

**APPENDIX A
NOMINAL MACHINING FEEDS AND SPEEDS**

TABLES 1 thru 10 give nominal speeds and feeds for machining various materials. The following charts list the materials used in each table.

1300, . . . 9850, but with sulfur added
Leaded (Free-cutting) Low Alloy Steels
41L30,41L40,41L50,43L47,51L32,
86L20,86L40,52L100

TABLE 1. MACHINING CARBON & LOW ALLOY STEELS

1. Low Carbon Steels
1006,1008-1010,1012,1015-1026
Medium & High Carbon Steels
1027,1030,1033-1050,1052,1055,1060,
1062,1064-1066,1070,1074,1078,1080,
1084-1086,1090,1095
Low Alloy Steels, Medium & High Carbon
1330,1332,1335,1340,1345,2330,2335,
2340,2345,3130,3135,3140,3141,3145,
3150,4030,4032,4037,4042,4047,4063,
4130,4135,4137,4140,4142,4145,4147,
4150,4337,4340,4640,50B40,50B44,
5046,50B46,50B50,50B60,5075,5080,
5130,5132,5135,5140,5145,5147,5150,
5155,5160,51B60,50100,51100,52100,
6145,6150,6180,6240,6250,6260,6270,
6290,6342,6382,6440,6475,81B45,8630,
8637,8640,8642,8645,86B45,8650,8655,
8660,8740,8742,9255,9260,9262,94B30,
94B40,9445,9840,9845,9850
Low Alloy Carburizing Steels
1320,2317,2512,2515,2517,3115,3120,
3125,3310,3316,4012,4017,4023,4024,
4027,4028,4118,4125,4128,4317,4320,
4608,4615,4617,4620,4621,4720,4815,
4817,4820,5015,5020,5024,5120,6118,
6120,6317,6325,6415,8115,8615,8617,
8620,8622,8625,8627,8720,8822,9310,
9315,94B15,94B17
2. Low Alloy Nitriding Steels
7140
3. Resulturized (Free-cutting) Low Carbon Steels
1111,1112,1113,1119,1212,1213,1213+Te,
1108,1109,1115,1117,1118,1120,1126,
1144,1211
Leaded (Free-cutting) Low Carbon Steel
10L18,10L20,12L13,12L14
4. Resulturized (Free-cutting) Medium-Carbon Steel
1132,1137,1138,1139,1140,1141,1145,
1146,1151,
Resulturized (Free-cutting) Low Alloy Steels

TABLE 2. MACHINING CAST IRON

- Gray Irons
1. Class 20 & 25
 2. Class 30
 3. Class 35 & 40
 4. Class 45 & 50
 5. Class 55 & 60
- Nodular Irons
6. 60-48-18,65-45-12
 7. 80-55-06
 8. 100-70-03
 9. 120-90-02
- Malleable Irons
10. 32510,35018
 11. 45007,45010,48004,50007
 12. 53004,60003
 13. 80002

TABLE 3. MACHINING TOOL STEEL

- W. Water Hardening Tool Steels
W1,W2,W3,W4,
- S. Shock-Resisting Tool Steel
S1
- O. Oil-Hardening Cold Work Tool Steels
O1,O2,O6,O7
- A. Medium-Alloy Air Hardening Cold Work Tool Steels
A2,A4-A7
- D. High Carbon, High Chromium Cold Work Tool Steels
D1-D7
1. Chromium Hot Work Tool Steels
H10-H19
 2. Tungsten Hot Work Tool Steels
H20-H25,H41-H43
 3. Molybdenum High Speed Steel & Tungsten High Speed Steel
M1,M2,M6,M10,T1,T2,T6,T7
 4. M3,M4,M7,M30,M33-M36,M41-M44,T4,T5,T8
 5. M15,T15
 - L. Low Alloy Special-Purpose Tool Steels
L1,L2,L3,L6,L7

- F. Carbon Tungsten Special Purpose Tool Steels
F1-F3
- 6. Low Carbon Mold Steels
P1-P6
- 7. P20,P21

TABLE 4. MACHINING STAINLESS STEEL

- 1. Free-Machining Ferritic
430F,430F(Se)
- 2. Free-Machining Martensitic
416,416F
- 3. Free-Machining Austenitic
303,303Se,303FF,347F(Se)
- 4. Ferritic
405,430,434,436,442,443,446,449,502
- 5. Martensitic (410)
403,410,420,501
- 6. Martensitic (431)
414,422,431
- 7. Martensitic (440)
418,440A,440B,440C
- 8. Austenitic (304)
201,202,301,302,304,304L,305,321,
347,348
- 9. Austenitic (316)
302B,309,309S,310,310S,314,316,316L,
317,318,329,330
- 10. Precipitation Hardened
17-4Ph,17-7Ph,PH15-7Mo,AM-350,
AM-355,AM-359
- 11. Cast Free-Machining
CF-16F(303),Cn-7M
- 12. Cast Ferritic & Martensitic
CA-15(410), CA-40(420),CB-30(431)
CC-50(446)
- 13. Cast Austenitic
CF-3(304L),CF-3M(316L),CF-8(304),
CF-8C(347),CF8M(316),CF-12M(316),
CF-20(302),CG-8M(317),CH-20(309),
CK-20(310)

ANN = Annealed, CD = Cold Drawn, Q & T = Quenched and Tempered, HARD = Hardened, N & T = Normalized and Tempered.

TABLE 5. MACHINING HEAT-RESISTING ALLOYS

- 1. Iron-Base Wrought Alloys
16-25-6.19-9DL,A-286, Discaloy, Incoloy 800, Incoloy 801, Incoloy 805,N-155,V-57, W-545
- 2. Nickel-Base Wrought Alloys
Incoloy 901, Inconel 700, Inconel 702, Inconel 718, Inconel 721, Inconel 722, Inconel 751, Inconel X-750, M-252, Nimonic 80, Nimonic 90, Nimonic 95, Rene 41, Rene 62, U-500, U-700 Waspaloy
- 3. Hastelloy B, Hastelloy X, Incoloy 804, Refractaloy 26
- 4. Nickel-Base Casting Alloys
GMR-235, Hastelloy B, Hastelloy C, Alloy 713C, IN-100, MAR-M200, M-252, Nimonic 75, Nimonic 80, Nimonic 90, Nimonic 95, Nomonic 100, U-500, U-700
- 5. Cobalt-Chromium-Nickel Base Wrought Alloys
HS-25,J-1570,J-1650,S-816,V-36
- 6. Cobalt-Chromium-Nickel Base Casting Alloys
HS-6,HS-21,HS-31,HS-36,MAR-M302, MAR-M322,Wr-52
- 7. Heat Resistant Casting Alloys (AC1)
HA,HC,HD,HT,HU,HW,HX,
- 8. HE,HF,HH,HI,HK,HL,HM

ST = Solution Treated, AG = Aged, ANN = Annealed, CD = Cold Drawn, AC = As Cast.

TABLE 6. MACHINING REFRACTORY METALS

- 1. Colmbium Alloy 752,D-31,D-43
- 2. Tantalum-10W
- 3. Molybdenum-.05Ti,TZM,Mo-30W,TZC
- 4. Tungsten (85%)
- 5. Tungsten (95%)
- 6. Tungsten (W-2Th)
- 7. Tungsten (W-15Mo)
- 8. Tungsten (W-10Ag)

AC=As Cast, PS=Pressed and Sintered, SR=Stress Relieved.

TABLE 7. MACHINING ALUMINUM

<u>Machinability</u>	<u>Casting Alloys</u>	<u>Wrought Alloys</u>
Free-cutting, very small broken chips and excellent finish	A140-F;750-T5;A750-T5; B750-T5	2011-T3,T4,T6,T8
Curled or easily broken chips and good to excellent finish	108-F;A108-F;113-F;C113-F; 138-F;142-T21,T571,T61,T77; 195-T4,T6,T7,T62;214-F;A214-F; F214-F;218-F;B218-F;220-24; 319-T5,T6,T7;333-T5,T6,T7; 354-T61,T62;355-T51,T6,T61, T62,T7,T71;C355-T61;A356-T61; A357-T61;357-T6;359-T61,T62; 380-F,T5;A380-F,T5;603-F;607-F (Ternalloy 5&7);A612-F;C612-F; D612(40E)-F;613-F(Tenzalloy); Red X8-T4,T51;Tens 50-T6	2014-T3,T4,T6,2017-T4; 2018-T61;2024-T3,T4,T6,T8; 2219-T3,T6,T8;2618-T6; 6262-T4,T9;7075-T6,T73; 7079-T6;7178-T6
Continuous chips and good finish	A132-T551,T65;F136-T5;319-F; 333-F;356-T51,T6,T7,T71;360-F; A360-F;364-F,T5	2014-0;2017-0;3004-H34 to H38; 5050-H34 to H38; 5052-H34 to H38; 5056-H18,H38;5083-H131,H343; 5086-H34 to H38;5154-H34 to H38; 5257-H25,H28,H38;5357-H25,H28,H38; 5454-H343;5456-H343;5457-H25,H28, H38;6061-T4,T6;6063-T5,T6,T8;6463-T4, T5,T6
Continuous chips and satisfactory finish	344-F	1100-H14 to H18;3003-H14 to H18; 3004-0,H112,H32;5005-H14 to H18, H34 to H38;5050-0,H112,H32;5052-0, H112,H32;5056-0;5083-0,H112,H321, H323;5086-0,H112,H32;5154-0,H112, H32;5237-0;5357-0;5454-0,H112,H311; 5456-0,H112,H311;5457-0;5557-H25, H28,H38;5657-H25,H28,H38;6161-0; 6063-0,T2,T4;6463-0,T1
Optimum machining parameters	13-F,43-F,Red X11-T5, Red X20-T5	1100-0,4112,H12;3003-0,H112,H12; 5005-0,H112,H12,H32;5557-0;5657-0
1. Non heat-treated, cast 2. Heat-treated, cast 3. Cold drawn, wrought 4. Heat-treated, wrought		

TABLE 8. MACHINING COPPER ALLOYS

1. Free-Cutting Alloys
 - 187 Leaded Copper
 - 145 Tellurium Copper
 - 330,335 Low-Leaded Brass
 - 340 Medium-Leaded Brass
 - 332,342 High-Leaded Brass
 - 356 IExtra High-Leaded Brass
 - 360 IFree-cutting Brass
 - 365-368 Leaded Muntz Metal
 - 370 Free-cutting Muntz Metal
 - 377 Forging Brass
 - 485 Leaded Naval Brass
 - 385 Architectural Bronze
 - 544 Free-cutting phosphor Bronze
 - 798 Leaded Nickel Silver

2. Moderately Machinable Alloys
 - 230 Red Brass
 - 240 Low Brass
 - 260 Cartridge Brass
 - 270 Yellow Brass
 - 280 Muntz Metal
 - 443-445 Inhibited admiralty
 - 464 Naval Brass
 - 651 Low Silicon Bronze
 - 655 High Silicon Bronze
 - 675 Manganese Bronze
 - 534 Leaded Phosphor Bronze,5%
 - 792 Leaded Nickel Silver,12%
 - 794 Leaded Nickel Silver,18%
 - 661 Leaded Silicon Bronze
 - 639 Aluminum Silicon Bronze
 - 687 Aluminum Brass

3. Alloys Difficult to Machine
 - 110 Electrolytic tough pitch Copper
 - 122 Phosphorus deoxidized Copper
 - 102 Oxygen-free Copper
 - 113,114,116, Silver-bearing tough pitch Copper
 - 182 Chromium Copper
 - 210 Gilding,95%
 - 220 Commercial Bronze,90%
 - 226 Jewelry Bronze,87.5%
 - 510,521,524 Phosphor Bronze
 - 614,628 Aluminum Bronze
 - 706,715 Copper Nickel
 - 745,752,754,757,770 Nickel Silver, Beryllium Copper

TABLE 9. MACHINING NICKEL ALLOYS

1. 95% or more Nickel Alloys
Nickel 200,201,204,205,211,220,230,233

2. Nickel-Copper Alloys
Monel 400,401,402,403,404,501 graphitized

3. Nickel-Chromium Alloys
Nickel 270, Monel K-500 unaged, Inconel 600, Inconel 604, Incoloy 800, Incoloy 801, Incoloy 804, Incoloy 825

4. Age Hardenable Alloys
Permanickel 300, Duranickel 301, Ni-span-C902, Monel K-500, Monel 501, Inconel 700, Inconel 702, Inconel 718, Inconel 721, Inconel 722, Inconel X-750, Inconel 751

5. Monel R-405

TABLE 10. MACHINING TITANIUM ALLOYS

1. 99.5 Titanium
2. 99.2 Titanium with 0.15 Pd
3. 99.0 Titanium
4. Ti-2,Fe-2,Cr-2 Mo
5. Ti-6,Al-4 V
6. Ti-7,Al-4 Mo
7. Ti-1,Al-8,V-5 Fe
8. Ti-3,Al-13,V-11 Cr

HOW TO USE THE CHARTS

Example:

Workpiece is C1117 steel (to be milled)
Cutter is HSS 1" dia., 4 flute
Refer to Table 1, Item 3. The nominal speed is 615 rpm. The nominal feed is $4 \times 3.7 \approx 15$ ipm.

TABLE 1. MACHINING CARBON & LOW ALLOY STEELS

MATERIAL	BRINELL H	BORE (2")		DRILL		C'BORE SPOTFACE		TAP RPM 1/4"	END MILL		Finish .015"								
		Rough RPM	Finish	1/4"	1"	1/4"	1"		Rough .05"	1/4"	1/4"	1/4"							
①	85-125	230	260	1.3	345	6.2	1680	5.0	420	2.5	840	2120	4.2	530	3.2	2760	2.8	690	3.5
		790	880	5.3	1380	6.9	5600	3.3	1400	15.	6500	16.3	6500	16.3	1625	13.0	8400	12.6	2100
	125-175	190	210	1.1	305	4.3	1380	4.1	345	2.0	690	1750	3.5	440	2.6	2300	2.3	575	2.9
		650	720	4.3	1220	6.1	4600	2.7	1150	13.	6100	15.2	6100	15.2	1525	12.2	8000	12.0	2000
	175-275	135	150	.75	210	2.1	920	1.8	230	.69	460	1380	2.7	345	1.7	1530	1.5	380	1.5
		540	640	3.8	840	3.4	3800	1.5	950	7.6	5100	10.2	5100	10.2	1275	9.0	6600	6.6	1650
	275-325	115	125	.50	170	1.5	760	.76	190	.57	380	920	.92	230	1.2	1230	.86	310	1.3
		460	550	2.7	690	2.1	3200	6.4	800	4.8	3900	7.8	3900	7.8	975	5.9	5100	5.1	1300
	325-375	95	105	.34	130	1.1	690	.69	170	.51	300	770	.39	195	.78	1000	.50	250	1.0
		390	430	1.7	530	1.6	2700	5.4	675	4.0	3060	3.1	3060	3.1	785	4.6	4000	4.0	1000
375-425	67	77	.24	95	.85	460	.46	115	.34	150	690	.35	175	.52	920	.46	230	.46	
	305	330	1.3	380	1.1	2100	4.2	525	3.1	2300	2.3	2300	2.3	575	2.3	3000	3.0	750	2.3
②	200-250																		
③	300-350																		
④	100-150	258	280	1.4	420	7.5	1840	7.3	160	3.2	920	2900	5.8	725	4.3	3750	3.8	940	4.7
		960	1060	6.5	1680	8.4	6600	5.2	1650	20.	7650	19.2	7650	19.2	1900	15.3	10000	15.0	2500
④	150-200	276	310	1.5	440	7.9	2000	8.0	500	3.0	1000	2450	4.9	615	3.7	3300	3.3	830	4.3
		1060	1200	7.2	1760	8.8	7500	6.0	1875	22.	7250	18.1	7250	18.1	1800	14.5	9400	14.1	2350
④	200-250																		
④	150-200	820	240	1.2	345	6.2	1380	5.5	345	2.0	760	2150	4.3	540	3.2	2760	2.8	690	3.5
		820	920	5.5	1380	6.9	4900	39.	1225	14.	6500	16.3	6500	16.3	1625	13.0	8400	12.6	2100
④	200-250	180	200	1.0	345	6.2	1160	3.5	290	1.4		1760	3.5	440	2.2	2300	2.3	580	2.9
		620	690	4.1	1380	6.9	4400	29.	1100	11.	5900	14.8	5900	14.8	1475	11.8	7600	11.4	1800
④	275-325	152	170	.68	250	3.0	760	1.2	190	.57	530	1240	1.2	310	1.55	1610	1.1	400	2.0
		580	650	3.8	1000	4.0	3400	10.	850	5.1	4750	11.9	4750	11.9	1200	9.6	6200	9.3	1530
④	325-375	95	105	.34	150	1.3					300	770	.39	170	.50	1000	.50	125	.50
		390	430	1.7	610	1.8						3060	3.1	760	4.6	4000	4.0	1000	5.0
④	375-425	67	77	.24	115	1.0	460	.46	115	.33	150	690	.35	175	.35	920	.46	230	.46
		290	330	1.3	460	1.4	2100	4.2	525	3.1	2300	2.3	2300	2.3	575	2.3	3000	3.0	750

TABLE 2. MACHINING CAST IRON

MATERIAL	BRINELL H	BORE (2")		DRILL		C'BORE, SPOTFACE		TAP	END MILL		(RPM, IPM/FLUTE)										
		Rough RPM	Finish IPM	1/4"	1/2"	1/4"	1/2"	RPM 1/4"	1/4"	Rough .05" 1/4"	1/4"	1/4"	Finish .015" 1/4"								
①	110-140	240 12.	268 880	1.6 7.0	2140 3500	13. 21.	535 875	.75 12.	1680 5800	5.8 28.	420 1400	2.1 11.	690	2060 6900	4.1 13.8	515 1725	4.1 17.2	2200 9000	2.2 9.0	550 2250	3.8 20.2
②	150-190	142 600	162 670	.97 5.3	1460 3000	7.3 15.	365 750	4.4 9.0	X	X	X	X	610	1530 5400	3.0 10.8	380 1350	2.6 10.8	2000 7100	2.0 7.1	570 1800	3.0 12.6
③	190-220	124 470	133 530	.65 3.7	1300 2740	6.5 13.	325 685	3.9 8.2	840 3400	2.1 13.	810 850	.84 4.7	530	1150 4200	2.3 8.4	285 1050	1.4 8.4	1530 5500	1.5 5.5	385 1375	1.5 9.6
④	220-260	86 380	96 430	.48 3.0	1060 2440	4.2 9.7	265 610	2.7 6.1	600 2700	1.2 9.4	150 675	.52 3.4	460	1000 3400	2.0 6.8	250 850	1.0 5.1	1300 4400	1.3 4.4	345 1100	1.0 5.5
⑤	250-320	47 200	57 220	1.7 .88	1460	4.4	365	3.2	X	X	X	X	150	460 1900	.46 1.9	1.5 475	.46 2.4	610 6400	.30 1.2	150 600	.45 2.4
⑥	140-190	238 790	268 880	1.6 7.0	1530	7.6	380	4.6	1680 5800	5.8 28.	420 1400	2.1 11.	610	1830 6100	3.6 12.2	460 1525	3.6 15.2	2400 8000	2.4 8.0	600 2000	4.2 18.0
⑦	190-260	140 470	163 570	.97 4.5	760	2.6	190	1.9	1060 3500	2.1 10.	265 875	.93 4.4	350	1150 3400	1.2 5.3	285 850	1.4 6.0	1450 4400	.72 4.4	365 1100	1.4 6.6
⑧	240-300	105 340	115 380	.67 2.6	600	1.8	150	1.5	760 2400	1.1 7.2	190 600	.57 2.7	230	840 3000	.84 3.0	210 750	1.0 4.5	1080 4000	.51 2.0	270 1000	1.1 5.0
⑨	270-330	47 210	57 230	1.7 .92	X	X	X	X	X	X	X	X	150	540 1500	.54 1.5	135 375	.54 1.9	690 2000	.35 1.0	175 570	.53 2.0
⑩	110-160	340 1200	380 1350	2.3 10.	1840	7.3	460	5.5	2440 8500	8.5 42.	610 2375	3.1 18.	760	2300 7400	4.6 14.4	575 1850	4.6 18.5	3000 9570	3.0 9.5	750 2375	5.2 21.4
⑪	160-240	140 470	153 530	.76 4.2	1220	4.9	305	3.1	1060 3600	3.3 16.	265 900	1.2 6.7	610	1250 4200	2.5 8.4	315 1050	1.6 6.3	1700 5500	1.7 5.5	425 1375	1.7 6.9
⑫	200-255	105 320	115 380	.67 2.6	1220	4.9	305	3.1	840 2700	1.7 10.	210 675	.73 4.7	460	1150 3800	2.3 7.6	285 950	1.4 5.7	1400 5700	1.4 5.0	350 1250	1.4 6.3
⑬	240-280	76 258	86 285	.43 2.0	1060	4.2	265	2.7	540 1800	1.1 6.3	185 450	.40 2.7	380	920 2700	.92 4.0	230 675	.92 3.4	1220 3500	1.2 3.5	305 875	.91 3.1

TABLE 3. MACHINING TOOL STEEL

MATERIAL	BRINELL	BORE (2")		DRILL		C'BORE, SPOTFACE		TAP	END MILL		RPM, IPM/FLUTE)	
		Rough RPM	Finish IPM	1/4"	1"	1/4"	1"		Rough .05" 1/4"	Finish .015" 1"	2400	600
④	150-200	220	250	1.3	3.9			1/4"	1830	2.7	2.4	2400
		860	960	5.7				1/4"	7600	15.2	15.	10000
⑤	175-225	143	162	.64	2.1				1300	1.6	1.7	1700
		580	650	3.3					5600	9.8	7.3	7300
⑥	200-250	124	134	.40	1.5				1100	1.1	1.0	1400
		470	520	2.1					4600	5.8	6.0	6000
⑦	200-250	124	134	.40	1.5				1100	1.1	1.0	1400
		470	520	2.1					4600	5.8	6.0	6000
⑧	200-250	67	76	.23	.57				610	1.1	.54	760
		276	300	1.2					3000	3.8	4.0	4000
⑨	150-200	153	172	.86	2.3				1300	1.3	.85	1700
		560	620	3.7					4600	4.6	6.0	6000
⑩	200-250	124	144	.57	1.7				1150	1.2	1.0	1450
		500	550	2.8					4200	5.2	5.5	5500
⑪	325-375	86	95	.38	1.0				760	.76	.50	1000
		342	380	1.9					2600	1.9	8.5	3500
⑫	150-200	115	124	.49	1.3				1100	1.1	.70	1400
		430	480	2.4					3500	3.5	4.6	4600
⑬	200-250	105	115	.46	1.2				920	.92	.60	1200
		400	450	2.3					3400	2.9	4.4	4400
⑭	200-250	105	115	.46	1.3				920	.92	.84	1200
		400	450	2.3					3400	4.3	4.4	4400
⑮	225-275	86	96	.38	1.2				760	.76	.70	1000
		330	380	1.9					3100	3.7	4.0	4000
⑯	225-275	57	67	.20	.45				540	.38	.35	700
		240	270	1.0					2500	2.5	3.3	3300
⑰	150-200	153	172	.86	2.3				1300	1.6	1.7	1700
		600	670	4.0					5800	10.	7.4	7400
⑱	200-250	124	144	.45	1.7				1100	1.1	1.0	1400
		516	570	2.2					5000	6.3	6.4	6400
⑲	100-150	191	210	1.1	3.0				1600	2.4	2.1	2100
		770	860	5.2					7100	14.	14.	9300
⑳	150-200	163	180	.90	2.3				1400	1.7	1.8	1800
		650	720	4.3					6000	10.	8.0	8000

TABLE 4. MACHINING STAINLESS STEEL

MATERIAL	BRINELL H.	BORE (2")		DRILL		C'BORE, SPOTFACE		TAP	END MILL (RPM, IPM/FLUTE)								
		Rough RPM	Finish IPM	1/4"	1"	1/4"	1"		1/4"	Rough .05"	Finish .015"						
① ANN	135-185	258	288	2/40	535	1/4"	1"	760	2/20	530	2/6	2760	1/4	690	2.8		
		860	950	10.	10.	6/100	9.6	1/4"	1"	6100	10.7	8000	4.0	2000	12.0		
② ANN	135-185	258	288	2/40	535	1/4"	1"	760	2/20	530	2/6	2760	1/4	690	2.8		
		860	950	10.	10.	6/100	9.6	1/4"	1"	6100	10.7	8000	4.0	2000	14.0		
ANN, CD	185-240			2000	500	10.	9.0	610	1900	1.9	2.1	2460	1.2	615	2.5		
Q&T	275-325	124	134	1000	250	4.0	2.5	460	5300	5.3	9.3	7000	3.5	1750	10.5		
		560	620	4.0	2.5	3000	3.8	1/4"	1"	1000	1.0	250	1.0	1300	.65	325	.97
Q&T	375-425	67	77	610	150	1.2	1.2	150	610	.31	.45	760	.38	190	.38		
		258	286	1.1	1.2	1530	7.6	380	610	1.5	1.5	2000	2.0	500	1.5		
③ ANN	135-185	162	182	1380	345	6.2	6.2	610	2060	2.1	2.6	2700	1.4	675	2.7		
		690	765	4.5	4.5	5300	5.3	1/4"	1"	1680	1.7	410	2.1	2200	1.1	550	2.2
CD	225-275								5000	5.0	8.7	6400	3.2	1600	9.6		
④ ANN	135-185	190	210	920	230	2.3	2.3	460	1680	1.7	1.7	2200	1.1	550	1.6		
		775	860	5.1	5.1	5300	5.3	1/4"	1"	1680	1.7	410	2.1	2200	1.1	550	1.6
⑤ ANN	135-185	190	210	1060	265	2.7	2.7	610	1680	1.7	1.7	2200	1.1	550	1.6		
		775	860	5.1	5.1	5300	5.3	1/4"	1"	1680	1.7	410	2.1	2200	1.1	550	1.6
ANN	175-225	172	190	920	230	2.5	2.5	460	1530	1.5	1.5	2000	1.0	500	1.5		
		690	765	4.5	4.5	4600	4.6	1/4"	1"	1530	1.5	380	1.5	2000	1.0	500	1.5
Q&T	275-325	105	115	760	190	2.1	2.1	300	920	.92	.92	1220	.61	305	.91		
		430	475	1.9	1.9	3400	3.4	1/4"	1"	920	.92	340	3.4	850	5.1	4400	2.2
Q&T	375-425	67	77	610	150	1.2	1.2	150	610	.31	.45	760	.38	190	.38		
		258	288	1.1	1.1	1530	1.5	1/4"	1"	610	.31	150	.45	380	1.5	2000	2.0
⑥ ANN	225-275	124	134	760	190	2.1	2.1	380	1060	1.1	1.1	1380	.69	345	1.1		
		516	570	2.8	2.8	3800	3.8	1/4"	1"	1060	1.1	265	1.1	5000	2.5	1250	6.3
Q&T	275-325	86	105	690	170	1.8	1.8	300	840	.84	.84	1060	.53	265	.80		
		390	430	1.7	1.7	3000	3.0	1/4"	1"	840	.84	210	.84	750	4.5	4000	2.0
Q&T	375-425	67	77	610	150	1.2	1.2	150	610	.31	.45	760	.38	190	.38		
		258	288	1.1	1.1	1530	1.5	1/4"	1"	610	.31	150	.45	380	1.5	2000	2.0

Continued

TABLE 4 continued. MACHINING STAINLESS STEEL

MATERIAL	BRINELL H.	BORE (2")		DRILL		C'BORE, SPOTFACE		TAP		END MILL (RPM, IPM, FLUTE)					
		Rough RPM	Finish IPM	1/4"	1"	1/4"	1"	RPM 1/4"	IPM 1/4"	Rough .05"		Finish .015"			
										1/4"	1"	1/4"	1"		
⑦ ANN	225-275	105	.73	115	.46	610	1.8	150	1.5	300	1.0	1300	.65	325	.97
		470	4.2	530	2.7	530	1.0	130	.78	3400	3.4	4400	2.2	1100	5.5
Q&T	275-325	86	.51	96	.29	530	1.0	130	.78	230	.77	1000	.50	250	.75
		340	2.7	380	1.5	380	.76	95	.47	2700	2.7	3500	1.7	875	4.4
Q&T	375-425	67	.40	77	.23	380	.76	95	.47	150	.27	690	.35	170	.34
		258	2.0	288	1.1	760	2.2	190	1.9	1360	1.4	1800	1.8	450	1.4
ANN	135-185	134	1.0	152	.76	760	2.2	190	1.9	380	1.3	1700	.85	425	1.3
		480	4.8	530	3.1	680	2.0	170	1.8	4200	4.2	5400	2.7	1350	5.4
CD	225-275					680	2.0	170	1.8	300	1.2	290	1.5	365	.79
ANN	135-185	124	.87	144	.58	680	2.0	170	1.8	300	3.8	950	2.5	1250	3.8
		430	3.8	480	2.4	680	2.0	170	1.8	3800	3.8	5000	2.5	1250	5.0
ANN	150-200	115	.92	124	.62	680	2.0	170	1.7	380	1.1	265	.69	345	1.1
		470	4.7	530	3.1	680	2.0	170	1.7	4200	4.2	5400	2.7	1350	6.7
HARD	275-325	105	.63	115	.35	610	1.8	150	1.2	300	.84	210	.54	270	.81
		430	3.4	480	1.9	450	1.3	115	.80	3400	3.4	4400	2.2	1100	5.5
HARD	325-375	96	.58	105	.31	450	1.3	115	.80	230	.39	190	.50	250	.50
		390	3.1	430	1.7	300	.60	75	.37	3000	3.0	4000	4.0	1000	3.0
HARD	375-440	57	.34	67	.20	300	.60	75	.37	150	.31	150	.39	190	.38
		250	2.0	288	1.1	840	3.3	210	2.5	1140	1.1	285	1.5	375	1.1
ANN	140-170	134	1.0	152	.76	840	3.3	210	2.5	380	1.2	305	1.6	400	1.6
		560	6.6	620	3.7	680	2.0	170	1.5	5300	13.2	7000	10.0	1750	10.0
N&T	175-225	124	1.0	135	.67	680	2.0	170	1.5	300	1.1	265	.97	345	1.4
		470	5.6	530	3.1	530	1.6	130	1.1	4600	9.2	6000	6.0	1500	7.5
ANN	140-190	86	.69	96	.48	530	1.6	130	1.1	230	.77	190	.70	250	1.0
		390	4.7	430	2.5	680	2.0	170	1.5	3800	7.6	5000	5.0	1250	6.3

TABLE 5. MACHINING HEAT-RESISTING ALLOYS

MATERIAL	BRINELL	BORE (2")		DRILL		C'BORE, SPOTFACE		TAP RPM 1/4"	END MILL (RPM, IPM/FLUTE)							
		Rough RPM	Finish IPM	1/4"	1"	1/4"	1"		ROUGH .05"		Finish .05"					
									1/4"	1"						
① ST	180-230	.33	57	.22	75	.38	.19	230	460	.96	.115	.46	610	.61	150	.3
		210	240	1.2	300	1.2	300	3.0	375	1500	1.4	360	1.4	2120	2.1	530
ST, AG	250-320	.22	48	.14	60	.30	.15	150	300	.60	.75	.30	460	.46	115	.23
		190	210	1.1	230	.92	60	2.7	345	1380	.92	230	.92	1140	1.5	285
② ANN or ST	200-300	.17	29	.08	75	.15	.08	120	230	.46	.60	.23	380	.38	85	.19
		105	115	.46	300	.30	75	1.5	190	760	.76	190	.76	1060	1.1	265
ST, AG	300-400	.17	29	.08	60	.15	.08	76	180	.27	.45	.14	300	.15	75	.15
		105	115	.46	230	.23	60	1.5	190	600	.90	150	.45	920	.46	230
③ ANN	140-220	.53	86	.34	115	.54	.27	150	610	1.2	150	.61	840	.84	210	.42
		210	240	1.2	460	1.8	1500	3.0	375	1680	1.7	420	1.7	2500	2.5	625
CD	240-310	.40	67	.26	75	.46	.23	76	460	.92	.115	.43	610	.61	150	.31
		172	190	.95	300	.60	75	2.4	300	1360	1.4	340	1.4	2500	2.5	625
④ AC	250-350	.09	19	.04	40	.12	.08	76	150	.23	.40	.12	230	.12	60	.12
		48	57	.17	150	.15	40	.57	95	380	.69	115	.35	610	.31	150
⑤ ST	180-230	.23	38	.11	95	.23	.12	230	300	.60	.75	.30	380	.38	95	.19
		135	152	.61	380	1.5	95	2.0	250	1000	.92	230	.92	1140	1.1	285
ST, AG	270-320	.17	29	.08	60	.15	.08	120	230	.35	.60	.17	300	.15	75	.15
		105	115	.46	230	.46	60	1.5	190	760	1.1	190	.55	1000	.50	250
⑥ AC	220-290	.09	19	.04	40	.12	.08	76	150	.23	.40	.12	230	.12	60	.12
		48	57	.17	150	.15	40	.57	95	380	.67	115	.33	610	.31	150
⑦ AC	160-210	.92	124	.62	150	1.5	.57	300	920	.92	230	1.1	1200	.84	300	1.2
		480	525	3.1	600	1.8	3400	13.0	650	4500	9.0	1375	8.2	6000	6.0	1500
⑧ AC	160-210	.69	96	.48	135	.91	.37	230	680	.68	.170	.85	920	.64	230	.92
		390	430	2.5	540	1.6	2800	8.4	700	3800	7.6	700	4.2	5000	5.0	1250

TABLE 6. MACHINING REFRACTORY METALS

MATERIAL	BORE (2")		DRILL		C'BORE, SPOTFACE	TAP	END MILL (RPM, IPM/FLUTE)							
	Rough RPM	Finish IPM	1/4"	1"			1/4" .05"		1/4" .015"					
							Rough	Finish	Rough	Finish				
①	1300	19.	9200	61.	1/4"	1750	1200	48	3000	30	1500	45.	3750	26
	2800	56.					15000	60.	3750	30.	20000	60.	5000	35.
②	1050	15.	9200	61.	1/4"	1370	9000	36	2750	28	1200	36.	3000	21.
	1900	58.					15000	60.	3750	38.	20000	60.	5000	35.
③	1050	15.	9200	61.	1/4"	1900	9000	36.	2750	28	1200	36.	3000	21.
	1900	38.					15000	60.	3750	38.	20000	60.	5000	35.
④	1050	15.	9200	61.	1/4"	1530	9000	27.	2750	28	1200	24.	3000	21.
	1900	38.					15000	45.	3750	38.	20000	40.	5000	35.

TABLE 7. MACHINING ALUMINUM

MATERIAL	BRINELL	BORE (2")		DRILL		C'BORE, SPOTFACE	TAP	END MILL (RPM, IPM/FLUTE)							
		Rough RPM	Finish IPM	1/4"	1"			1/4" .05"		1/4" .015"					
								Rough	Finish	Rough	Finish				
①	SR	170-225	.48	1150	5.8	1/4"	153	1220	2.4	305	1.3	1530	2.3	380	1.1
			430	2.2					2300	4.6	575	2.3	2600	4.0	665
②	SR	200-250	.40	780	1.5	1/4"	16	840	1.6	210	.84	1000	1.0	250	.63
			124	.87											
③	SR	220-290	3.3	1530	7.6	1/4"	760	2440	4.8	610	2.4	2900	2.9	725	1.5
			480	2.6					1600	9.2	1150	4.6	5000	5.0	1250
④	PS	180-200	1.0	3000	1.5	1/4"				575	1.7			750	2.3
			133	.62											
⑤	PS	290-320	1.0			1/4"				575	1.7			750	2.3
			124	.54											
⑥	PS	260-320	1.6			1/4"				575	1.7			750	2.3
			210	.92											
⑦	AL	260-320	1.6			1/4"				575	1.7			750	2.3
			210	.92											
⑧	PS	290-320	3.4			1/4"				750	3.7			950	.95
			380	2.1											

TABLE 10. MACHINING TITANIUM ALLOYS

MATERIAL	BRINELL H	BORE (2")		DRILL		C'BORE, SPOTFACE		TAP RPM 1/4"	END MILL (RPM, IPM, FLUTE)													
		Rough RPM	Finish IPM	1/4"	1"	1/4"	1"		1/4"		1"											
									Rough .05"	Finish .015"	Rough .05"	Finish .015"										
① ANN	110-170	340	2.7	380	1.9	1500	3.0	375	3.0	2400	4.8	600	1.8	760	1900	3.8	475	3.3	2300	3.4	575	4.0
		770	7.7	860	6.0	1200	3.6	300	2.4	5500	22.	1375	8.3	610	1840	3.6	1150	6.9	5600	5.6	1400	8.4
② ANN	140-200	270	2.1	300	1.5	760	3.8	190	1.5	1200	1.8	300	.75	460	920	1.4	230	1.4	1140	1.1	285	1.4
		640	6.4	720	5.0	3000	9.0	750	3.8	3000	9.0	750	3.8	2400	2400	3.6	600	4.8	2900	2.9	725	5.0
③ ANN	200-275	172	1.3	190	.85	610	3.1	150	1.2	840	.84	210	.92	380	840	1.2	210	1.2	1060	1.1	265	1.1
		430	4.3	480	3.3	300	.60	75	.30	2200	4.4	550	2.2	2100	2100	3.1	525	4.2	2600	2.6	650	4.5
④ ANN	300-340	124	.87	135	.54	460	2.3	115	.92	460	.46	115	.23	150	530	.79	130	.79	680	.68	170	.85
		310	2.8	340	1.7	460	2.3	115	.92	1200	2.4	300	1.2	1400	1400	2.1	350	2.4	1760	1.8	440	2.6
ST, AG	375-420	67	.33	76	.22	300	.60	75	.30	760	.76	190	.38	300	760	1.1	190	1.1	1000	1.0	250	1.0
		170	1.1	190	.76	460	2.3	115	.92	1800	3.6	450	1.8	1900	1900	2.8	475	3.8	2500	2.5	625	4.3
⑤ ANN	310-350	105	.73	115	.46	380	.76	95	.38	680	.68	170	.34	150	530	.79	130	.79	680	.68	170	.85
		250	2.2	290	1.5	380	.76	95	.38	1440	2.8	355	1.4	1400	1400	2.1	350	2.4	1760	1.8	440	2.6
ST, AG	350-400	96	.48	105	.34	300	1.5	75	.60	680	.68	170	.34	230	680	1.0	170	1.0	840	.84	210	1.1
		210	1.4	230	.92	300	1.5	75	.60	1440	2.8	355	1.4	1400	1400	2.1	440	3.5	2140	2.1	535	3.7
⑥ ANN	320-370	86	.60	96	.38	230	.92	60	.42	530	.53	130	.68	170	530	.79	130	.79	680	.68	170	.85
		220	2.0	250	1.3	230	.92	60	.42	1400	2.1	350	1.4	1400	1400	2.1	440	3.5	2140	2.1	535	3.7
⑦ ANN	320-380	38	.26	38	.15	230	.92	60	.42	530	.53	130	.68	170	530	.79	130	.79	680	.68	170	.85
		150	1.3	170	.85	230	.92	60	.42	1400	2.1	350	1.4	1400	1400	2.1	440	3.5	2140	2.1	535	3.7
ST, AG	375-440	38	.19	48	.14	230	.23	60	.12	530	.53	130	.65	170	530	.79	130	.79	680	.68	170	.85
		135	.94	150	.60	230	.23	60	.12	1400	2.1	350	1.4	1400	1400	2.1	440	3.5	2140	2.1	535	3.7
⑧ ST	310-350	38	.26	48	.19	300	.90	75	.45	680	.68	170	.34	230	680	1.0	170	1.0	840	.84	210	1.1
		170	1.5	190	.95	300	.90	75	.45	1760	2.6	440	3.5	2140	2140	3.5	440	3.5	2140	2.1	535	3.7
ST, AG	375-440	38	.19	48	.14	230	.23	60	.12	530	.53	130	.65	170	530	.79	130	.79	680	.68	170	.85
		135	.94	150	.60	230	.23	60	.12	1400	2.1	350	1.4	1400	1400	2.1	440	3.5	2140	2.1	535	3.7