 50 teeth and one of 127 teeth respectively on the intermediate stud. These gears should run loose on the stud. The gear of 50 teeth meshing in on gear on screw, and gear of 127 teeth meshing in on gear on the stud.

It is easily understood how the English or American system is converted into the Metric system; by the use of two gears, one of 50 and one of 127, the ratio of these two gears is .3937; that is, 50 divided by 127 equals .3937, the length in inches of one centimeter.

Courtesy of the Greenfield Tap and Die Corporation.

LETTER SIZES OF DRILLS

Diameter Inches	Decimals of 1 Inch	Diameter Inches	Decimals of 1 Inch
A 15/64	.234	N	.302
B	.238	O 5/16	.316
C	.242	P 21/64	.323
D	.246	Q	.332
E 1/4	.250	R 11/32	.339
F	.257	S	.348
G	.261	T 23/64	.358
H 17/64	.266	U	.368
I	.272	V 3/8	.377
J	.277	W 25/64	.386
K 9/32	.281	X	.397
L	.290	Y 13/32	.404
M 19/64	.295	Z	.413

SIZES OF TAP DRILLS

Tap Diameter	Threads per Inch	Drill for V Thread	Drill for U. S. Standards	Drill for Whitworth
1/4	16, 18, 20	5/32 5/32 11/64	3/16	3/16
9/32	16, 18, 20	3/16 13/64 13/64		
5/16	16, 18	7/32 15/64	1/4	15/64
11/32	16, 18	1/4 17/64		
3/8	14, 16, 18	1/4 9/32 9/32	9/32	9/32
3/32	14, 16, 18	19/64 21/64 21/64		
7/16	14, 16	21/64 11/32	11/32	11/32
15/32	14, 16	23/64 3/8		
1/2	12, 13, 14	3/8 25/64 25/64	13/32	3/8
9/16	12, 14	7/16 29/64	7/16	
5/8	10, 11, 12	15/32 1/2 1/2	1/2	1/2
11/16	11, 12	9/16 9/16		
3/4	10, 11, 12	19/32 5/8 5/8	5/8	5/8
13/16	10	21/32		
7/8	9, 10	45/64 23/32	23/32	23/32
15/16	9	49/64		
1	8	13/16	27/32	27/32

TAP DRILL SIZES FOR S. A. E. STANDARD THREADS

Diam. of Tap	No. of Threads	Diam. of Tap Drill	Diam. of Tap	No. of Threads	Diam. of Tap Drill	Diam. of Tap	No. of Threads	Diam. of Tap Drill
1/4	28	0.213	9/16	18	0.500	1	14	0.921
5/16	24	0.272	5/8	18	0.562	1 1/8	12	1.031
3/8	24	0.332	11/16	16	0.625	1 1/4	12	1.156
7/16	20	0.386	3/4	16	0.687	1 3/8	12	1.281
1/2	20	0.437	7/8	14	0.796	1 1/2	12	1.406

TAPS FOR A. S. M. E. STANDARD MACHINE SCREWS

Size			Outside Diameters			Pitch Diameters			Root Diameters		
No.	Outside Diameter	Thds. P.I.	Minimum	Maximum	Difference	Minimum	Maximum	Difference	Minimum	Maximum	Difference
0	.060	80	.0609	.0632	.0023	.0528	.0538	.0010	.0447	.0466	.0019
1	.073	72	.0740	.0765	.0025	.0650	.0660	.0010	.0560	.0580	.0020
2	.086	64	.0871	.0898	.0027	.0770	.0781	.0011	.0668	.0689	.0021
3	.099	56	.1002	.1033	.0031	.0886	.0897	.0011	.0770	.0793	.0023
4	.112	48	.1133	.1168	.0035	.0998	.1010	.0012	.0862	.0887	.0025
5	.125	44	.1263	.1301	.0038	.1116	.1129	.0013	.0968	.0995	.0027
6	.138	40	.1394	.1435	.0041	.1232	.1246	.0014	.1069	.1097	.0028
7	.151	36	.1525	.1569	.0044	.1345	.1359	.0014	.1164	.1193	.0029
8	.164	36	.1655	.1699	.0044	.1475	.1489	.0014	.1294	.1323	.0029
9	.177	32	.1786	.1835	.0049	.1583	.1598	.0015	.1380	.1411	.0031
10	.190	30	.1916	.1968	.0052	.1700	.1716	.0016	.1483	.1515	.0032
12	.216	28	.2176	.2232	.0056	.1944	.1961	.0017	.1712	.1745	.0033
14	.242	24	.2438	.2500	.0062	.2167	.2184	.0017	.1897	.1932	.0035
16	.268	22	.2698	.2765	.0067	.2403	.2421	.0018	.2108	.2144	.0036
18	.294	20	.2959	.3031	.0072	.2634	.2652	.0018	.2309	.2346	.0037
20	.320	20	.3219	.3291	.0072	.2894	.2912	.0018	.2569	.2606	.0037
22	.346	18	.3479	.3559	.0080	.3118	.3138	.0020	.2757	.2796	.0039
24	.372	16	.3740	.3828	.0088	.3334	.3354	.0020	.2928	.2968	.0040
26	.398	16	.4000	.4088	.0088	.3594	.3614	.0020	.3188	.3228	.0040
28	.424	14	.4261	.4359	.0098	.3797	.3818	.0021	.3333	.3374	.0041
30	.450	14	.4521	.4619	.0098	.4057	.4078	.0021	.3593	.3634	.0041

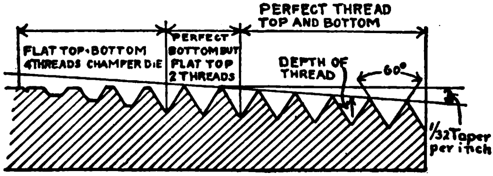
Courtesy of the Greenfield Tap and Die Corporation

TAPS FOR A. S. M. E. SPECIAL MACHINE SCREWS

Size			Outside Diameters			Pitch Diameters			Root Diameters		
No.	Outside Diameter	Thds. Per In.	Minimum	Maximum	Difference	Minimum	Maximum	Difference	Minimum	Maximum	Difference
1	.073	64	.0741	.0768	.0027	.0640	.0651	.0011	.0538	.0559	.0021
2	.086	56	.0872	.0903	.0031	.0756	.0767	.0011	.0640	.0663	.0023
3	.099	48	.1003	.1038	.0035	.0868	.0880	.0012	.0732	.0757	.0025
4	.112	40	.1134	.1175	.0041	.0972	.0986	.0014	.0809	.0837	.0028
		36	.1135	.1179	.0044	.0955	.0969	.0014	.0774	.0803	.0029
5	.125	40	.1264	.1305	.0041	.1102	.1116	.0014	.0939	.0967	.0028
		36	.1265	.1309	.0044	.1085	.1099	.0014	.0904	.0933	.0029
6	.138	36	.1395	.1439	.0044	.1215	.1229	.0014	.1034	.1063	.0029
		32	.1396	.1445	.0049	.1193	.1208	.0015	.0990	.1021	.0031
7	.151	32	.1526	.1575	.0049	.1323	.1338	.0015	.1120	.1151	.0031
		30	.1526	.1578	.0052	.1310	.1326	.0016	.1093	.1125	.0032
8	.164	32	.1656	.1705	.0049	.1453	.1468	.0015	.1250	.1281	.0031
		30	.1656	.1708	.0052	.1440	.1456	.0016	.1223	.1255	.0032
9	.177	30	.1786	.1838	.0052	.1569	.1585	.0016	.1353	.1385	.0032
		24	.1788	.1850	.0062	.1517	.1534	.0017	.1247	.1282	.0035
10	.190	32	.1916	.1965	.0049	.1713	.1728	.0015	.1510	.1541	.0031
		24	.1918	.1980	.0062	.1647	.1664	.0017	.1377	.1412	.0035
12	.216	24	.2178	.2240	.0062	.1907	.1924	.0017	.1637	.1672	.0035
14	.242	20	.2439	.2511	.0072	.2114	.2132	.0018	.1789	.1826	.0037
16	.268	20	.2699	.2771	.0072	.2374	.2392	.0018	.2049	.2086	.0037
18	.294	18	.2959	.3039	.0080	.2598	.2618	.0020	.2237	.2276	.0039
20	.320	18	.3219	.3299	.0080	.2858	.2878	.0020	.2497	.2536	.0039
22	.346	16	.3480	.3568	.0088	.3074	.3094	.0020	.2668	.2708	.0040
24	.372	18	.3739	.3819	.0080	.3378	.3398	.0020	.3017	.3056	.0039
26	.398	14	.4001	.4099	.0098	.3537	.3558	.0021	.3073	.3114	.0041
28	.424	16	.4260	.4348	.0088	.3854	.3874	.0020	.3448	.3488	.0040
30	.450	16	.4520	.4608	.0088	.4114	.4134	.0020	.3708	.3748	.0010

Courtesy of the Greenfield Tap and Die Corporation

BRIGGS'S STANDARD TAPER PIPE THREAD



Taper of thread = ¾ in. per foot = $\frac{1}{16}$ in. per inch

Depth of thread at (E) = $\dfrac{8}{\text{threads per inch}}$

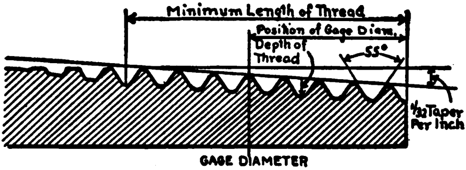
N = number of threads per inch

Pipe Diameters			Depth of Thread	No. Threads per Inch	Length of Thread Inches	No. Turns Pipe Screws into Fitting by Hand	No. Turns to be Made with Wrench	Distance Pipe Screws into Fitting	No. of Turns Pipe Screws into Fitting
Nominal Size	Actual Inch Size	Actual Outside							
⅛	0.270	0.405	.029	27	.412	4	1.13	0.19	5.13
¼	0.364	0.540	.044	18	.624	4	1.22	0.29	5.22
⅜	0.494	0.675	.044	18	.634	4	1.40	0.30	5.40
½	0.623	0.840	.057	14	.818	4	1.46	0.40	5.46
¾	0.824	1.050	.057	14	.828	4	1.60	0.51	5.78
1	1.048	1.315	.069	11½	1.03	4½	1.37	0.55	6.21
1¼	1.380	1.660	.069	11½	1.06	5	1.21	0.58	6.33
1½	1.610	1.900	.069	11½	1.07	5	1.33	0.89	6.67
2	2.067	2.375	.069	11½	1.10	5	1.67	0.95	7.12
2½	2.468	2.875	.100	8	1.64	5	2.12	1.00	7.60
3	3.067	3.500	.100	8	1.70	5	2.60	1.05	8.00
3½	3.548	4.000	.100	8	1.75	5	3.00	1.05	8.40
4	4.026	4.500	.100	8	1.80	5½	2.90	1.10	8.80
4½	4.508	5.000	.100	8	1.85	5½	3.30	1.10	8.80
5	5.045	5.563	.100	8	1.91	5½	3.78	1.16	9.28
6	6.065	6.625	.100	8	2.01	6	4.08	1.26	10.08
7	7.023	7.625	.100	8	2.11	7	3.88	1.36	10.88
8	7.981	8.625	.100	8	2.21	8	3.68	1.46	11.68
9	8.941	9.625	.100	8	2.32	9	3.56	1.57	12.56
10	10.020	10.750	.100	8	2.43	10	3.44	1.68	13.44

Courtesy of the Greenfield
Tap and Die Corporation

BRITISH STANDARD WHITWORTH PIPE THREAD

Taper ¾ inch per foot



Nominal Size	Approx. Outside Diam.	*Gage Diam.	Depth of Thread	No. of Threads per Inch	Length of Thread On Pipe End Min.	Length of Thread In Coupler Min.	Distance of Gage Diam'r from Pipe end on taper screws Std.
1/8	13/32	.383	.0230	28	3/8	3/4	5/32
1/4	17/32	.518	.0335	19	7/16	7/8	3/16
3/8	11/16	.656	.0335	19	1/2	1	1/4
1/2	27/32	.825	.0455	14	5/8	1 1/4	1/4
5/8	15/16	.902	.0455	14	5/8	1 1/4	1/4
3/4	1 1/16	1.041	.0455	14	3/4	1 1/2	3/8
7/8	1 7/32	1.189	.0455	14	3/4	1 1/2	3/8
1	1 11/32	1.309	.0580	11	7/8	1 3/4	3/8
1 1/4	1 11/16	1.650	.0580	11	1	2	1/2
1 1/2	1 1/2	1.882	.0580	11	1	2	1/2
1 3/4	2 5/32	2.116	.0580	11	1 1/8	2 1/4	5/8
2	2 3/8	2.347	.0580	11	1 1/4	2 1/4	5/8
2 1/4	2 5/8	2.587	.0580	11	1 1/4	2 1/2	11/16
2 1/2	3	2.960	.0580	11	1 1/4	2 1/2	11/16
2 3/4	3 1/4	3.210	.0580	11	1 3/8	2 3/4	11/16
3	3 1/2	3.460	.0580	11	1 3/8	2 3/4	11/16
3 1/4	3 3/4	3.700	.0580	11	1 1/2	3	7/8
3 1/2	4	3.950	.0580	11	1 1/2	3	7/8
3 3/4	4 1/4	4.200	.0580	11	1 1/2	3	7/8
4	4 1/2	4.450	.0580	11	1 5/8	3 1/4	1
4 1/2	5	4.950	.0580	11	1 5/8	3 1/4	1
5	5 1/2	5.450	.0580	11	1 3/4	3 1/2	1 1/8
5 1/2	6	5.950	.0580	11	1 7/8	3 3/4	1 1/4
6	6 1/2	6.450	.0580	11	2	4	1 3/8

*Gage Diameter is the full diameter of the Standard Male Parallel Screw Gage which the Parallel Coupler, to be used with a pipe of that size, is required to fit.

DRILL SIZES FOR PIPE TAP

Size Tap Inches	Briggs Standard Thread	Briggs Standard Drill	British Standard Thread	British Standard Drill	Size Tap Inches	Briggs Standard Thread	Briggs Standard Drill	British Standard Thread	British Standard Drill
1/8	27	21/64	28	5/16	2 1/4	..	..	11	2 15/32
1/4	18	27/64	19	7/16	2 1/2	8	2 9/16	11	2 27/32
3/8	18	9/16	19	9/16	2 3/4	..	..	11	3 1/32
1/2	14	11/16	14	23/32	3	8	3 3/16	11	3 9/32
5/8	..	..	14	25/32	3 1/4	..	..	11	3 1/2
3/4	14	29/32	14	29/32	3 1/2	8	3 11/16	11	3 3/4
7/8	..	..	14	1 1/16	3 3/4	..	..	11	4
1	11 1/2	1 1/8	11	1 5/32	4	8	4 3/16	11	4 1/4
1 1/4	11 1/2	1 15/32	11	1 1/2	4 1/2	8	4 11/16	11	4 3/4
1 1/2	11 1/2	1 23/32	11	1 23/32	5	8	5 1/4	11	5 1/4
1 3/4	..	..	11	1 31/32	5 1/2	..	..	11	5 3/4
2	11 1/2	2 3/16	11	2 3/16	6	8	6 3/16	11	6 1/4

MICROMETER READINGS (PITCH DIAMETER)

for U. S. Form Threads $= D - \frac{.6495}{P}$

United States Standard Threads

Diam.	Threads per Inch	Micro. Reading or Pitch Diam.		Diam.	Threads per Inch	Micro. Reading or Pitch Diam.	
D	P	$D-\frac{.6495}{P}$	$\frac{.6495}{P}$	D	P	$D-\frac{.6495}{P}$	$\frac{.6495}{P}$
	64		.0101	¼"	20	.2175	.0325
	62		.0105	5/16	18	.2764	.0361
	60		.0108	⅜	16	.3344	.0406
	58		.0112	7/16	14	.3911	.0464
	56		.0116	½	13	.4501	.0499
	54		.0120	9/16	12	.5084	.0541
	52		.0125	⅝	11	.566	.0590
	50		.0130	¾	10	.6851	.0649
	48		.0135	⅞	9	.8029	.0721
	46		.0141	1	8	.9188	.0812
	44		.0148	1⅛	7	1.0322	.0928
	42		.0155	1¼	7	1.1572	.0928
	40		.0162	1⅜	6	1.2668	.1082
	38		.0171	1½	6	1.3918	.1082
	36		.0180	1⅝	5½	1.507	.1180
	34		.0191	1¾	5	1.6201	.1299
	32		.0203	1⅞	5	1.7451	.1299
	30		.0217	2	4½	1.8557	.1443
	28		.0232	2½	4	2.3376	.1624
	26		.0250	3	3½	2.8145	.1855
	24		.0271	3½"	3¼	3.3002	.1998
	22		.0295	4	3	3.7835	.2165

As there is no standard of diameter for the finer pitches, the columns for diameter and micrometer reading, or pitch diameter, are left blank. The fourth and eighth columns give the numbers to be subtracted from the diameter to obtain the micrometer reading or pitch diameter.

S. A. E. Standard Threads

Diam.	Threads per Inch	Micro. Reading or Pitch Diam.		Diam.	Threads per Inch	Micro. Reading or Pitch Diam.	
D	P	$D-\frac{.6495}{P}$	$\frac{.6495}{P}$	D	P	$D-\frac{.6495}{P}$	$\frac{.6495}{P}$
¼	28	.2268	.0232	¾	16	.7094	.0406
5/16	24	.2855	.0270	⅞	14	.8285	.0465
⅜	24	.3480	.0270	⅞	18	.8389	.0361
7/16	20	.4050	.0325	1	14	.9535	.0465
½	20	.4675	.0325	1⅛	12	1.0709	.0541
9/16	18	.5264	.0361	1¼	12	1.1959	.0541
⅝	18	.5889	.0361	1⅜	12	1.3209	.0541
11/16	16	.6469	.0406	1½	12	1.4459	.0541

Courtesy of the Greenfield Tap and Die Corporation

MICROMETER READINGS (PITCH DIAMETER)

Caliper Reading or Pitch Diameter, Whitworth Threads $= D - \frac{.640}{N}$

Whitworth Standard Threads

Diameter	Threads per Inch	Caliper Reading or Pitch Diameter	
D	N	$D - \frac{.640}{N}$	$\frac{.640}{N}$
1/4	20	.2180	.0320
5/16	18	.2769	.0355
3/8	16	.3350	.0400
7/16	14	.3918	.0457
1/2	12	.4467	.0533
9/16	12	.5092	.0533
5/8	11	.5668	.0582
11/16	11	.6293	.0582
3/4	10	.6860	.0640
13/16	10	.7485	.0640
7/8	9	.8039	.0711
15/16	9	.8664	.0711
1	8	.9200	.0800
1 1/8	7	1.0336	.0914
1 1/4	7	1.1586	.0914
1 3/8	6	1.2684	.1066
1 1/2	6	1.3934	.1066
1 5/8	5	1.4970	.1280
1 3/4	5	1.6220	.1280
1 7/8	4 1/2	1.7328	.1422
2	4 1/2	1.8578	.1422
2 1/8	4 1/2	1.9828	.1422

Caliper Reading or Pitch Diameter, A. S. M. E. Standard $= D - \frac{.6495}{N}$

Same form of thread as the U. S. Standard

A. S. M. E. Standard Threads

No.	Basic and Maximum Outside Diam.	Threads per Inch	Caliper Reading or Maximum Pitch Diameter	
	D	N	$D - \frac{.6495}{N}$	$\frac{.6495}{N}$
0	.060	80	.0519	.0081
1	.073	72	.064	.0090
2	.086	64	.0759	.0101
3	.099	56	.0874	.0116
4	.112	48	.0985	.0135
5	.125	44	.1102	.0148
6	.138	40	.1218	.0162
7	.151	36	.1330	.0180
8	.164	36	.146	.0180
9	.177	32	.1567	.0203
10	.190	30	.1684	.0217
12	.216	28	.1928	.0232
14	.242	24	.2149	.0271
16	.268	22	.2385	.0295
18	.294	20	.2615	.0325
20	.320	20	.2875	.0325
22	.346	18	.3099	.0361
24	.372	16	.3314	.0406
26	.398	16	.3574	.0406
28	.424	14	.3776	.0464
30	.450	14	.4036	.0464

See also Tables in Starrett Catalogue.

DIMENSIONS FOR STANDARD SCREW THREADS

Coarse Threads

Threads per Inch	*h* Single Depth	2*h* Double Depth	Width of Flat		Pitch
4	0.1624	0.3248	0.0312	0.02702	0.2500
5	0.1299	0.2598	0.0250	0.02165	0.2000
6	0.1083	0.2165	0.0208	0.01801	0.1667
7	0.0928	0.1856	0.0179	0.01550	0.1430
8	0.0812	0.1624	0.0156	0.01351	0.1250
9	0.0722	0.1443	0.0139	0.01204	0.1111
10	0.0650	0.1299	0.0125	0.01082	0.1000
11	0.0590	0.1181	0.0114	0.00987	0.0909
12	0.0541	0.1083	0.0104	0.00900	0.0833
13	0.0500	0.0999	0.0096	0.00831	0.0769
14	0.0464	0.0928	0.0089	0.00770	0.0714
16	0.0406	0.0812	0.0078	0.00675	0.0625
18	0.0361	0.0722	0.0069	0.00597	0.0556

Fine Threads

Threads per Inch	*h* Single Depth	2*h* Double Depth	Width of Flat		Pitch
20	0.0325	0.0650	0.0062	0.00537	0.0500
22	0.0295	0.0590	0.0057	0.00493	0.0454
24	0.0271	0.0541	0.0052	0.00456	0.0417
28	0.0232	0.0464	0.0045	0.00389	0.0357
30	0.0217	0.0433	0.0042	0.00363	0.0333
32	0.0203	0.0406	0.0039	0.00337	0.0312
36	0.0180	0.0361	0.0035	0.00303	0.0278
40	0.0162	0.0325	0.0031	0.00268	0.0250
44	0.0148	0.0295	0.0028	0.00242	0.0227
48	0.0135	0.0271	0.0026	0.00225	0.0208
56	0.0116	0.0232	0.0022	0.00190	0.0179
64	0.0101	0.0203	0.0020	0.00173	0.0156
72	0.0090	0.0180	0.0017	0.00147	0.0139
80	0.0081	0.0162	0.0016	0.00138	0.0125

TOLERANCES

The subject of dimensions and tolerances for screw threads is of great importance. The data in the accompanying tables represents the tolerances established by the Ordnance Department of the United States Army for use in the manufacture of artillery ammunition, trench warfare material, and gun parts. Figs. 1, 2, and 3 (page 153) show how the Ordnance Department drawings will be prepared. The class of tolerance applying to any nut and screw depends upon the function of the part. The percentage of strength of full thread required should be duly considered, also the accuracy required should be taken account of. When the two factors are fully appreciated then the class of tolerance, such as close, medium, or loose fit, can be selected as best suits these conditions.

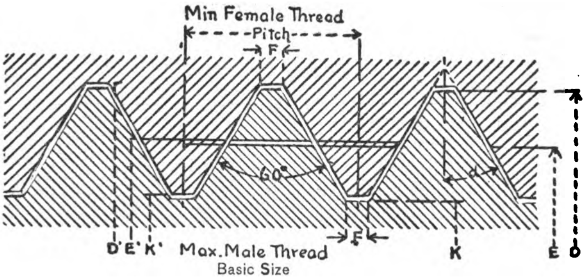
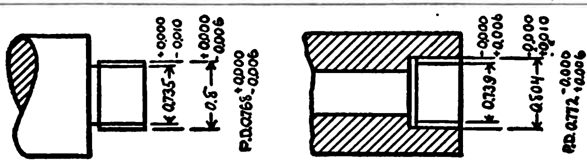


Fig. 1. Key to Symbols used in Tables

SCREW AND NUT TOLERANCES FOR CLOSE FITS

Thds. per Inch	Tolerances on Screws: *D* Full Diam.	Tolerances on Screws: *E* Effect. Diam.	Tolerances on Screws: *K* Core Diam.	Neutral Space between Max. Screw and Min. Nut	Tolerances on Nuts: *D'* Full Diam.	Tolerances on Nuts: *E'* Effect. Diam.	Tolerances on Nuts: *K'* Core Diam.	Minimum per Cent Strength (Approx.)
4–6	+0.000 —0.008	+0.000 —0.008	+0.000 —0.025	0.008	—0.000 +0.025	—0.000 +0.008	—0.000 +0.008	87
7–10	+0.000 —0.006	+0.000 —0.006	+0.000 —0.016	0.006	—0.000 +0.016	—0.000 +0.006	—0.000 +0.006	84
11–18	+0.000 —0.005	+0.000 —0.005	+0.000 —0.010	0.005	—0.000 +0.010	—0.000 +0.005	—0.000 +0.005	76
20–28	+0.000 —0.004	+0.000 —0.004	+0.000 —0.008	0.004	—0.000 +0.008	—0.000 +0.004	—0.000 +0.004	70
30–40	+0.000 —0.003	+0.000 —0.003	+0.000 —0.006	0.003	—0.000 +0.006	—0.000 +0.003	—0.000 +0.003	68
44–56	+0.000 —0.002	+0.000 —0.002	+0.000 —0.004	0.002	—0.000 +0.004	—0.000 +0.002	—0.000 +0.002	70
64–80	+0.000 —0.0015	+0.000 —0.0015	+0.000 —0.003	0.001	—0.000 +0.003	—0.000 +0.0015	—0.000 +0.0015	70



Figs. 2 and 3. Ordnance Department Drawing Practice for Screws and Nuts

SCREW AND NUT TOLERANCES FOR MEDIUM FITS

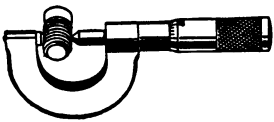
Thds. per Inch	Tolerances on Screws			Neutral Space between Max. Screw and Min. Nut	Tolerances on Nuts			Minimum per Cent Strength (Approx.)
	D Full Dia.	*E* Effect. Diam.	*K* Core Diam.		*D′* Full Diam.	*E′* Effect. Diam.	*K′* Core Diam.	
4–6	+0.000 —0.016	+0.000 —0.016	+0.000 —0.035	0.008	—0.000 +0.035	—0.000 +0.016	—0.000 +0.016	78
7–10	+0.000 —0.012	+0.000 —0.012	+0.000 —0.022	0.006	—0.000 +0.022	—0.000 +0.012	—0.000 +0.012	72
11–18	+0.000 —0.008	+0.000 —0.008	+0.000 —0.014	0.005	—0.000 +0.014	—0.000 +0.008	—0.000 +0.008	65
20–28	+0.000 —0.006	+0.000 —0.006	+0.000 —0.010	0.004	—0.000 +0.010	—0.000 +0.006	—0.000 +0.006	60
30–40	+0.000 —0.004	+0.000 —0.004	+0.000 —0.007	0.003	—0.000 +0.007	—0.000 +0.004	—0.000 +0.004	60
44–56	+0.000 —0.003	+0.000 —0.003	+0.000 —0.005	0.002	—0.000 +0.005	—0.000 +0.003	—0.000 +0.003	59
64–80	+0.000 —0.002	+0.000 —0.002	+0.000 —0.003	0.001	—0.000 +0.003	—0.000 +0.002	—0.000 +0.002	63

SCREW AND NUT TOLERANCES FOR LOOSE FITS

Thds. per Inch	Tolerances on Screws			Neutral Space between Max. Screw and Min. Nut	Tolerances on Nuts			Minimum per Cent Strength (Approx.)
	D Full Diam.	*E* Effect. Diam.	*K* Core Diam.		*D′* Full Diam.	*E′* Effect. Diam.	*K′* Core Diam.	
4–6	+0.000 —0.030	+0.000 —0.030	+0.000 —0.045	0.008	—0.000 +0.045	—0.000 +0.030	—0.000 +0.030	61
7–10	+0.000 —0.020	+0.000 —0.020	+0.000 —0.030	0.006	—0.000 +0.030	—0.000 +0.020	—0.000 +0.020	56
11–18	+0.000 —0.012	+0.000 —0.012	+0.000 —0.018	0.005	—0.000 +0.018	—0.000 +0.012	—0.000 +0.012	51
20–28	+0.000 —0.008	+0.000 —0.008	+0.000 —0.012	0.004	—0.000 +0.012	—0.000 +0.008	—0.000 +0.008	48
30–40	+0.000 —0.006	+0.000 —0.006	+0.000 —0.008	0.003	—0.000 +0.008	—0.000 +0.006	—0.000 +0.006	45
44–56	+0.000 —0.004	+0.000 —0.004	+0.000 —0.006	0.002	—0.000 +0.006	—0.000 +0.004	—0.000 +0.004	48
64–80	+0.000 —0.003	+0.000 —0.003	+0.000 —0.004	0.001	—0.000 +0.004	—0.000 +0.003	—0.000 +0.003	47

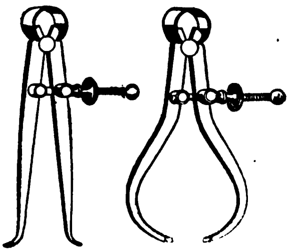
Tables refer to illustrations on page 153

STARRETT TOOLS FOR USE IN CONNECTION WITH THREADS AND SCREWS



Screw Thread Micrometer Calipers

In Starrett Screw Thread Micrometers, the movable spindle is pointed and the end of the anvil is of the same form as the thread to be measured. The reading of the caliper indicates the pitch diameter or the full size of the thread, less the depth of one thread. Made in one and two inch capacities, with a range of from 8 to 30 threads and in V, U. S., and Whitworth standards. Also furnished in corresponding Metric sizes.

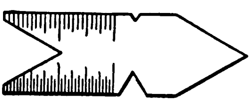


Inside and Outside Thread Calipers

These calipers are designed for measuring diameters at the bottom of threads. Made with spring or solid nut, hardened points, and fulcrum stud and extra strong bow.

Positive Stop Thread Gages

Gage has positive stop which holds blade in fixed and convenient position for use. 30 pitches from 6 to 60 inclusive, the number of the pitches being stamped on the right side of each blade. Made in V and Whitworth standards.



Center Gages

Graduated one corner each in 32ds, 24ths, and 20ths. Angles are 60°, except the Whitworth standard, where they are 55°.

A Center Gage Attachment may be had which by means of a flat spring frictionally holds the center gage parallel with the V block of the attachment, permitting a threading tool to be adjusted to line to cut both sides of the thread to the proper angle.

For further information concerning these and other tools which may be used to advantage in connection with Threads and Screws, see pages 18 and 93 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

CUTTING SPEEDS AND FEEDS FOR TURNING TOOLS

Tools of a good grade of high speed steel, properly ground and heat-treated

Steel — Standard 7/8 inch Tool

Depth of Cut in inches	Feed in inches	Speed in Feet per Minute for a Tool which is to last 1½ Hours before Regrinding: Soft Steel	Medium Steel	Hard Steel
3/32	1/64	476	238	108
	1/32	325	162	73.8
	1/16	222	111	50.4
	3/32	177	88.4	40.2
1/8	1/64	420	210	95.5
	1/32	286	143	65.0
	1/16	195	97.6	44.4
	1/8	133	66.4	30.2
3/16	1/64	352	176	80.0
	1/32	240	120	54.5
	1/16	164	82	37.3
	1/8	112	56	25.5
1/4	1/64	312	156	70.9
	1/32	213	107	48.4
	1/16	145	72.6	33.0
	3/32	116	58.1	26.4
3/8	1/64	264	132	60.0
	1/32	180	90.2	41.0
	1/16	122	61.1	27.8
1/2	1/64	237	118	53.8
	1/32	162	80.8	36.7

Cast Iron — Standard 7/8 inch Tool

Depth of Cut in inches	Feed in inches	Speed in Feet per Minute for a Tool which is to last 1½ Hours before Regrinding: Soft Cast Iron	Medium Cast Iron	Hard Cast Iron
3/32	1/16	122	61.2	35.7
	1/8	86.4	43.2	25.2
	3/16	70.1	35 1	20.5
1/8	1/32	156	77.8	45.4
	1/16	112	56.2	32.8
	1/8	79.3	39.7	23.2
	3/16	64.3	32.2	18.8
3/16	1/32	137	68.6	40.1
	1/16	99.4	49.7	29.0
	1/8	70.1	35.0	20.5
	3/16	56.8	28.4	16.6
1/4	1/32	126	62.9	36.7
	1/16	90.8	45.4	26.5
	1/8	64.1	32.0	18.7
	3/16	52	26.0	15.2
3/8	1/32	111	55.4	32.3
	1/16	80	40.0	23.4
	1/8	56.4	28.2	16.5
1/2	1/32	104	52.1	30.4
	1/16	75.2	37.6	22.0
	1/8	43.1	21.6	12.6

Steel — Standard 5/8 inch Tool

Depth of Cut	Feed	Soft Steel	Medium Steel	Hard Steel
1/16	1/64	548	274	125
	1/32	358	179	81.6
	1/16	235	117	53.3
3/32	1/64	467	234	106
	1/32	306	153	69.5
	1/16	200	100	45.5
	3/32	156	78	35.5
1/8	1/64	417	209	94.8
	1/32	273	136	62.0
	1/16	179	89.3	40.6
	3/32	140	69.8	31.7
3/16	1/64	362	181	82.2
	1/32	236	118	53.8
	1/16	155	77.4	35.2
1/4	1/64	328	164	74.5
	1/32	215	107	48.8
3/8	1/64	286	143	65.0

Cast Iron—Standard 5/8 inch Tool

Depth of Cut	Feed	Soft Cast Iron	Medium Cast Iron	Hard Cast Iron
3/32	1/32	160	80.0	46.6
	1/16	110	55.0	32.2
	1/8	75.4	37.7	22.0
1/8	1/32	148	74.0	43.3
	1/16	104	51.8	32.0
	1/8	69.6	34.8	20.3
3/16	1/64	183	91.6	68.0
	1/32	135	67.5	39.4
	1/16	94	47.0	27.4
	1/8	64.3	32.2	18.8
1/4	1/64	171	85.7	50.1
	1/32	126	63.2	36.9
	1/16	87.8	43.9	25.6
	3/32	70.4	35.2	20.6
3/8	1/64	156	77.8	45.4
	1/32	116	57.8	33.8
	1/16	79.7	39.9	23.3

From "Machinery's" Handbook, The Industrial Press, New York

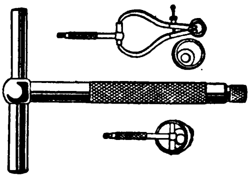
TIME REQUIRED FOR CUTTING TOOL TO TRAVEL 1 INCH, WHEN THE FEED IS $\frac{1}{32}$ INCH PER REVOLUTION

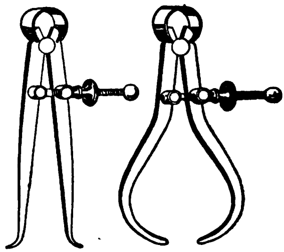
Dia. Ins.	Surface Speeds in Feet per Minute															
	20 Feet		25 Feet		30 Feet		35 Feet		40 Feet		45 Feet		50 Feet		60 Feet	
	min.	sec.	min.	sec.	min.	sec.	min.	sec.	min.	sec.	min.	sec.	min.	sec.	min.	sec.
1	0	25	0	20	0	17	0	14	0	12	0	11	0	10	0	8
2	0	50	0	40	0	33	0	29	0	25	0	22	0	20	0	17
3	1	15	1	0	0	50	0	43	0	38	0	33	0	30	0	25
4	1	40	1	20	1	7	0	57	0	50	0	45	0	40	0	33
5	2	6	1	41	1	24	1	12	1	3	0	56	0	50	0	42
6	2	31	2	1	1	41	1	26	1	15	1	7	1	0	0	50
7	2	56	2	21	1	57	1	41	1	28	1	18	1	10	0	58
8	3	21	2	41	2	14	1	35	1	40	1	29	1	20	1	7
9	3	46	3	1	2	31	2	9	1	53	1	41	1	30	1	15
10	4	11	3	21	2	48	2	24	2	6	1	52	1	41	1	24
11	4	36	3	41	3	4	2	38	2	18	2	3	1	51	1	32
12	5	2	4	1	3	21	2	52	2	31	2	14	2	1	1	41
13	5	27	4	21	3	38	3	7	2	43	2	25	2	11	1	49
14	5	52	4	41	3	55	3	21	2	56	2	36	2	21	1	57
15	6	17	5	2	4	11	3	35	3	8	2	48	2	31	2	6
16	6	42	5	22	4	28	3	50	3	21	2	59	2	41	2	14
17	7	7	5	42	4	45	4	4	3	34	3	10	2	51	2	22
18	7	32	6	2	5	2	4	18	3	46	3	21	3	1	2	31
19	7	57	6	22	5	18	4	33	3	59	3	32	3	11	2	39
20	8	22	6	42	5	35	4	47	4	11	3	43	3	21	2	48
21	8	48	7	2	5	52	5	2	4	24	3	55	3	31	2	56
22	9	13	7	22	6	9	5	16	4	36	4	6	3	41	3	4
23	9	38	7	42	6	25	5	30	4	49	4	17	3	51	3	12
24	10	3	8	3	6	42	5	45	5	2	4	28	4	1	3	21
25	10	28	8	23	6	59	5	59	5	15	4	39	4	11	3	30
26	10	53	8	43	7	16	6	13	5	27	4	50	4	21	3	38
27	11	19	9	3	7	32	6	28	5	39	5	2	4	31	3	46
28	11	44	9	23	7	49	6	42	5	52	5	13	4	41	3	55
29	12	9	9	43	8	6	6	56	6	4	5	24	4	51	4	3
30	12	34	10	3	8	23	7	11	6	17	5	35	5	2	4	11
31	12	59	10	23	8	39	7	25	6	30	5	46	5	12	4	19
32	13	24	10	43	8	56	7	40	6	42	5	57	5	22	4	28
33	13	49	11	3	9	13	7	54	6	55	6	9	5	32	4	36
34	14	15	11	24	9	30	8	8	7	7	6	20	5	42	4	45
35	14	40	11	44	9	46	8	23	7	20	6	31	5	52	4	53
36	15	5	12	4	10	3	8	37	7	32	6	42	6	2	5	2
37	15	30	12	24	10	20	8	51	7	45	6	53	6	12	5	10
38	15	55	12	44	10	37	9	6	7	57	7	4	6	22	5	18
39	16	20	13	4	10	53	9	20	8	10	7	16	6	32	5	27
40	16	45	13	24	11	11	9	34	8	22	7	27	6	42	5	35

STARRETT TOOLS FOR USE IN CONNECTION WITH TURNING AND BORING

Telescoping Inside Gages

The ends of the telescope head are hardened and are made on a radius of the smallest hole the head will enter. A knurled screw in the end of the handle locks the head when compressed for insertion and when expanded across the hole to a fit. Made to enter holes from ½ inch to 6 inches.



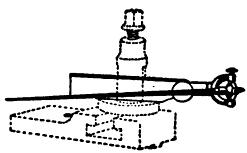


Yankee Outside and Inside Calipers

Made with either solid or quick adjusting nut. The bow is stiff, making the caliper reliable. Ranging sizes from 2½ to 12 inches.

Center Tester

The indicating needle is adjustable to any length. The ball, which holds the needle as a chuck, forms a universal joint, but may be converted to a single joint for tilting motion by tightening the knurled nut, adapting it for inside or outside surface contact. The instrument is joined to a tool post shank by a flexible steel ribbon.



For further information concerning these and other tools which may be used to advantage in connection with Turning and Boring, see pages 13, 18, 40, 75, 93, 98, and 122 of this volume; also Vol. I of The Starrett Books, and the Starrett Catalogue.

RULES RELATIVE TO THE CIRCLE, ETC.

To Find Circumference
Multiply diameter by 3.1416.
Or divide " " 0.3183.

To Find Diameter
Multiply circumference by 0.3183.
Or divide " " 3.1416.

To Find Radius
Multiply circumference by 0.15915.
Or divide " " 6.28318.

To Find Side of an Inscribed Square
Multiply diameter by 0.7071.
Or multiply circumference by 0.2251.
Or divide " " 4.4428.

To Find Side of an Equal Square
Multiply diameter by 0.8862.
Or divide " " 1.1284.
Or multiply circumference by 0.2821.
Or divide " " 3.545.

SQUARE
A side multiplied by 1.4142 equals diameter of its circumscribing circle.
A side multiplied by 4.443 equals circumference of its circumscribing circle.
A side multiplied by 1.128 equals diameter of an equal circle.
A side multiplied by 3.547 equals circumference of an equal circle.
Square inches multiplied by 1.273 equal circle inches of an equal circle.

To Find the Area of a Circle
Multiply circumference by one quarter of the diameter.
Or multiply the square of diameter by 0.7854.
Or multiply the square of circumference by .07958.
Or multiply the square of one half the diameter by 3.1416.

To Find the Surface of a Sphere or Globe
Multiply the diameter by the circumference.
Or multiply the square of diameter by 3.1416.
Or multiply four times the square of radius by 3.1416.

To Find the Weight of Brass and Copper Sheets, Rods, and Bars
Ascertain the number of cubic inches in piece and multiply same by weight per cubic inch.

Brass, 0.2972. Copper, 0.3212.

Or multiply the length by the breadth (in feet) and product by weight in pounds per square foot.

EQUIVALENTS OF VARIOUS MEASURES AND WEIGHTS

	U. S. Gallon	Imperial Gallon	Cubic Inch	Cubic Foot	Pound	Cwt.	Ton	Liter	Cubic Meter
U. S. Gal.	1.	.83	231.	.133	8.33	.0746	.0037	3.8	.0038
Imp'l Gal.	1.2	1.	277.274	.16	10.	.0892	.0045	4.537	.0045
Cubic In.	.0043	.0036	1.	.0006	.0361	....	....	.0163	......
Cubic Ft.	7.48	6.23	1728.	1.	62.35	.557	.028	28.375	.0283
Pound ..	.083	.10	27.72	.016	1.	112.	2240.	....	......
Cwt.....	13.44	11.2	....	1.8	......	1.	20.	....	......
Ton	268.8	224.	....	35.9	......	.05	1.	1000.	1.
Liter	.264	.22	61.	.0353	......	....	.001	1.	.001
Cu. Meter	264.	220.	61028.	35.31	......	....	1.	1000.	1.

THE METRIC SYSTEM OF MEASUREMENT

Measures of Length

1 Millimeter (mm.) =...................... 0.03937079 inch, or about $\frac{1}{25}$ inch

10 Millimeters = 1 Centimeter (cm.) =........................0.3937079 "

10 Centimeters = 1 Decimeter (dm.) =........................3.937079 "

10 Decimeters = 1 Meter (m.) = 39.37079 inches, 3.2808992 feet, or 1.09361 yards

10 Meters = 1 Decameter (Dm.) = ...32.808992 feet

10 Decameters = 1 Hectometer (Hm.) =......................19.927817 rods

10 Hectometers = 1 Kilometer (Km.) =....... 1093.61 yards, or 0.6213824 mile

10 Kilometers = 1 Myriameter (Mm.) =......................6.213824 miles

1 inch = 2.54 cm., 1 foot = 0.3048 m., 1 yard = 0.9144 m., 1 rod = 0.5029 dm., 1 mile = 1.6093 km.

Measures of Weight

1 Gramme (g.) = 15.4324874 gr. troy, or 0.03215 oz. troy, or 0.03527398 oz. avoir.

10 Grammes = 1 Decagramme (Dg.) =..................0.3527398 " "

10 Decagrammes = 1 Hectogramme (Hg.) = ...3.527398 " "

10 Hectogrammes = 1 Kilogramme (Kg.) =.................. 2.20462125 lbs.

1,000 Kilogrammes = 1 Tonne (T.) = 2204.62125 lbs., or 1.1023 tons of 2,000 lbs., or 0.9842 ton of 2,240 lbs., or 19.68 cwts.

1 grain = 0.0648 g., 1 oz. avoir. = 28.35 g., 1 lb. = 0.4536 Kg., 1 ton 2,000 lbs. = 0.9072 T., 1 ton 2,240 lbs. = 1.016 T., or 1,016 Kg.

Measures of Capacity

1 Liter (l.) = 1 Cubic Decimeter = 61.0270515 cubic in., or 0.03531 cu. ft., or 1.0567 liquid qts., or 0.908 dry qt., or 0.26417 Amer. gal.

10 Liters = 1 Decaliter (Dl.). = 2.6417 gal., or 1.135 pk.

10 Decaliters = 1 Hectoliter (Hl.) = 2.8375 bu.

10 Hectoliters = 1 Kiloliter (Kl.) = 61027.0515 cu. in., or 28.375 bu.

1 cu. foot = 28.317 l., 1 gallon, Amer. = 3.785 l., 1 gallon Brit. = 4.543 l.

TABLE OF DECIMAL EQUIVALENTS

OF MILLIMETERS AND FRACTIONS OF MILLIMETERS

$\frac{1}{100}$ mm. = .0003937 inch

mm.	inches	mm.	inches	mm.	inches
1/50	.00079	26/50	.02047	2	.07874
2/50	.00157	27/50	.02126	3	.11811
3/50	.00236	28/50	.02205	4	.15748
4/50	.00315	29/50	.02283	5	.19685
5/50	.00394	30/50	.02362	6	.23622
6/50	.00472	31/50	.02441	7	.27559
7/50	.00551	32/50	.02520	8	.31496
8/50	.00630	33/50	.02598	9	.35433
9/50	.00709	34/50	.02677	10	.39370
10/50	.00787	35/50	.02756	11	.43307
11/50	.00866	36/50	.02835	12	.47244
12/50	.00945	37/50	.02913	13	.51181
13/50	.01024	38/50	.02992	14	.55118
14/50	.01102	39/50	.03071	15	.59055
15/50	.01181	40/50	.03150	16	.62992
16/50	.01260	41/50	.03228	17	.66929
17/50	.01339	42/50	.03307	18	.70866
18/50	.01417	43/50	.03386	19	.74803
19/50	.01496	44/50	.03465	20	.78740
20/50	.01575	45/50	.03543	21	.82677
21/50	.01654	46/50	.03622	22	.86614
22/50	.01732	47/50	.03701	23	.90551
23/50	.01811	48/50	.03780	24	.94488
24/50	.01890	49/50	.03858	25	.98425
25/50	.01969	1	.03937	26	1.02362

10 mm. = 1 centimeter = 0.3937 inch
10 cm. = 1 decimeter = 3.937 inches
10 dm. = 1 meter = 39.37 inches
25.4 mm. = 1 English inch

METRIC CONVERSION TABLE

The following metric conversion table has been compiled by C. W. Hunt, and is most convenient in dealing with metric weights and measures:

Millimeters × 0.03937	= inches
Millimeters ÷ 25.4	= inches
Centimeters × 0.3937	= inches
Centimeters ÷ 2.54	= inches
Meters × 39.37	= inches (Act of Congress)
Meters × 3.281	= feet
Meters × 1.094	= yards
Kilometers × 0.621	= miles
Kilometers ÷ 1.6093	= miles
Kilometers × 3280.7	= feet
Square millimeters × 0.0155	= square inches
Square millimeters ÷ 645.1	= square inches
Square centimeters × 0.155	= square inches
Square centimeters ÷ 6.451	= square inches
Square meters × 10.764	= square feet
Square kilometers × 247.1	= acres
Hectares × 2.471	= acres
Cubic centimeters ÷ 16.383	= cubic inches
Cubic centimeters ÷ 3.69	= fluid drachms (U.S. Pharmacopœia)
Cubic centimeters ÷ 29.57	= fluid ounce (U.S. Pharmacopœia)
Cubic meters × 35.315	= cubic feet
Cubic meters × 1.308	= cubic yards
Cubic meters × 264.2	= gallons (231 cubic inches)
Liters × 61.022	= cubic inches (Act of Congress)
Liters × 33.84	= fluid ounces (U.S. Pharmacopœia).
Liters × 0.2642	= gallons (231 cubic inches)
Liters ÷ 3.78	= gallons (231 cubic inches)
Liters ÷ 28.316	= cubic feet
Hectoliters × 3.531	= cubic feet
Hectoliters × 2.84	= bushels (2,150.42 cubic inches)
Hectoliters × 0.131	= cubic yards
Hectoliters × 26.42	= gallons (231 cubic inches)
Grams × 15.432	= grains (Act of Congress)
Grams × 981	= dynes
Grams (water) ÷ 29.57	= fluid ounces
Grams ÷ 28.35	= ounces avoirdupois
Grams per cubic centimeter ÷ 27.7	= pounds per cubic inch
Joule × 0.7373	= foot-pounds
Kilograms × 2.2046	= pounds
Kilograms × 35.3	= ounces avoirdupois
Kilograms ÷ 1102.3	= tons (2,000 pounds)
Kilograms per sq. cm. × 14.223	= pounds per square inch
Kilogrammeters × 7.233	= foot-pounds
Kilograms per meter × 0.672	= pounds per square foot
Kilograms per cubic meter × 0.062	= pounds per cubic foot
Kilograms per cheval-vapeur × 2.235	= pounds per horsepower
Kilowatts × 1.34	= horsepower
Watts ÷ 746	= horsepower
Watts × 0.7373	= foot-pounds per second
Calorie × 3.968	= British thermal units (B. T. U.)
Cheval-vapeur × 0.9863	= horsepower
(Centigrade × 1.8) + 32	= degrees Fahrenheit
Francs × 0.193	= dollars
Gravity, Paris	= 980.94 centimeter per second

TABLES OF DECIMAL EQUIVALENTS

Of 8ths, 16ths, 32ds, and 64ths of an inch

8ths.	$\frac{9}{16}$ = .5625	$\frac{17}{32}$ = .53125	$\frac{9}{64}$ = .140625	$\frac{37}{64}$ = .578125
$\frac{1}{8}$ = .125	$\frac{11}{16}$ = .6875	$\frac{19}{32}$ = .59375	$\frac{11}{64}$ = .171875	$\frac{39}{64}$ = .609375
$\frac{1}{4}$ = .250	$\frac{13}{16}$ = .8125	$\frac{21}{32}$ = .65625	$\frac{13}{64}$ = .203125	$\frac{41}{64}$ = .640625
$\frac{3}{8}$ = .375	$\frac{15}{16}$ = .9375	$\frac{23}{32}$ = .71875	$\frac{15}{64}$ = .234375	$\frac{43}{64}$ = .671875
$\frac{1}{2}$ = .500		$\frac{25}{32}$ = .78125	$\frac{17}{64}$ = .265625	$\frac{45}{64}$ = .703125
$\frac{5}{8}$ = .625	**32ds.**	$\frac{27}{32}$ = .84375	$\frac{19}{64}$ = .296875	$\frac{47}{64}$ = .734375
$\frac{3}{4}$ = .750	$\frac{1}{32}$ = .03125	$\frac{29}{32}$ = .90625	$\frac{21}{64}$ = .328125	$\frac{49}{64}$ = .765625
$\frac{7}{8}$ = .875	$\frac{3}{32}$ = .09375	$\frac{31}{32}$ = .96875	$\frac{23}{64}$ = .359375	$\frac{51}{64}$ = .796875
	$\frac{5}{32}$ = .15625		$\frac{25}{64}$ = .390625	$\frac{53}{64}$ = .828125
16ths.	$\frac{7}{32}$ = .21875	**64ths.**	$\frac{27}{64}$ = .421875	$\frac{55}{64}$ = .859375
$\frac{1}{16}$ = .0625	$\frac{9}{32}$ = .28125	$\frac{1}{64}$ = .015625	$\frac{29}{64}$ = .453125	$\frac{57}{64}$ = .890625
$\frac{3}{16}$ = .1875	$\frac{11}{32}$ = .34375	$\frac{3}{64}$ = .046875	$\frac{31}{64}$ = .484375	$\frac{59}{64}$ = .921875
$\frac{5}{16}$ = .3125	$\frac{13}{32}$ = .40625	$\frac{5}{64}$ = .078125	$\frac{33}{64}$ = .515625	$\frac{61}{64}$ = .953125
$\frac{7}{16}$ = .4375	$\frac{15}{32}$ = .46875	$\frac{7}{64}$ = .109375	$\frac{35}{64}$ = .546875	$\frac{63}{64}$ = .984375

Of 6ths, 12ths, and 24ths of an inch*

$\frac{1}{24}$ = .041667	$\frac{3}{12}$ = .25	$\frac{11}{24}$ = .458333	$\frac{2}{3}$ = .666667	$\frac{21}{24}$ = .875
$\frac{1}{12}$ = .083333	$\frac{7}{24}$ = .291667	$\frac{1}{2}$ = .5	$\frac{17}{24}$ = .708333	$\frac{11}{12}$ = .916667
$\frac{3}{24}$ = .125	$\frac{1}{3}$ = .333333	$\frac{13}{24}$ = .541667	$\frac{9}{12}$ = .75	$\frac{23}{24}$ = .958333
$\frac{1}{6}$ = .166667	$\frac{9}{24}$ = .375	$\frac{7}{12}$ = .583333	$\frac{19}{24}$ = .791667	....
$\frac{5}{24}$ = .208333	$\frac{5}{12}$ = .416667	$\frac{15}{24}$ = .625	$\frac{5}{6}$ = .833333	....

Of 7ths, 14ths, and 28ths of an inch*

$\frac{1}{28}$ = .035714	$\frac{7}{28}$ = .25	$\frac{13}{28}$ = .464286	$\frac{19}{28}$ = .678571	$\frac{25}{28}$ = .892857
$\frac{1}{14}$ = .071429	$\frac{2}{7}$ = .285714	$\frac{7}{14}$ = .5	$\frac{5}{7}$ = .714286	$\frac{13}{14}$ = .928571
$\frac{3}{28}$ = .107143	$\frac{9}{28}$ = .321429	$\frac{15}{28}$ = .535714	$\frac{21}{28}$ = .75	$\frac{27}{28}$ = .964286
$\frac{1}{7}$ = .142857	$\frac{5}{14}$ = .357143	$\frac{4}{7}$ = .571429	$\frac{11}{14}$ = .785714	....
$\frac{5}{28}$ = .178571	$\frac{11}{28}$ = .392857	$\frac{17}{28}$ = .607143	$\frac{23}{28}$ = .821429	....
$\frac{3}{14}$ = .214286	$\frac{3}{7}$ = .428571	$\frac{9}{14}$ = .642867	$\frac{6}{7}$ = .857143	....

*From "Machinery's" Handbook, The Industrial Press, New York

WEIGHTS AND MEASURES

Troy Weight

24 grains = 1 pwt. 20 pwts. = 1 ounce 12 ounces = 1 pound

Used for weighing gold, silver, and jewels

Apothecaries' Weight

20 grains = 1 scruple	8 drams = 1 ounce
3 scruples = 1 dram	12 ounces = 1 pound

The ounce and pound in this are the same as in troy weight

Avoirdupois Weight

$27\frac{11}{32}$ grains = 1 dram	4 quarters = 1 cwt.
16 drams = 1 ounce	2,000 pounds = 1 short ton
16 ounces = 1 pound	2,240 pounds = 1 long ton
25 pounds = 1 quarter	

Dry Measure

2 pints = 1 quart	4 pecks = 1 bushel
8 quarts = 1 peck	36 bushels = 1 chaldron

Liquid Measure

4 gills = 1 pint	31½ gallons = 1 barrel
2 pints = 1 quart	2 barrels = 1 hogshead

Measure of Solidity

1,728 cubic inches = 1 cubic foot 27 cubic feet = 1 cubic yard

Time Measure

60 seconds = 1 minute	24 hours = 1 day
60 minutes = 1 hour	7 days = 1 week

28, 29, 30, or 31 days = 1 calendar month (30 days = 1 month in computing interest)

365 days = 1 year 366 days = 1 leap year

Circular Measure

60 seconds = 1 minute	30 degrees = 1 sign
60 minutes = 1 degree	90 degrees = 1 quadrant

4 quadrants = 12 signs, or 360 degrees = 1 circle

Long Measure

12 inches = 1 foot	40 rods = 1 furlong
3 feet = 1 yard	8 furlongs = 1 statute mile
5½ yards = 1 rod	3 miles = 1 league

Cloth Measure

2¼ inches = 1 nail 4 nails = 1 quarter 4 quarters = 1 yard

Mariner's Measure

6 feet = 1 fathom	5,280 feet = 1 statute mile
120 fathoms = 1 cable length	6,085 feet = 1 nautical mile
7½ cable lengths = 1 mile	

Square Measure

144 sq. inches = 1 sq. foot	30¼ sq. yards = 1 sq. rod	4 roods = 1 acre
9 sq. feet = 1 sq. yd.	40 sq. rods = 1 rood	640 acres = 1 sq. mile

Weights

The Gram is the primary unit of weights, in the metric system, and is the weight in a vacuum of a cubic centimeter of distilled water at the temperature of 39.2°F.

10 milligrams (mg.)	= 1 centigram (cg.)	= 0.1543 troy grain
10 centigrams	= 1 decigram (dg.)	= 1.543 troy grains
10 decigrams	= 1 gram (g.)	= 15.432 troy grains
10 grams	= 1 decagram	= 0.3527 avoirdupois ounce
10 decagrams	= 1 hectogram	= 3.5274 avoirdupois ounces
10 hectograms	= 1 kilogram (kg.)	= 2.2046 avoirdupois pounds
10 kilograms	= 1 myriagram	= 22.046 avoirdupois pounds
10 myriagrams	= 1 quintal (q.)	= 220.46 avoirdupois pounds
10 quintals	= 1 tonneau (t.)	= 2204.6 avoirdupois pounds

1 kilogram per kilometer	= 0.67195 pound per thousand feet
1 pound per thousand feet	= 1.4882 kilograms per kilometer
1 kilogram per square millimeter	= 1.423 pounds per square inch
1 pound per square inch	= 0.000743 kilogram per square millimeter

INCHES AND SIXTEENTHS CONVERTED INTO MILLIMETERS

Inches	0	1	2	3	4	5
..	......	25.400	50.799	76.199	101.60	127.00
1/16	1.5875	26.987	52.387	77.786	103.19	128.59
1/8	3.1749	28.574	53.974	79.374	104.77	130.17
3/16	4.7624	30.162	55.561	80.961	106.36	131.76
1/4	6.3499	31.749	57.149	82.549	107.95	133.35
5/16	7.9374	33.337	58.736	84.136	109.54	134.94
3/8	9.5248	34.924	60.324	85.723	111.12	136.52
7/16	11.112	36.512	61.911	87.311	112.71	138.11
1/2	12.700	38.099	63.499	88.898	114.30	139.70
9/16	14.287	39.687	65.086	90.486	115.89	141.28
5/8	15.875	41.274	66.674	92.073	117.47	142.87
11/16	17.462	42.862	68.261	93.661	119.06	144.46
3/4	19.050	44.449	69.849	95.248	120.65	146.05
13/16	20.637	46.037	71.436	96.836	122.24	147.63
7/8	22.225	47.624	73.024	98.423	123.82	149.22
15/16	23.812	49.212	74.611	100.01	125.41	150.81

Inches	6	7	8	9	10	11
..	152.40	177.80	203.20	228.60	254.00	279.39
1/16	153.98	179.38	204.78	230.18	255.58	280.98
1/8	155.57	180.97	206.37	231.77	257.17	282.57
3/16	157.16	182.56	207.96	233.36	258.76	284.16
1/4	158.75	184.15	209.55	234.95	260.35	285.74
5/16	160.33	185.73	211.13	236.53	261.93	287.33
3/8	161.92	187.32	212.72	238.12	263.52	288.92
7/16	163.51	188.91	214.31	239.71	265.11	290.51
1/2	165.10	190.50	215.90	241.30	266.70	292.09
9/16	166.68	192.08	217.48	242.88	268.28	293.68
5/8	168.27	193.67	219.07	244.47	269.87	295.27
11/16	169.86	195.26	220.66	246.06	271.46	296.86
3/4	171.45	196.85	222.25	247.65	273.05	298.44
13/16	173.03	198.43	223.83	249.23	274.63	300.03
7/8	174.62	200.02	225.42	250.82	276.22	301.62
15/16	176.21	201.61	227.01	252.41	277.81	303.21

For meters, move the decimal point THREE figures forward.

EXAMPLE: 8 3/16 inches = 207.96 millimeters = 20.796 centimeters = 2.0796 decimeters = 0.20796 meter.

DECIMAL EQUIVALENTS, SQUARES, SQUARE ROOTS, CUBES, AND CUBE ROOTS OF FRACTIONS; CIRCUMFERENCES AND AREAS OF CIRCLES FROM 1/64 TO 1 INCH

Fraction	Dec. Equiv.	Square	Sq. Root	Cube	Cube Root	Circum. Circle	Area Circle
1/64	.015625	.000244	.1250	.000003815	.2500	.04909	.000192
1/32	.03125	.0009765	.1768	.00003052	.3150	.09818	.000767
3/64	.046875	.002197	.2165	.000103	.3606	.1473	.001726
1/16	.0625	.003906	.2500	.0002442	.3968	.1963	.003068
5/64	.078125	.006104	.2795	.0004768	.4275	.2455	.004794
3/32	.09375	.008789	.3062	.0008240	.4543	.2945	.006903
7/64	.109375	.01196	.3307	.001308	.4782	.3436	.009396
1/8	.1250	.01563	.3535	.001953	.5000	.3927	.01228
9/64	.140625	.01978	.3750	.002781	.5200	.4438	.01553
5/32	.15625	.02441	.3953	.003815	.5386	.4909	.01916
11/64	.171875	.02954	.4161	.005078	.5560	.5400	.02321
3/16	.1875	.03516	.4330	.006592	.5724	.5890	.02761
13/64	.203125	.04126	.4507	.008381	.5878	.6381	.03241
7/32	.21875	.04786	.4677	.01047	.6025	.6872	.03758
15/64	.234375	.05493	.4841	.01287	.6166	.7363	.04314
1/4	.2500	.0625	.5000	.01562	.6300	.7854	.04909
17/64	.265625	.07056	.5154	.01874	.6428	.8345	.05541
9/32	.28125	.07910	.5303	.02225	.6552	.8836	.06213
19/64	.296875	.08813	.5449	.02616	.6671	.9327	.06922
5/16	.3125	.09766	.5590	.03052	.6786	.9817	.07670
21/64	.328125	.1077	.5728	.03533	.6897	1.031	.08456
11/32	.34375	.1182	.5863	.04062	.7005	1.080	.09281
23/64	.359375	.12913	.5995	.04641	.7110	1.129	.1014
3/8	.3750	.1406	.6124	.05273	.7211	1.178	.1104
25/64	.390625	.1526	.6250	.05960	.7310	1.227	.1226
13/32	.40625	.1650	.6374	.06705	.7406	1.276	.1296
27/64	.421875	.17800	.6495	.07508	.7500	1.325	.1398
7/16	.4375	.1914	.6614	.08374	.7592	1.374	.1503
29/64	.453125	.2053	.6732	.09304	.7681	1.424	.1613
15/32	.46875	.2197	.6847	.1030	.7768	1.473	.1726
31/64	.484375	.2346	.6960	.1136	.7853	1.522	.1843
1/2	.5000	.2500	.7071	.1250	.7937	1.571	.1963

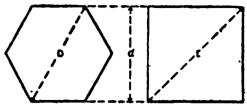
From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

DECIMAL EQUIVALENTS, SQUARES, SQUARE ROOTS, CUBES, AND CUBE ROOTS OF FRACTIONS; CIRCUMFERENCES AND AREAS OF CIRCLES FROM 1/64 TO 1 INCH—(*continued*)

Fraction	Dec. Equiv.	Square	Sq. Root	Cube	Cube Root	Circum. Circle	Area Circle
33/64	.515625	.2659	.7181	.1371	.8019	1.620	.2088
17/32	.53125	.2822	.7289	.1499	.8099	1.669	.2217
35/64	.546875	.2991	.7395	.1636	.8178	1.718	.2349
9/16	.5625	.3164	.7500	.1780	.8255	1.767	.2485
37/64	.578125	.3342	.7603	.1932	.8331	1.816	.2625
19/32	.59375	.3525	.7706	.2093	.8405	1.865	.2769
39/64	.609375	.3713	.7806	.2263	.8478	1.914	.2916
5/8	.6250	.3906	.7906	.2441	.8550	1.963	.3068
41/64	.640625	.4104	.8004	.2629	.8621	2.013	.3223
21/32	.65625	.4307	.8101	.2826	.8690	2.062	.3382
43/64	.671875	.4514	.8197	.3033	.8758	2.111	.3545
11/16	.6875	.4727	.8292	.3250	.8826	2.160	.3712
45/64	.703125	.4944	.8385	.3476	.8892	2.209	.3883
23/32	.71875	.5166	.8478	.3713	.8958	2.258	.4057
47/64	.734375	.5393	.8569	.3961	.9022	2.307	.4236
3/4	.7500	.5625	.8660	.4219	.9086	2.356	.4418
49/64	.765625	.5862	.8750	.4488	.9148	2.405	.4604
25/32	.78125	.6104	.8839	.4768	.9210	2.454	.4794
51/64	.796875	.6350	.8927	.5060	.9271	2.503	.4987
13/16	.8125	.6602	.9014	.5364	.9331	2.553	.5185
53/64	.828125	.6858	.9100	.5679	.9391	2.602	.5386
27/32	.84375	.7119	.9186	.6007	.9449	2.651	.5592
55/64	.859375	.7385	.9270	.6347	.9507	2.700	.5801
7/8	.8750	.7656	.9354	.6699	.9565	2.749	.6013
57/64	.890625	.7932	.9437	.7064	.9621	2.798	.6230
29/32	.90625	.8213	.9520	.7443	.9677	2.847	.6450
59/64	.921875	.8499	.9601	.7835	.9732	2.896	.6675
15/16	.9375	.8789	.9682	.8240	.9787	2.945	.6903
61/64	.953125	.9084	.9763	.8659	.9841	2.994	.7135
31/32	.96875	.9385	.9843	.9091	.9895	3.043	.7371
63/64	.984375	.9690	.9922	.9539	.9948	3.093	.7610
1	1	1	1	1	1	3.1416	.7854

From American Machinists' Handbook by F. N. Colvin and F. A. Stanley, New York. McGraw-Hill Book Company, Inc.

DISTANCE ACROSS CORNERS OF SQUARES AND HEXAGONS



$D = 1.1547\,d$

$E = 1.4142\,d$

d	*D*	*E*	*d*	*D*	*E*	*d*	*D*	*E*
1/4	0.2886	0.3535	1 1/4	1.4434	1.7677	2 5/16	2.6702	3.2703
9/32	0.3247	0.3977	1 9/32	1.4794	1.8119	2 3/8	2.7424	3.3587
5/16	0.3608	0.4419	1 5/16	1.5155	1.8561	2 7/16	2.8145	3.4471
11/32	0.3968	0.4861	1 11/32	1.5516	1.9003	2 1/2	2.8867	3.5355
3/8	0.4329	0.5303	1 3/8	1.5877	1.9445	2 9/16	2.9589	3.6239
13/32	0.4690	0.5745	1 13/32	1.6238	1.9887	2 5/8	3.0311	3.7123
7/16	0.5051	0.6187	1 7/16	1.6598	2.0329	2 11/16	3.1032	3.8007
15/32	0.5412	0.6629	1 15/32	1.6959	2.0771	2 3/4	3.1754	3.8891
1/2	0.5773	0.7071	1 1/2	1.7320	2.1213	2 13/16	3.2476	3.9794
17/32	0.6133	0.7513	1 17/32	1.7681	2.1655	2 7/8	3.3197	4.0658
9/16	0.6494	0.7955	1 9/16	1.8042	2.2097	2 15/16	3.3919	4.1542
19/32	0.6855	0.8397	1 19/32	1.8403	2.2539	3	3.4641	4.2426
5/8	0.7216	0.8839	1 5/8	1.8764	2.2981	3 1/16	3.5362	4.3310
21/32	0.7576	0.9281	1 21/32	1.9124	2.3423	3 1/8	3.6084	4.4194
11/16	0.7937	0.9723	1 11/16	1.9485	2.3865	3 3/16	3.6806	4.5078
23/32	0.8298	1.0164	1 23/32	1.9846	2.4306	3 1/4	3.7527	4.5962
3/4	0.8659	1.0606	1 3/4	2.0207	2.4708	3 5/16	3.8249	4.6846
25/32	0.9020	1.1048	1 25/32	2.0568	2.5190	3 3/8	3.8971	4.7729
13/16	0.9380	1.1490	1 13/16	2.0929	2.5632	3 7/16	3.9692	4.8613
27/32	0.9741	1.1932	1 27/32	2.1289	2.6074	3 1/2	4.0414	4.9497
7/8	1.0102	1.2374	1 7/8	2.1650	2.6516	3 9/16	4.1136	5.0381
29/32	1.0463	1.2816	1 29/32	2.2011	2.6958	3 5/8	4.1857	5.1265
15/16	1.0824	1.3258	1 15/16	2.2372	2.7400	3 11/16	4.2579	5.2149
31/32	1.1184	1.3700	1 31/32	2.2733	2.7842	3 3/4	4.3301	5.3033
1	1.1547	1.4142	2	2.3094	2.8284	3 13/16	4.4023	5.3917
1 1/32	1.1907	1.4584	2 1/32	2.3453	2.8726	3 7/8	4.4744	5.4801
1 1/16	1.2268	1.5026	2 1/16	2.3815	2.9168	3 15/16	4.5466	5.5684
1 3/32	1.2629	1.5468	2 3/32	2.4176	2.9610	4	4.6188	5.6568
1 1/8	1.2990	1.5910	2 1/8	2.4537	3.0052	4 1/8	4.7631	5.8336
1 5/32	1.3351	1.6352	2 5/32	2.4898	3.0494	4 1/4	4.9047	6.0104
1 3/16	1.3712	1.6793	2 3/16	2.5259	3.0936	4 3/8	5.0518	6.1872
1 7/32	1.4073	1.7235	2 1/4	2.5981	3.1820	4 1/2	5.1961	6.3639

HANDY EQUIVALENT TABLES

Made from Spring Steel

Ready Reference tables that are accurate, can be carried in pocket or used around bench. Do not soil and will wear well.

Decimal Equivalents

NO. 589

THE L.S.STARRETT CO.
ATHOL.MASS.U.S.A.

DECIMAL EQUIVALENTS

Fraction	Decimal
1/64	.015625
1/32	.03125
3/64	.046875
1/16	.0625
5/64	.078125
3/32	.09375
7/64	.109375
1/8	.125
9/64	.140625
5/32	.15625
11/64	.171875
3/16	.1875
13/64	.203125
7/32	.21875
15/64	.234375
1/4	.25
17/64	.265625
9/32	.28125
19/64	.296875
5/16	.3125
21/64	.328125
11/32	.34375
23/64	.359375
3/8	.375
25/64	.390625
13/32	.40625
27/64	.421875
7/16	.4375
29/64	.453125
15/32	.46875
31/64	.484375
1/2	.5
33/64	.515625
17/32	.53125
35/64	.546875
9/16	.5625
37/64	.578125
19/32	.59375
39/64	.609375
5/8	.625
41/64	.640625
21/32	.65625
43/64	.671875
11/16	.6875
45/64	.703125
23/32	.71875
47/64	.734375
3/4	.75
49/64	.765625
25/32	.78125
51/64	.796875
13/16	.8125
53/64	.828125
27/32	.84375
55/64	.859375
7/8	.875
57/64	.890625
29/32	.90625
59/64	.921875
15/16	.9375
61/64	.953125
31/32	.96875
63/64	.984375

Tap Drills For Machine Screws

NO. 590

THE L.S.STARRETT CO
ATHOL.MASS U.S.A.

TAP DRILLS FOR MACHINE SCREW TAPS

TAP	DRL.	SIZE	O.S.D.	SIZE
2-48	50	.070	44	.086
2-56	49	.073	44	.086
2-64	48	.076	44	.086
3-40	47	.0785	39	.0995
3-48	45	.082	39	.0995
3-56	44	.086	39	.0895
4-32	43	.089	33	.113
4-36	42	.0935	33	.113
4-40	41	.096	33	.113
5-30	40	.098	30	.1285
5-32	40	.098	30	.1285
5-36	38	.1015	30	.1285
5-40	37	.104	30	.1235
6-30	35	.110	28	.1405
6-32	35	.110	28	.1405
6-36	33	.113	28	.1405
6-40	32	.116	28	.1405
7-28	32	.116	24	.152
7-30	31	.120	24	.152
7-32	30	.1285	24	.152
8-24	30	.1295	19	.166
8-30	30	.1285	19	.166
8-32	29	.136	19	.166
9-24	29	.136	16	.177
9-28	28	.1405	16	.177
9-30	27	.144	16	.177
9-32	25	.1495	16	.177
10-24	25	.1495	11	.191
10-30	22	.157	11	.191
10-32	21	.159	11	.191
11-24	21	.159	6	.204
11-28	17	.173	6	.204
11-30	17	.173	6	.204
12-20	19	.166	2	.221
12-22	17	.173	2	.221
12-24	17	.173	2	.221
12-28	15	.180	2	.221
13-20	15	.180	A	.234
13-22	15	.180	A	.234
13-24	13	.185	A	.234
14-20	13	.185	D	.246
14-22	11	.191	D	.246
14-24	9	.196	D	.246
15-18	10	.1935	F	.257
15-20	8	.199	F	.257
15-27	6	.204	F	.257
15-24	5	.2055	F	.257
16-16	7	.201	I	.272
16-18	6	.204	I	.272
16-20	5	.2055	I	.272
17-16	6	.204	L	.290
17-18	2	.221	L	.290
17-20	2	.221	L	.290
16-16	2	.221	N	.302
18-10	1	.228	N	.302
18-20	8	238	N	.302

FOR STEEL WORK USE TAP DRILLS ONE OR TWO SIZES LARGER THAN LIST

Drill Size Tables

NO. 591

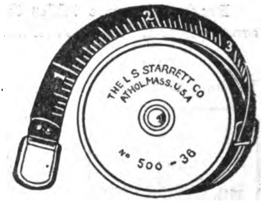
THE L.S.STARRETT CO.
ATHOL, MASS. U.S.A.

DRILL SIZE TABLE

LETTER SIZES			
A	.234	N	.302
B	.238	O	.316
C	.242	P	.323
D	.246	Q	.332
E	.250	R	.339
F	.257	S	.348
G	.261	T	.358
H	.266	U	.368
I	.272	V	.377
J	.277	W	.386
K	.281	X	.397
L	.290	Y	.404
M	.295	Z	.413
NUMBER SIZES			
1	.228	41	.096
2	.221	42	.0935
3	.213	43	.089
4	.209	44	.086
5	.2055	45	.082
6	.204	46	.081
7	.201	47	.0785
8	.199	48	.076
9	.196	49	.073
10	.1935	50	.070
11	.191	51	.067
12	.189	52	.0635
13	.185	53	.0595
14	.182	54	.055
15	.180	55	.052
16	.177	56	.0465
17	.173	57	.043
18	.1695	58	.042
19	.166	59	.041
20	.161	60	.040
21	.159	61	.039
22	.157	62	.038
23	.154	63	.037
24	.152	64	.036
25	.1495	65	.035
26	.147	66	.033
27	.144	67	.032
28	.1405	68	.031
29	.136	69	.0293
30	.1285	70	.028
31	.120	71	.026
32	.116	72	.025
33	.113	73	.024
34	.111	74	.0225
35	.110	75	.021
36	.1065	76	.020
37	.104	77	.018
38	.1015	78	.016
39	.0995	79	.0145
40	.098	80	.0135

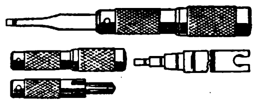
STARRETT POCKET TOOLS

Pocket Steel Tape



Tape is ¼ inch wide, in well-finished nickel-plated case with rounded edges. Spring wind with center stop. Graduated in inches and sixteenths. Quick reading. Also made graduated in inches and sixteenths on one side; feet, tenths, and hundredths on the other.

Magazine Screwdriver

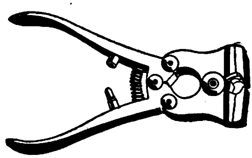


Blades are $\frac{3}{32}$, $\frac{5}{32}$, ¼ and ⅜ in. Carried in handle. When in use blade locks automatically. Steel throughout. Knurled grip.

Pocket Scriber

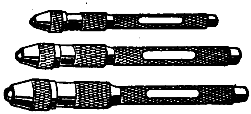
Made from steel tubing, knurled and nickel plated. Scriber is made from best steel, nicely tempered, held by knurled chuck. Reversible. Telescopes into stock and is held there by a turn of the chuck.

Adjustable Jaw Cut Nippers



Jaws are detachable so that they can be removed, ground, and adjusted. Head and handle are of drop-forged steel. All parts, except jaws, are case hardened.

Pin Vises



Have hardened jaws with chucks that will hold firmly anything inserted in them. The hole extends through the full length of the handle. Knurled and nickeled.

For further information concerning these and other convenient pocket tools see Vol. I of The Starrett Books, and the Starrett Catalogue.

INDEX

For Additional Machinists' Data see Starrett Book for Machinists' Apprentices, Volume I of The Starrett Books

INDEX

DIGEST OF CONTENTS OF

THE STARRETT BOOK

FOR MACHINISTS' APPRENTICES

Vol. I of The Starrett Books

INDEX