

# APPENDICES

## Appendix A: List of SAE/AISI Steel Grades and Composition

Table A-A1. Plain carbon steels.

SAE No.	%C	%Mn	%S (max)	%P (max)
1005	0.06 max	0.35 max	0.040	0.050
1006	0.08 max	0.25/0.40	0.040	0.050
1008	0.10 max	0.30/0.50	0.040	0.050
1010	0.08/0.13	0.30/0.60	0.040	0.050
1011	0.08/0.14	0.60/0.90	0.040	0.050
1012	0.10/0.15	0.30/0.60	0.040	0.050
1013	0.11/0.16	0.30/0.60	0.040	0.050
1015	0.13/0.18	0.30/0.60	0.040	0.050
1016	0.13/0.18	0.60/0.90	0.040	0.050
1017	0.15/0.20	0.30/0.60	0.040	0.050
1018	0.15/0.20	0.60/0.90	0.040	0.050
1020	0.18/0.23	0.30/0.60	0.040	0.050
1021	0.18/0.23	0.60/0.90	0.040	0.050
1022	0.18/0.23	0.70/10.00	0.040	0.050
1023	0.20/0.25	0.30/0.60	0.040	0.050
1025	0.22/0.28	0.30/0.60	0.040	0.050
1026	0.22/0.28	0.60/0.90	0.040	0.050
1029	0.25/0.31	0.60/0.90	0.040	0.050
1030	0.28/0.34	0.60/0.90	0.040	0.050
1035	0.32/0.38	0.60/0.90	0.040	0.050
1038	0.35/0.42	0.60/0.90	0.040	0.050
1039	0.37/0.44	0.70/10.00	0.040	0.050
1040	0.37/0.44	0.60/0.90	0.040	0.050
1042	0.40/0.47	0.60/0.90	0.040	0.050
1043	0.40/0.47	0.70/1.00	0.040	0.050
1044	0.43/0.50	0.30/0.60	0.040	0.050
1045	0.43/0.50	0.60/0.90	0.040	0.050
1046	0.43/0.50	0.70/1.00	0.040	0.050

⊛ **Steel Metallurgy: Properties, Specifications and Applications**

SAE No.	%C	%Mn	%S (max)	%P (max)
1049	0.46/0.53	0.60/0.90	0.040	0.050
1050	0.48/0.55	0.60/0.90	0.040	0.050
1053	0.48/0.55	0.70/1.00	0.040	0.050
1055	0.50/0.60	0.60/0.90	0.040	0.050
1060	0.55/0.65	0.60/0.90	0.040	0.050
1065	0.60/0.70	0.60/0.90	0.040	0.050
1070	0.65/0.75	0.60/0.90	0.040	0.050
1074	0.70/0.80	0.50/0.80	0.040	0.050
1078	0.72/0.85	0.30/0.60	0.040	0.050
1080	0.75/0.88	0.60/0.90	0.040	0.050
1086	0.80/0.93	0.30/0.50	0.040	0.050
1090	0.85/0.98	0.60/0.90	0.040	0.050
1095	0.90/1.03	0.30/0.50	0.040	0.050

*Notes:*

1. Steels requiring strength for applications are generally chosen with higher C and Mn levels, such as for forged and heat-treated parts. But, for sheet metal uses where forming is critical, steels with lower level of C and Mn grades are preferred.
2. At high carbon level, grades with controlled Mn are generally used for cold rolled strips for springs and allied applications.

**Table A-A2. Standard SAE grade alloy steels.\***

SAE No.	%C	%Mn	%Cr	%Ni	%Mo	Others
1330	0.28/0.33	1.60/1.80	—	—	—	—
1335	0.33/0.38	1.60/1.90	—	—	—	—
1340	0.38/0.43	1.60/1.90	—	—	—	—
4023	0.20/0.25	0.70/0.90	—	—	0.20/0.30	—
4027	0.25/0.30	0.70/0.90	—	—	0.20/0.30	—
4037	0.35/0.40	0.70/0.90	—	—	0.20/0.30	—
4047	0.45/0.50	0.70/0.90	—	—	20/0.30	—
4118	0.18/0.23	0.70/0.90	0.40/0.60	—	0.08/0.15	—
4120	0.18/0.23	0.90/1.20	0.40/0.60	—	0.13/0.20	—
4130	0.28/0.33	0.40/0.60	0.80/1.10	—	0.15/0.25	—
4137	0.35/0.40	0.70/0.90	0.80/1.10	—	0.15/0.25	—
4140	0.38/0.43	0.75/1.00	0.80/1.10	—	0.15/0.25	—
4142	0.40/0.45	0.75/1.00	0.80/1.10	—	0.15/0.25	—
4145	0.43/0.48	0.75/1.00	0.80/1.10	—	0.15/0.25	—

SAE No.	%C	%Mn	%Cr	%Ni	%Mo	Others
4150	0.48/0.53	0.75/1.00	0.80/1.10	—	0.15/0.25	—
4320	0.17/0.22	0.45/0.65	0.40/0.60	1.65/2.00	0.20/0.30	—
4340	0.38/0.43	0.60/0.80	0.70/0.90	1.65/2.00	0.20/0.30	—
4620	0.17/0.22	0.45/0.65	—	1.65/2.00	0.20/0.30	—
4820	0.18/0.23	0.50/0.70	—	3.25/3.75	0.20/0.30	—
50B46	0.44/0.49	0.75/1.00	0.20/0.35	—	—	Boron
5120	0.17/0.22	0.70/0.90	0.70/0.90	—	—	—
5130	0.28/0.33	0.70/0.90	0.80/1.10	—	—	—
5132	0.30/0.35	0.60/0.80	0.75/1.00	—	—	—
5140	0.38/0.43	0.70/0.90	0.70/0.90	—	—	—
5150	0.48/0.53	0.70/0.90	0.70/0.90	—	—	—
5160	0.56/0.64	0.75/1.00	0.70/0.90	—	—	—
51B60	0.56/0.64	0.75/1.00	0.70/0.90	—	—	Boron
51100	0.98/1.10	0.25/0.45	0.90/1.15	—	—	—
E52100	0.98/1.10	0.25/0.45	1.30/1.60	—	—	P/S 0.025
52100	0.93/1.05	0.25/0.45	1.35/1.60	—	—	P/S 0.025
6150	0.48/0.53	0.70/0.90	0.80/1.10	—	—	—
8615	0.13/0.18	0.70/0.90	0.40/0.60	0.40/0.70	0.15/0.25	—
8617	0.15/0.23	0.70/0.90	0.40/0.60	0.40/0.70	0.15/0.25	—
8620	0.18/0.23	0.70/0.90	0.40/0.60	0.40/0.70	0.15/0.25	—
8622	0.20/0.25	0.70/0.90	0.40/0.60	0.40/0.70	0.15/0.25	—
8630	0.28/0.33	0.70/0.90	0.40/0.60	0.40/0.70	0.15/0.25	—
8640	0.38/0.43	0.75/1.00	0.40/0.60	0.40/0.70	0.15/0.25	—
8645	0.43/0.48	0.75/1.00	0.40/0.60	0.40/0.70	0.15/0.25	—
8720	0.18/0.23	0.70/0.90	0.40/0.60	0.40/0.70	0.20/0.30	—
8822	0.20/0.25	0.75/1.00	0.40/0.60	0.40/0.70	0.30/0.40	—
9259	0.56/0.64	0.75/1.00	0.45/0.65	—	—	Si 0.70/1.10
9260	0.56/0.64	0.75/1.00	—	—	—	Si 1.8/2.2

\* Chemical composition ranges of alloys and limits.

*Notes:*

1. Unless specified Si: .15/.35, P: .035 max, S: .040 max. Trace elements: Ni: .25 max, Cr: .25 max, Mo: .06 max.
2. Boron level is .0005 to .003% in 'Boron' grade steels.
3. These standard grades can have modification of chemistry by agreement between supplier and user.
4. Steels with sufficient carbon and alloy can be obtained under 'Hardenability' guaranteed condition (see AISI/SAE Steel Specification chart for 'H' steels).

## Steel Metallurgy: Properties, Specifications and Applications

**Table A-A3. SAE grade free cutting resulphurised steels: chemical composition.**

SAE No.	%C	%Mn	%P	%S
1117	0.14/0.20	1.0/1.30	0.03 max	0.08/0.13
1118	0.14/0.23	1.30/1.60	0.03 max	0.08/0.13
1126	0.23/0.29	0.70/1.00	0.03 max	0.08/0.13
1132	0.27/0.34	1.35/1.65	0.03 max	0.08/0.13
1137	0.32/0.39	1.35/1.65	0.03 max	0.08/0.13
1138	0.34/0.40	0.70/1.00	0.03 max	0.08/0.13
1140	0.37/0.44	0.70/1.00	0.03 max	0.08/0.13
1141	0.37/0.45	1.35/1.65	0.03 max	0.08/0.13
1144	0.40/0.48	1.35/1.65	0.03 max	0.08/0.13
1146	0.42/0.49	0.70/1.00	0.03 max	0.08/0.13
1151	0.48/0.55	0.70/1.00	0.03 max	0.08/0.13
*1212	0.13 max	0.70/1.00	0.07/0.12	0.16/0.23
*1213	0.13 max	0.70/1.00	0.07/0.12	0.24/0.33
*1215	0.09 max	0.75/1.05	0.04/0.09	0.26/0.35

\* 12XX grades are rephosphorised and resulphurised steels.

*Note:* Resulphurised steels are customarily furnished without specified silicon content because of adverse effect silicon on machinability.

Table A-A4. Stainless steel designations and compositions.

SAE Designation	UNS Designation	% Cr	% Ni	% C	% Mn	% Si	% P	% S	% N	Other
<b>Austenitic</b>										
201	S20100	16-18	3.5-5.5	0.15	5.5-7.5	0.75	0.06	0.03	0.25	—
202	S20200	17-19	4-6	0.15	7.5-10.0	0.75	0.06	0.03	0.25	—
205	S20500	16.5-18	1-1.75	0.12-0.25	14-15.5	0.75	0.06	0.03	0.32-0.40	—
254	S31254	20	18	0.02 max	—	—	—	—	0.20	6 Mo; 0.75 Cu; "Super austenitic"; All values nominal
301	S30100	16-18	6-8	0.15	2	0.75	0.045	0.03	—	—
302	S30200	17-19	8-10	0.15	2	0.75	0.045	0.03	0.1	—
302B	S30215	17-19	8-10	0.15	2	2.0-3.0	0.045	0.03	—	—
303	S30300	17-19	8-10	0.15	2	1	0.2	0.15 min	—	Mo 0.60 (optional)
303Se	S30323	17-19	8-10	0.15	2	1	0.2	0.06	—	0.15 Se min
304	S30400	18-20	8-10.50	0.08	2	0.75	0.045	0.03	0.1	—
304L	S30403	18-20	8-12	0.03	2	0.75	0.045	0.03	0.1	—
304Cu	S30430	17-19	8-10	0.08	2	0.75	0.045	0.03	—	3-4 Cu
304N	S30451	18-20	8-10.50	0.08	2	0.75	0.045	0.03	0.10-0.16	—
305	S30500	17-19	10.50-13	0.12	2	0.75	0.045	0.03	—	—
308	S30800	19-21	10-12	0.08	2	1	0.045	0.03	—	—
309	S30900	22-24	12-15	0.2	2	1	0.045	0.03	—	—
309S	S30908	22-24	12-15	0.08	2	1	0.045	0.03	—	—
310	S31000	24-26	19-22	0.25	2	1.5	0.045	0.03	—	—
310S	S31008	24-26	19-22	0.08	2	1.5	0.045	0.03	—	—
314	S31400	23-26	19-22	0.25	2	1.5-3.0	0.045	0.03	—	—
316	S31600	16-18	10-14	0.08	2	0.75	0.045	0.03	0.10	2.0-3.0 Mo

316L	S31603	16-18	10-14	0.03	2	0.75	0.045	0.03	0.10	2.0
316F	S31620	16-18	10-14	0.08	2	1	0.2	0.10 min	—	1.75-2.50 Mo
316N	S31651	16-18	10-14	0.08	2	0.75	0.045	0.03	0.10-0.16	2.0-3.0 Mo
317	S31700	18-20	11-15	0.08	2	0.75	0.045	0.03	0.10 max	3.0-4.0 Mo
317L	S31703	18-20	11-15	0.03	2	0.75	0.045	0.03	0.10 max	3.0-4.0 Mo
321	S32100	17-19	9-12	0.08	2	0.75	0.045	0.03	0.10 max	Ti 5(C + N) min, 0.70 max
329	S32900	23-28	2.5-5	0.08	2	0.75	0.04	0.03	—	1-2 Mo
330	N08330	17-20	34-37	0.08	2	0.75-1.50	0.04	0.03	—	—
347	S34700	17-19	9-13	0.08	2	0.75	0.045	0.030	—	Nb + Ta, 10 × C min, 1 max
348	S34800	17-19	9-13	0.08	2	0.75	0.045	0.030	—	Nb + Ta, 10 × C min, 1 max, but 0.10 Ta max; 0.20 Ca
384	S38400	15-17	17-19	0.08	2	1	0.045	0.03	—	—
<b>Ferritic</b>										
405	S40500	11.5-14.5	—	0.08	1	1	0.04	0.03	—	0.1-0.3 Al, 0.60 max
409	S40900	10.5-11.75	0.05	0.08	1	1	0.045	0.03	—	Ti 6 × C, but 0.75 max
429	S42900	14-16	0.75	0.12	1	1	0.04	0.03	—	—
430	S43000	16-18	0.75	0.12	1	1	0.04	0.03	—	—
430F	S43020	16-18	—	0.12	1.25	1	0.06	0.15 min	—	0.60 Mo (optional)
430FSe	S43023	16-18	—	0.12	1.25	1	0.06	0.06	—	0.15 Se min
434	S43400	16-18	—	0.12	1	1	0.04	0.03	—	0.75-1.25 Mo
436	S43600	16-18	—	0.12	1	1	0.04	0.03	—	0.75-1.25 Mo; Nb + Ta 5 × C min, 0.70 max
442	S44200	18-23	—	0.2	1	1	0.04	0.03	—	—
446	S44600	23-27	0.25	0.2	1.5	1	0.04	0.03	—	—

Martensitic										
403	S40300	11.5-13.0	0.60	0.15	1	0.5	0.04	0.03	—	—
410	S41000	11.5-13.5	0.75	0.15	1	1	0.04	0.03	—	—
414	S41400	11.5-13.5	1.25-2.50	0.15	1	1	0.04	0.03	—	—
416	S41600	12-14	—	0.15	1.25	1	0.06	0.15 min	—	0.060 Mo (optional)
416Se	S41623	12-14	—	0.15	1.25	1	0.06	0.06	—	0.15 Se min
420	S42000	12-14	—	0.15 min	1	1	0.04	0.03	—	—
420F	S42020	12-14	—	0.15 min	1.25	1	0.06	0.15 min	—	0.60 Mo max (optional)
422	S42200	11.0-12.5	0.50-1.0	0.20-0.25	0.5-1.0	0.5	0.025	0.025	—	0.90-1.25 Mo; 0.20-0.30 V; 0.90-1.25 W
431	S41623	15-17	1.25-2.50	0.2	1	1	0.04	0.03	—	—
440A	S44002	16-18	—	0.60-0.75	1	1	0.04	0.03	—	0.75 Mo
440B	S44003	16-18	—	0.75-0.95	1	1	0.04	0.03	—	0.75 Mo
440C	S44004	16-18	—	0.95-1.20	1	1	0.04	0.03	—	0.75 Mo
Heat Resisting										
501	S50100	4-6	—	0.10 min	1	1	0.04	0.03	—	0.40-0.65 Mo
502	S50200	4-6	—	0.1	1	1	0.04	0.03	—	0.40-0.65 Mo

## endix B. Equivalent Grades of Steel

Table A-B1. Comparison of SAE/AISI/ASTM steel grades with other international standards.

Comparison of USA Standards to International Standards for Chemistry						
USA	EUROPE	GERMANY		ENGLAND	ITALY	JAPAN
A.S.T.M. S.A.E. A.I.S.I.	Euronorm	Werkstoff W.-Nr	Kurzname DIN	BS 970	UNI	JIS
<b>CARBON</b>						
1018	C15D	1.1141	CK15	040A15	C15	S15
1018	C18D	1.0401	C15	080M15	C16	S15CK
1018		1.0453	C16.8	080A15	1C15	S15C
1018				EN3B		
1045	C45	1.0503	C45	060A47	C45	S45C
1045		1.1191	CK45	080A46	1C45	S48C
1045		1.1193	CF45	080M46	C46	
1045		1.1194	CQ45	EN9D	C43	
1140/1146	35S20	1.0726	35S20	212M40		
1140/1146	45S20	1.0727	45S20	En8M		
1215	11SMn37	1.0715	9SMn28	230M07	CF9SMn28	SUM 25
1215		1.0736	9SMn36	En1A	CF9SMn36	SUM 22
12L14	11SMnPb30	1.0718	9SMnPb28	230M07Leaded	CF9SMnPb28	SUM 22L
12L14	11SMnPb37	1.0737	9SMnPb36	En1A Leaded	CF9SMnPb36	SUM 23L
12L14						SUM 24L
<b>ALLOY</b>						
4130		1.7218	25CrMo4	708A30	25CrMo4 (KB)	SCM 420
4130			GS-25CrMo4	CDS110	30CrMo4	SCM 430
4130					30CrMo4	SCCrM1
4140/4142	42CrMo4	1.7223	41CrMo4	708M40	41CrMo4	SCM 440
4140/4142		1.7225	42CrMo4	708A42	38CrMo4 KB	SCM 440H
4140/4142		1.7227	42CrMoS4	709M40	G40 CrMo4	SNB 7
4140/4142		1.3563	43CrMo4	En19	42CrMo4	SCM 4M
4140/4142				En19C		SCM 4
4340	34CrNiMo6	1.6582	34CrNiMo6	817M40	35NiCrMo6 KB	SNCM 447
4340		1.6562	40 NiCrMo8 4	En24	40NiCrMo7 KB	SNB24-1-5
8620	20NiCrMo2-2	1.6543	21NiCrMo22	805A20	20NiCrMo2	SNCM 220 (H)
8620		1.6523	21NiCrMo2	805M20		
<b>STAINLESS</b>						
303	X8CrNiS18-9	1.4305	X10CrNiS18-9	303S 21	X10CrNiS 18 09	SUS 303
303				En58M		
304		1.4301	X5CrNi 18 9	304S 15	X5CrNi 18 10	SUS 304
304	X2CrNi19-11		X5CrNi 18 10	304S 16		SUS 304-CSP
304	X2CrNi18-10		XCrNi 19 9	304S 18		
304				304S 25		
304				En58E		
304L	X2CrNi19 11	1.4306		304S 11		SUS304L
316	X5CrNiMo17-12-2	1.4401	X5CrNiMo17 12 2	316S 29	X5CrNiMo17 12	SUS 316
316	X5CrNiMo18-14-3	1.4436	X5CrNiMo17 13 3	316S 31	X5CrNiMo17 13	SUS 316TP
316			X5CrNiMo 19 11	316S 33	X8CrNiMo17 13	
316			X5CrNiMo 18 11	En58J		
316L	X2CrNiMo17 12 2	1.4404		316S 11		SUS316L
316Ti		1.4571	X6CrNiMoTi17 12	320S 33		
321		1.4541	X6CrNiTi18 10	321S 31		SUS321
430		1.4016	X6Cr17	430S 17		SUS430
430F		1.4104	X14CrMoS17			SUS430F
<b>TOOL STEEL</b>						
A-2	X100CrMoV5	1.2363	X100CrMoV51	BA 2	X100CrMoV5 1 KU	SKD 12
D-2	X153CrMoV12	1.2379	X155CrVMo12 1	BD 2	X155CrVMo12 1	SKD 11
O-1		1.2510	100MnCrW4	BO 1	95MnWCr 5 KU	

Substitution is only possible after a complete examination of the individual specifications.



Table A-B2. Common case-carburising grade steels and their near equivalents.

IS Grade: IS-1570: 1961	Nominal Composition (Average)					BS 970: Old/(New) Designation	SAE	DIN
	%C	Mn	Cr	Ni	Mo			
C-10	0.15	0.60	—	—	—	EN 32A (045M10)	1012/1015	—
17Mn1Cr95	0.17	1.1	0.95	—	—	—	—	16MnCr5
20MnCr1	0.20	1.2	1.1	—	—	—	—	20MnCr5
20Ni2Mo25	0.17	0.60	—	1.8	0.25	EN 34 (665M17)	4620	—
15Cr65	0.15	0.60	0.75	—	—	EN 207(527A19)	5115	15Cr3
16Ni80Cr60	0.17	0.90	0.70	0.80	—	En 351 (635M15)	—	—
20Ni55CR50Mo20	0.18	0.80	0.50	0.60 (op)	0.20	En362 (805M20)	8620, 8720	—
13Ni3Cr80	0.14	0.60	0.80	3.4	—	En 36A, B (655M13)	3310	—
15NiCr1Mo12	0.16	0.90	1.0	1.22	0.12	EN 353 (822M17)	—	—
15Ni2Cr1Mo15	0.17	0.80	1.0	1.7	0.15	En 354 (815M17)	4320	—
16NiCr2Mo20	0.18	0.60	1.5	2.0	0.20	En 355 (822M17)	—	(15CrNi6)

Note: S and P limited to 0.050 and 0.035 max; Si is generally, 0.35 max. Comparative grades are near equivalents.

Table A-B3. Miscellaneous grades of popular steels (special).

Types	IS Grade	Nominal Composition (Average)						BS Grade	SAE	DIN
		%C	Mn	Cr	V	Mo	Others			
Alloy spring steels	50Cr1	0.50	0.70	1.1	—	—	—	EN 48	5147/5150	—
	50Cr1V23	0.50	0.75	1.1	0.20	—	—	EN 47	6150	50CrV4
Nitriding steel	40Cr2A11Mo18	0.40	0.60	1.6	—	0.20	Al, 10	En 41B	—	34CrAlMo5
	40Cr3Mo1V20	0.40	0.60	0.32	0.20	1.0	—	En 40C	—	—
Bearing steels	1003Cr1	1.0	0.60	1.0	S&P: 0.025 max		—	—	51100	—
	103Cr2	1.0	0.60	1.40	S&P: 0.25 max		—	EN 31	52100	100Cr6
Carbon tool steels	T70	0.70	0.30	—	S&P: 0.03 max		—	—	W-1	—
	T80	0.80	0.30	—	S&P: 0.03 max		—	—	W-1	—
	T90	0.90	0.30	—	S&P: 0.03 max		—	—	W-1	—

## Appendix C. Properties of Some Common UNS and SAE/AISI Grade Steels

Table A-C1. Properties of steel.

UNS Number	Processing Method	Yield Strength (kpsi)	Tensile Strength (kpsi)	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation in 2 in. (%)	Reduction in Area (%)	Brinell Hardness (H <sub>b</sub> )
G10100	Hot Rolled	26	47	179	324	28	50	95
G10100	Cold Drawn	44	53	303	365	20	40	105
G10150	Hot Rolled	27	50	186	345	28	50	101
G10150	Cold Drawn	47	56	324	386	18	40	111
G10180	Hot Rolled	32	58	220	400	25	50	116
G10180	Cold Drawn	54	64	372	441	15	40	126
G10350	Hot Rolled	39	72	269	496	18	40	143
G10350	Cold Drawn	67	80	462	551	12	35	163
G10350	Drawn 800 °F	81	110	558	758	18	51	220
G10350	Drawn 1000 °F	72	103	496	710	23	59	201
G10350	Drawn 1200 °F	62	91	427	627	27	66	180
G10400	Hot Rolled	42	76	289	524	18	40	149
G10400	Cold Drawn	71	85	489	586	12	35	170
G10400	Drawn 1000 °F	86	113	593	779	23	62	235
G10500	Hot Rolled	49	90	338	620	15	35	179
G10500	Cold Drawn	84	100	579	689	10	30	197
G10500	Drawn 600 °F	180	220	1240	1516	10	30	450
G10500	Drawn 900 °F	130	155	896	1068	18	55	310
G10500	Drawn 1200 F	80	105	551	723	28	65	210
G15216	Hot Rolled, Annealed	81	100	558	689	25	57	192
G41300	Hot Rolled, Annealed	60	90	413	620	30	45	183
G41300	Cold Drawn, Annealed	87	98	599	675	21	52	201
G41300	Drawn 1000 °F	133	146	916	1006	17	60	293
G41400	Hot Rolled, Annealed	63	90	434	620	27	58	187
G41400	Cold Drawn, Annealed	90	102	620	703	18	50	223
G41400	Drawn 1000 °F	131	153	903	1054	16	45	302
G43400	Hot Rolled, Annealed	69	101	475	696	21	45	207
G43400	Cold Drawn, Annealed	99	111	682	765	16	42	223

G43400	Drawn 600 °F	234	260	1612	1791	12	43	498
G43400	Drawn 1000 °F	162	182	1116	1254	15	40	363
G46200	Case Hardened	89	120	613	827	22	55	248
G46200	Drawn 800 °F	94	130	648	896	23	66	256
G61500	Hot Rolled, Annealed	58	91	400	627	22	53	183
G61500	Drawn 1000 °F	132	155	909	1068	15	44	302
G87400	Hot Rolled, Annealed	64	95	441	655	25	55	190
G87400	Cold Drawn, Annealed	96	107	661	737	17	48	223
G87400	Drawn 1000 °F	129	152	889	1047	15	44	302
G92550	Hot Rolled, Annealed	78	115	537	792	22	45	223
G92550	Drawn 1000 °F	160	180	1102	1240	15	32	352

Note: G indicates UNS system for SAE/AISI steels and First 4 digits after G indicate the SAE/AISI grades.

## Appendix D. Physical Data and Conversion Tables

Table A-D1. Handy physical constants.

### HANDY PHYSICAL CONSTANTS

Acceleration of gravity, g	32.17 ft/s <sup>2</sup> = 9.807 m/s <sup>2</sup>
Density of water	62.4 lbm/ft <sup>3</sup> = 1 g/cm <sup>3</sup> 1 gal H <sub>2</sub> O = 8.345 lbm
Gas Constant, R	1545 ft-lbf/pmole-R = 8.314 J/gmole-K
Gas volume (STP: 68°F, 1 atm)	359 ft <sup>3</sup> /pmole = .02241 m <sup>3</sup> /gmole
Joule's Constant, J	778 ft-lbf/BTU
Poisson's ratio, $\mu$	.3 (for steel)

### STEEL CONSTANTS

Fe-Fe <sub>3</sub> C eutectoid composition	0.77 w/o carbon
Fe-Fe <sub>3</sub> C eutectoid temperature	1340°F (727°C)
Modulus of Elasticity (steel)	30 × 10 <sup>6</sup> psi
Densities:	
Carbon & Low-Alloy Steels	0.283 lbm/in <sup>3</sup> = 7.84 g/cm <sup>3</sup>
304 SS	0.29 lbm/in <sup>3</sup> = 7.88 g/cm <sup>3</sup>
Tool Steels	Carbon Steels × 1.000
Moly High Speed	Carbon Steels × 1.035
Multiphase Alloys	Carbon Steels × 1.074
Steel Tensile Strength (psi)	~ 500 × Brinell Number

### COMPARISON MATERIALS

Material	Density (g/cm <sup>3</sup> )	Modulus of Elasticity (psi)	Poisson's Ratio
Aluminum Alloys	2.6-2.9	10.0 × 10 <sup>6</sup>	0.33
Nickel-base Superalloys	8.0-8.9	28.5 -- 31.0 × 10 <sup>6</sup>	0.31
Titanium Alloys	4.4-5.0	15.0 × 16.8 × 10 <sup>6</sup>	0.34

### SI PREFIXES

giga	G	10 <sup>9</sup>
mega	M	10 <sup>6</sup>
kilo	k	10 <sup>3</sup>
hecto	h	10 <sup>2</sup>
deka	da	10 <sup>1</sup>
deci	d	10 <sup>-1</sup>
centi	c	10 <sup>-2</sup>
milli	m	10 <sup>-3</sup>
micro	$\mu$	10 <sup>-6</sup>
nano	n	10 <sup>-9</sup>

Table A-D2. Conversion factors.

## CONVERSION FACTORS

EQUATION: A × B = C		
A	B	C
<b>Area [L]<sup>2</sup></b>		
ft <sup>2</sup>	0.092903	m <sup>2</sup>
in <sup>2</sup>	645.16	mm <sup>2</sup>
in <sup>2</sup>	6.45160	cm <sup>2</sup>
<b>Energy, Work or Heat [M] [L]<sup>2</sup> [t]<sup>-2</sup></b>		
Btu	1.05435	kJ
Btu	0.251996	kcal
Calories (cal)	4.184*	Joules (J)
ft-lbf	1.355818	J
ft-lbf	0.138255	kgf-m
hp-hr	2.6845	MJ
KWH	3.600	MJ
m-kgf	9.80665*	J
N-m	1.	J
<b>Flow Rate [L]<sup>3</sup> [t]<sup>-1</sup></b>		
ft <sup>3</sup> /min	7.4805	gal/min
ft <sup>3</sup> /min	0.471934	l/s
gal/min	0.063090	l/s
<b>Force or Weight [M] [L] [t]<sup>-2</sup></b>		
kgf	9.80665*	Newton (N)
lbf	4.44822	N
lbf	0.453592	Kgf
<b>Fracture Toughness</b>		
ksi√in	1.098800	MPa√m
<b>Heat Content</b>		
Btu/lbm	0.555556	cal/g
Btu/lbm	2.324444	J/g
Btu/ft <sup>3</sup>	0.037234	MJ/m <sup>3</sup>
<b>Heat Flux</b>		
Btu/hr-ft <sup>2</sup>	7.5346 E-5	cal/s-cm <sup>2</sup>
Btu/hr-ft <sup>2</sup>	3.1525	W/m <sup>2</sup>
cal/s-cm <sup>2</sup>	4.184*	W/cm <sup>2</sup>
<b>Length [L]</b>		
Foot (ft)	0.304800	Meter (m)
Inch (in)	25.4000	Millimeter (mm)
Mile (mi)	1.609344	Kilometer (km)

\* Indicates exact conversion(s)

Table A-D2. Conversion factors (continued).

EQUATION: A × B = C		
A	B	C
<b>Mass Density [M] [L]<sup>-3</sup></b>		
lbm/in <sup>3</sup>	27.68	g/cm <sup>3</sup>
lbm/ft <sup>3</sup>	16.0184	kg/m <sup>3</sup>
<b>Power [M] [L]<sup>2</sup> [t]<sup>-3</sup></b>		
Btu/hr	0.292875	Watt (W)
ft-lbf/s	1.355818	W
Horsepower (hp)	745.6999	W
Horsepower	550.*	ft-lbf/s
<b>Pressure (fluid) [M] [L]<sup>-1</sup> [t]<sup>-2</sup></b>		
Atmosphere (atm)	14.696	lbf/in <sup>2</sup>
atm	1.01325 E5*	Pascal (Pa)
lbf/ft <sup>2</sup>	47.88026	Pa
lbf/in <sup>2</sup>	27.6807	in. H <sub>2</sub> O at 39.2°F
<b>Stress [M] [L]<sup>-1</sup> [t]<sup>-2</sup></b>		
kgf/cm <sup>2</sup>	9.80665 E-2*	MPa
ksi	6.89476	MPa
N/mm <sup>2</sup>	1.	MPa
kgf/mm <sup>2</sup>	1.42231	ksi
<b>Volume [L]<sup>3</sup> &amp; Capacity</b>		
in <sup>3</sup>	16.3871	cm <sup>3</sup>
ft <sup>3</sup>	0.028317	m <sup>3</sup>
ft <sup>3</sup>	7.4805	Gallon
ft <sup>3</sup>	28.3168	Liter (l)
Gallon	3.785412	Liter
<b>Specific Heat</b>		
Btu/lbm-°F	1.	cal/g-°C
<b>Temperature*</b>		
Fahrenheit	(°F-32)/1.8	Celsius
Fahrenheit	°F+459.67	Rankine
Celsius	°C+273.16	Kelvin
Rankine	R/1.8	Kelvin
<b>Thermal Conductivity</b>		
Btu-ft/hr-ft <sup>2</sup> -°F	14.8816	cal-cm/hr-cm <sup>2</sup> -°C

\* Indicates exact conversion(s)

Table A-D3. Metric-English stress conversion.

## METRIC-ENGLISH STRESS CONVERSION TABLE

### Kg Per Sq Mm to Psi to M Pa

Kg per sq mm	Psi	M Pa	Kg per sq mm	Psi	M Pa	Kg per sq mm	Psi	M Pa	Kg per sq mm	Psi	M Pa
10	14,223	98.1	50	71,117	490.3	90	128,011	882.6	130	184,904	1274.9
11	15,646	107.9	51	72,539	500.1	91	129,433	892.4	131	186,327	1284.7
12	17,068	117.7	52	73,962	510.0	92	130,855	902.2	132	187,749	1294.5
13	18,490	127.5	53	75,384	519.8	93	132,278	912.0	133	189,171	1304.3
14	19,913	137.3	54	76,806	529.6	94	133,700	921.8	134	190,594	1314.1
15	21,335	147.1	55	78,229	539.4	95	135,122	931.6	135	192,016	1323.9
16	22,757	156.9	56	79,651	549.2	96	136,545	941.4	136	193,438	1333.7
17	24,180	166.7	57	81,073	559.0	97	137,967	951.2	137	194,861	1343.5
18	25,602	176.5	58	82,496	568.8	98	139,389	961.0	138	196,283	1353.3
19	27,024	186.3	59	83,918	578.6	99	140,812	970.9	139	197,705	1363.1
20	28,447	196.1	60	85,340	588.4	100	142,234	980.7	140	199,128	1372.9
21	29,869	205.9	61	86,763	598.2	101	143,656	990.5	141	200,550	1382.7
22	31,291	215.7	62	88,185	608.0	102	145,079	1000.3	142	201,972	1392.5
23	32,714	225.6	63	89,607	617.8	103	146,501	1010.1	143	203,395	1402.4
24	34,136	235.4	64	91,030	622.6	104	147,923	1020.0	144	204,817	1412.2
25	35,558	245.2	65	92,452	637.4	105	149,346	1029.7	145	206,239	1422.0
26	36,981	255.0	66	93,874	647.2	106	150,768	1039.5	146	207,662	1431.8
27	38,403	264.8	67	95,297	657.0	107	152,190	1049.3	147	209,084	1441.6
28	39,826	274.6	68	96,719	666.9	108	153,613	1059.1	148	210,506	1451.4
29	41,248	284.4	69	98,141	676.7	109	155,035	1068.9	149	211,929	1461.2
30	42,670	294.2	70	99,564	686.5	110	156,457	1078.7	150	213,351	1471.0
31	44,093	304.0	71	100,986	696.3	111	157,880	1088.5	151	214,773	1480.8
32	45,515	313.8	72	102,408	706.1	112	159,302	1098.3	152	216,196	1490.6
33	46,937	323.6	73	103,831	715.9	113	160,724	1108.2	153	217,618	1500.4
34	48,360	333.4	74	105,253	725.7	114	162,147	1118.0	154	219,040	1510.2
35	49,782	343.2	75	106,675	735.5	115	163,569	1127.8	155	220,463	1520.0
36	51,204	353.0	76	108,098	745.3	116	164,991	1137.6	156	221,885	1529.8
37	52,627	362.8	77	109,520	755.1	117	166,414	1147.4	157	223,307	1539.6
38	54,049	372.7	78	110,943	764.9	118	167,836	1157.2	158	224,730	1549.5
39	55,471	382.5	79	112,365	774.7	119	169,258	1167.0	159	226,152	1559.3
40	56,894	393.3	80	113,787	784.5	120	170,681	1176.8			
41	58,316	402.1	81	115,210	794.3	121	172,103	1186.6			
42	59,738	411.9	82	116,632	804.1	122	173,525	1196.4			
43	61,161	421.7	83	118,054	814.0	123	174,948	1206.2			
44	62,583	431.5	84	119,477	823.8	124	176,370	1216.0			
45	64,005	441.3	85	120,899	833.6	125	177,792	1225.8			
46	65,428	451.1	86	122,321	843.4	126	179,215	1235.6			
47	66,850	460.9	87	123,744	853.2	127	180,637	1245.4			
48	68,272	470.7	88	125,166	863.0	128	182,059	1255.3			
49	69,695	480.5	89	126,588	872.8	129	183,482	1265.1			

Table A-D4. Temperature conversion.

## TEMPERATURE CONVERSION TABLES

Albert Sauveur type of table. Values revised.

-459.4 to 0			0 to 100						100 to 1000					
C	F/C	F	C	F/C	F	C	F/C	F	C	F/C	F	C	F/C	F
-273	-459.4		-17.8	0	32	10.0	50	122.0	38	100	212	260	500	932
-268	-450		-17.2	1	33.8	10.6	51	123.8	43	110	230	266	510	950
-262	-440		-16.7	2	35.6	11.1	52	125.6	49	120	248	271	520	968
-257	-430		-16.1	3	37.4	11.7	53	127.4	54	130	266	277	530	986
-251	-420		-15.6	4	39.2	12.2	54	129.2	60	140	284	282	540	1004
-246	-410		-15.0	5	41.0	12.8	55	131.0	66	150	302	288	550	1022
-240	-400		-14.4	6	42.8	13.3	56	132.8	71	160	320	293	560	1040
-234	-390		-13.9	7	44.6	13.9	57	134.6	77	170	338	299	570	1058
-229	-380		-13.3	8	46.4	14.4	58	136.4	82	180	356	304	580	1076
-223	-370		-12.8	9	48.2	15.0	59	138.2	88	190	374	310	590	1094
-218	-360		-12.2	10	50.0	15.6	60	140.0	93	200	392	316	600	1112
-212	-350		-11.7	11	51.8	16.1	61	141.8	99	210	410	321	610	1130
-207	-340		-11.1	12	53.6	16.7	62	143.6	100	212	413.6	327	620	1148
-201	-330		-10.6	13	55.4	17.2	63	145.4	104	220	428	332	630	1166
-196	-320		-10.0	14	57.2	17.8	64	147.2	110	230	446	338	640	1184
-190	-310		-9.4	15	59.0	18.3	65	149.0	116	240	464	343	650	1202
-184	-300		-8.9	16	60.8	18.9	66	150.8	121	250	482	349	660	1220
-179	-290		-8.3	17	62.6	19.4	67	152.6	127	260	500	354	670	1238
-173	-280		-7.8	18	64.4	20.0	68	154.4	132	270	518	360	680	1256
-169	-273	-459.4	-7.2	19	66.2	20.6	69	156.2	138	280	536	366	690	1274
-168	-270	-454	-6.7	20	68.0	21.1	70	158.0	143	290	554	371	700	1292
-162	-260	-436	-6.1	21	69.8	21.7	71	159.8	149	300	572	377	710	1310
-157	-250	-418	-5.6	22	71.6	22.2	72	161.6	154	310	590	382	720	1328
-151	-240	-400	-5.0	23	73.4	22.8	73	163.4	160	320	608	388	730	1346
-146	-230	-382	-4.4	24	75.2	23.3	74	165.2	166	330	626	393	740	1364
-140	-220	-364	-3.9	25	77.0	23.9	75	167.0	171	340	644	399	750	1382
-134	-210	-346	-3.3	26	78.8	24.4	76	168.8	177	350	662	404	760	1400
-129	-200	-328	-2.8	27	80.6	25.0	77	170.6	182	360	680	410	770	1418
-123	-190	-310	-2.2	28	82.4	25.6	78	172.4	188	370	698	416	780	1436
-118	-180	-292	-1.7	29	84.2	26.1	79	174.2	193	380	716	421	790	1454
-112	-170	-274	-1.1	30	86.0	26.7	80	176.0	199	390	734	427	800	1472
-107	-160	-256	-.6	31	87.8	27.2	81	177.8	204	400	752	432	810	1490
-101	-150	-238	0	32	89.6	27.8	82	179.6	210	410	770	438	820	1508
-96	-140	-220	.6	33	91.4	28.3	83	181.4	216	420	788	443	830	1526
-90	-130	-202	1.1	34	93.2	28.9	84	183.2	221	430	806	449	840	1544
-84	-120	-184	1.7	35	95.0	29.4	85	185.0	227	440	824	454	850	1562
-79	-110	-166	2.2	36	96.8	30.0	86	186.8	232	450	842	460	860	1580
-73	-100	-148	2.8	37	98.6	30.6	87	188.6	238	460	860	466	870	1598
-68	-90	-130	3.3	38	100.4	31.1	88	190.4	243	470	878	471	880	1616
-62	-80	-112	3.9	39	102.2	31.7	89	192.2	249	480	896	477	890	1634
-57	-70	-94	4.4	40	104.0	32.2	90	194.0	254	490	914	482	900	1652
-51	-60	-76	5.0	41	105.8	32.8	91	195.8				488	910	1670
-46	-50	-58	5.6	42	107.6	33.3	92	197.6				493	920	1688
-40	-40	-40	6.1	43	109.4	33.9	93	199.4				499	930	1706
-34	-30	-22	6.7	44	111.2	34.4	94	201.2				504	940	1724
-29	-20	-4	7.2	45	113.0	35.0	95	203.0				510	950	1742
-23	-10	14	7.8	46	114.8	35.6	96	204.8				516	960	1760
-17.8	0	32	8.3	47	116.6	36.1	97	206.6				521	970	1778
			8.9	48	118.4	36.7	98	208.4				527	980	1796
			9.4	49	120.2	37.2	99	210.2				532	990	1814
						37.8	100	212.0				538	1000	1832

Look up reading in middle column. If in degrees Celsius, read Fahrenheit equivalent in right hand column; if in Fahrenheit degrees, read Celsius equivalent in left hand column.



Table A-D4. Temperature conversion (continued).

**TEMPERATURE CONVERSION TABLES – continued**  
*Albert Sauveur type of table. Values revised.*

1000 to 2000						2000 to 3000					
C	F/C	F	C	F/C	F	C	F/C	F	C	F/C	F
538	1000	1832	816	1500	2732	1093	2000	3632	1371	2500	4532
543	1010	1850	821	1510	2750	1099	2010	3650	1377	2510	4650
549	1020	1868	827	1520	2768	1104	2020	3668	1382	2520	4568
554	1030	1886	832	1530	2786	1110	2030	3686	1388	2530	4586
560	1040	1904	838	1540	2804	1116	2040	3704	1393	2540	4604
566	1050	1922	843	1550	2822	1121	2050	3722	1399	2550	4622
571	1060	1940	849	1560	2840	1127	2060	3740	1404	2560	4640
577	1070	1958	854	1570	2858	1132	2070	3758	1410	2570	4658
582	1080	1976	860	1580	2876	1138	2080	3776	1416	2580	4676
588	1090	1994	866	1590	2894	1143	2090	3794	1421	2590	4694
593	1100	2012	871	1600	2912	1149	2100	3812	1427	2600	4712
599	1110	2030	877	1610	2930	1154	2110	3830	1432	2610	4730
604	1120	2048	882	1620	2948	1160	2120	3848	1438	2620	4748
610	1130	2066	888	1630	2966	1166	2130	3866	1443	2630	4766
616	1140	2084	893	1640	2984	1171	2140	3884	1449	2640	4784
621	1150	2102	899	1650	3002	1177	2150	3902	1454	2650	4802
627	1160	2120	904	1660	3020	1182	2160	3920	1460	2660	4820
632	1170	2138	910	1670	3038	1188	2170	3938	1466	2670	4838
638	1180	2156	916	1680	3056	1193	2180	3956	1471	2680	4856
643	1190	2174	921	1690	3074	1199	2190	3974	1477	2690	4874
649	1200	2192	927	1700	3092	1204	2200	3992	1482	2700	4892
654	1210	2210	932	1710	3110	1210	2210	4010	1488	2710	4910
660	1220	2228	938	1720	3128	1216	2220	4028	1493	2720	4928
666	1230	2246	943	1730	3146	1221	2230	4046	1499	2730	4946
671	1240	2264	949	1740	3164	1227	2240	4064	1504	2740	4964
677	1250	2282	954	1750	3182	1232	2250	4082	1510	2750	4982
682	1260	2300	960	1760	3200	1238	2260	4100	1516	2760	5000
688	1270	2318	966	1770	3218	1243	2270	4118	1521	2770	5018
693	1280	2336	971	1780	3236	1249	2280	4136	1527	2780	5036
699	1290	2354	977	1790	3254	1254	2290	4154	1532	2790	5054
704	1300	2372	982	1800	3272	1260	2300	4172	1538	2800	5072
710	1310	2390	988	1810	3290	1266	2310	4190	1543	2810	5090
716	1320	2408	993	1820	3308	1271	2320	4208	1549	2820	5108
721	1330	2426	999	1830	3326	1277	2330	4226	1554	2830	5126
727	1340	2444	1004	1840	3344	1282	2340	4244	1560	2840	5144
732	1350	2462	1010	1850	3362	1288	2350	4262	1566	2850	5162
738	1360	2480	1016	1860	3380	1293	2360	4280	1571	2860	5180
743	1370	2498	1021	1870	3398	1299	2370	4298	1577	2870	5198
749	1380	2516	1027	1880	3416	1304	2380	4316	1582	2880	5216
754	1390	2534	1032	1890	3434	1310	2390	4334	1588	2890	5234
760	1400	2552	1038	1900	3452	1316	2400	4352	1593	2900	5252
766	1410	2570	1043	1910	3470	1321	2410	4370	1599	2910	5270
771	1420	2588	1049	1920	3488	1327	2420	4388	1604	2920	5288
777	1430	2606	1054	1930	3506	1332	2430	4406	1610	2930	5306
782	1440	2624	1060	1940	3524	1338	2440	4424	1616	2940	5324
788	1450	2642	1066	1950	3542	1343	2450	4442	1621	2950	5342
793	1460	2660	1071	1960	3560	1349	2460	4460	1627	2960	5360
799	1470	2678	1077	1970	3578	1354	2470	4478	1632	2970	5378
804	1480	2696	1082	1980	3596	1360	2480	4496	1638	2980	5396
810	1490	2714	1088	1990	3614	1366	2490	4514	1643	2990	5414
			1093	2000	3632				1649	3000	5432

Look up reading in middle column. If in degrees Celsius, read Fahrenheit equivalent in right hand column; if in Fahrenheit degrees, read Celsius equivalent in left hand column.

Table A-D4. Hardness conversion.

## HARDNESS CONVERSION TABLES BASED ON BRINELL (APPROXIMATE)

BRINELL HARDNESS		ROCKWELL HARDNESS				Diamond Pyramid Hardness Number (Vickers)	Approx. Tensile Strength 1000 psi
Diameter mm 3000 Kg	Tungsten Carbide 10 mm Ball	A-Scale 60 Kg Brale	B-Scale 100 Kg 1/16" Ball	C-Scale 150 Kg Brale	Superficial 30 N		
....	....	86.5	....	70.0	86.0	1076	....
....	....	86.0	....	69.0	85.0	1004	....
....	....	85.6	....	68.0	84.4	940	....
....	....	85.0	....	67.0	83.6	900	....
....	757	84.4	....	65.9	82.7	860	....
2.25	745	84.1	....	65.3	82.2	840	....
....	722	83.4	....	64.0	81.1	800	....
....	710	83.0	....	63.3	80.4	780	....
2.35	682	82.2	....	61.7	79.0	737	....
2.40	653	81.2	....	60.0	77.5	697	....
2.45	627	80.5	....	58.7	76.3	667	323
2.50	601	79.8	....	57.3	75.1	640	309
2.55	578	79.1	....	56.0	73.9	615	297
2.60	555	78.4	....	54.7	72.7	591	285
2.65	534	77.8	....	53.5	71.6	569	274
2.70	514	76.9	....	52.1	70.3	547	263
2.75	495	76.3	....	51.0	69.4	528	253
2.80	477	75.6	....	49.6	68.2	508	243
2.85	461	74.9	....	48.5	67.2	491	235
2.90	444	74.2	....	47.1	65.8	472	225
2.95	429	73.4	....	45.7	64.6	455	217
3.00	415	72.8	....	44.5	63.5	440	210
3.05	401	72.0	....	43.1	62.3	425	202
3.10	388	71.4	....	41.8	61.1	410	195
3.15	375	70.6	....	40.4	59.9	396	188
3.20	363	70.0	....	39.1	58.7	383	182
3.25	352	69.3	(110.0)	37.9	57.6	372	176
3.30	341	68.7	(109.0)	36.6	56.4	360	170
3.35	331	68.1	(108.5)	35.5	55.4	350	166
3.40	321	67.5	(108.0)	34.3	54.3	339	160
3.45	311	66.9	(107.5)	33.1	53.3	328	155
3.50	302	66.3	(107.0)	32.1	52.2	319	150
3.55	293	65.7	(106.0)	30.9	51.2	309	145
3.60	285	65.3	(105.5)	29.9	50.3	301	141
3.65	277	64.6	(104.5)	28.8	49.3	292	137

Table A-D5. Hardness conversion (continued)

BRINELL HARDNESS		ROCKWELL HARDNESS				Diamond Pyramid Hardness Number (Vickers)	Approx. Tensile Strength 1000 psi
Diameter mm 3000 Kg	Tungsten Carbide 10 mm Ball	A-Scale 60 Kg Brale	B-Scale 100 Kg 1/16" Ball	C-Scale 150 Kg Brale	Superficial 30 N		
3.70	269	64.1	(104.0)	27.6	48.3	284	133
3.75	262	63.6	(103.0)	26.6	47.3	276	129
3.80	255	63.0	(102.0)	25.4	46.2	269	126
3.85	248	62.5	(101.0)	24.2	45.1	261	122
3.90	241	61.8	100.0	22.8	43.9	253	118
3.95	235	61.4	99.0	21.7	42.9	247	115
4.00	229	60.8	98.2	20.5	41.9	241	111
4.05	223	59.7	97.3	(18.8)	....	234	....
4.10	217	59.2	96.4	(17.5)	....	228	105
4.15	212	58.5	95.5	(16.0)	....	222	102
4.20	207	57.8	94.6	(15.2)	....	218	100
4.25	201	57.4	93.8	(13.8)	....	212	98
4.30	197	56.9	92.8	(12.7)	....	207	95
4.35	192	56.5	91.9	(11.5)	....	202	93
4.40	187	55.9	90.7	(10.0)	....	196	90
4.45	183	55.5	90.0	(9.0)	....	192	89
4.50	179	55.0	89.0	(8.0)	....	188	87
4.55	174	53.9	87.8	(6.4)	....	182	85
4.60	170	53.4	86.8	(5.4)	....	178	83
4.65	167	53.0	86.0	(4.4)	....	175	81
4.70	163	52.5	85.0	(3.3)	....	171	79
4.80	156	51.0	82.9	(.9)	....	163	76
4.90	149	49.9	80.8	....	....	156	73
5.00	143	48.9	78.7	....	....	150	71
5.10	137	47.4	76.4	....	....	143	67
5.20	131	46.0	74.0	....	....	137	65
5.30	126	45.0	72.0	....	....	132	63
5.40	121	43.9	69.8	....	....	127	60
5.50	116	42.8	67.6	....	....	122	58
5.60	111	41.9	65.7	....	....	117	56

Values in ( ) are beyond normal range and are given for information only.

The Brinell values in this table are based on the use of a 10mm tungsten carbide ball; at hardness levels of 429 Brinell and below, the values obtained with the tungsten carbide ball, the Hultgren ball, and the standard ball are the same.

The Hardness Conversion Tables are based on SAE J417 and ASTM E140.

Table A-D6. Work-energy conversion.

ft.-lb <sub>r</sub>		joules		ft.-lb <sub>r</sub>		joules	
0.7376	1	1.356		37.6157	51	69.147	
1.4751	2	2.712		38.3532	52	70.503	
2.2127	3	4.067		39.0908	53	71.858	
2.9502	4	5.423		39.8284	54	73.214	
3.6878	5	6.779		40.5659	55	74.570	
4.4254	6	8.135		41.3035	56	75.926	
5.1629	7	9.491		42.0410	57	77.282	
5.9005	8	10.847		42.7786	58	78.637	
6.6381	9	12.202		43.5162	59	79.993	
7.3756	10	13.558		44.2537	60	81.349	
8.1132	11	14.914		44.9913	61	82.705	
8.8507	12	16.270		45.7289	62	84.061	
9.5883	13	17.626		46.4664	63	85.417	
10.3259	14	18.981		47.2040	64	86.772	
11.0634	15	20.337		47.9415	65	88.128	
11.8010	16	21.693		48.6791	66	89.484	
12.5386	17	23.049		49.4167	67	90.840	
13.2761	18	24.405		50.1542	68	92.196	
14.0137	19	25.761		50.8918	69	93.551	
14.7512	20	27.116		51.6294	70	94.907	
15.4888	21	28.472		52.3669	71	96.263	
16.2264	22	29.828		53.1045	72	97.619	
16.9639	23	31.184		53.8420	73	98.975	
17.7015	24	32.540		54.5796	74	100.331	
18.4391	25	33.895		55.3172	75	101.686	
19.1766	26	35.251		56.0547	76	103.042	
19.9142	27	36.607		56.7923	77	104.398	
20.6517	28	37.963		57.5298	78	105.754	
21.3893	29	39.319		58.2674	79	107.110	
22.1269	30	40.675		59.0050	80	108.465	
22.8644	31	42.030		59.7425	81	109.821	
23.6020	32	43.386		60.4801	82	111.177	
24.3396	33	44.742		61.2177	83	112.533	
25.0771	34	46.098		61.9552	84	113.889	
25.8147	35	47.454		62.6928	85	115.245	
26.5522	36	48.809		63.4303	86	116.600	
27.2898	37	50.165		64.1679	87	117.956	
28.0274	38	51.521		64.9055	88	119.312	
28.7649	39	52.877		65.6430	89	120.668	
29.5025	40	54.233		66.3806	90	122.024	
30.2400	41	55.589		67.1182	91	123.379	
30.9776	42	56.944		67.8557	92	124.735	
31.7152	43	58.300		68.5933	93	126.091	
32.4527	44	59.656		69.3308	94	127.447	
33.1903	45	61.012		70.0684	95	128.803	
33.9279	46	62.368		70.8060	96	130.159	
34.6654	47	63.723		71.5435	97	131.514	
35.4030	48	65.079		72.2811	98	132.870	
36.1405	49	66.435		73.0186	99	134.226	
36.8781	50	67.791		73.7562	100	135.582	

Examples: 1 ft.-lb<sub>r</sub> = 1.356 joules  
 1 joule = 0.7376 ft.-lb<sub>r</sub>