TABLE OF CONTENTS

PAGE NO.

Steel Chemistries

German Industrial Standards

Japanese Industrial Standards

TABLE OF CONTENTS - *CONTINUED*

PAGE NO.

End-Quench Hardenability Bands

General Information

TABLE OF CONTENTS - *CONTINUED*

PAGE NO.

General Information - (continued)

STANDARD CARBON STEELS

Chemical Composition Ranges and Limits

SAE No.	C	Mn	SAE No.	C	Mn	SAE No.	C	Mn
1005	.06 max	.35 max	**1025**	.22/.28	.30/.60	**1050**	.48/.55	.60/.90
1006	.08 max	.25/.40	**1026**	.22/.28	.60/.90	**1053**	.48/.55	.70/1.00
1008	.10 max	.30/.50	**1029**	.25/.31	.60/.90	**1055**	.50/.60	.60/.90
1010	.08/.13	.30/.60	**1030**	.28/.34	.60/.90	**1059**	.55/.65	.50/.80
1011	.09/.14	.60/.90	**1035**	.32/.38	.60/.90	**1060**	.55/.65	.60/.90
1012	.10/.15	.30/.60	**1038**	.35/.42	.60/.90	**1065**	.60/.70	.60/.90
1015	.13/.18	.30/.60	**1039**	.37/.44	.70/1.00	**1070**	.65/.75	.60/.90
1016	.13/.18	.60/.90	**1040**	.37/.44	.60/.90	**1074**	.70/.80	.50/.80
1017	.15/.20	.30/.60	**1042**	.40/.47	.60/.90	**1078**	.72/.85	.30/.60
1018	.15/.20	.60/.90	**1043**	.40/.47	.70/1.00	**1080**	.75/.88	.60/.90
1020	.18/.23	.30/.60	**1044**	.43/.50	.30/.60	**1086**	.80/.93	.30/.50
1021	.18/.23	.60/.90	**1045**	.43/.50	.60/.90	**1090**	.85/.98	.60/.90
1022	.18/.23	.70/1.00	**1046**	.43/.50	.70/1.00	**1095**	.90/1.03	.30/.50
1023	.20/.25	.30/.60	**1049**	.46/.53	.60/.90			

NOTE: *Phosphorus = .040 max, Sulfur = .050 max.*

FREE CUTTING RESULFURIZED STEELS

Chemical Composition Ranges and Limits

SAE No.	C	Mn	P Max	S	SAE No.	C	Mn	P Max	S
1110	.08/.13	.30/.60	.040	.08/.13	**1140**	.37/.44	.70/1.00	.040	.08/.13
1117	.14/.20	1.00/1.30	.040	.08/.13	**1141**	.37/.45	1.35/1.65	.040	.08/.13
1118	.14/.20	1.30/1.60	.040	.08/.13	**1144**	.40/.48	1.35/1.65	.040	.24/.33
1123	.20/.27	1.20/1.50	.040	.06/.09	**1146**	.42/.49	.70/1.00	.040	.08/.13
1137	.32/.39	1.35/1.65	.040	.08/.13	**1152**	.48/.55	.70/1.00	.040	.06/.09

FREE CUTTING REPHOSPHORIZED AND RESULFURIZED STEELS

Chemical Composition Ranges and Limits

SAE No.	C	Mn	P	S	SAE No.	C	Mn	P	S
1212	.13 max	.70/1.00	.07/.12	.16/.23	**1215**	.09 max	.75/1.05	.04/.09	.26/.35
1213	.13 max	.70/1.00	.07/.12	.24/.33					

NOTE: *12XX grades are customarily furnished without specified silicon content because of adverse effect on machinability.*

HIGH MANGANESE CARBON STEELS

Chemical Composition Ranges and Limits

SAE No.	C	Mn	P Max	S Max	SAE No.	C	Mn	P Max	S Max
1513	.10/.16	1.10/1.40	.040	.050	**1545**	.43/.50	.80/1.10	.040	.050
1522	.18/.24	1.10/1.40	.040	.050	**1546**	.44/.52	1.00/1.30	.040	.050
1524	.19/.25	1.35/1.65	.040	.050	**1548**	.44/.52	1.10/1.40	.040	.050
1526	.22/.29	1.10/1.40	.040	.050	**1552**	.47/.55	1.20/1.50	.040	.050
1527	.22/.29	1.20/1.50	.040	.050	**1553**	.48/.55	.80/1.10	.040	.050
1533	.30/.37	1.10/1.40	.040	.050	**1566**	.60/.71	.85/1.15	.040	.050
1534	.30/.37	1.20/1.50	.040	.050	**1570**	.65/.75	.80/1.10	.040	.050
1541	.36/.44	1.35/1.65	.040	.050	**1580**	.75/.88	.80/1.10	.040	.050
1544	.40/.47	.80/1.10	.040	.050	**1590**	.85/.98	.80/1.10	.040	.050

MICRO-ALLOYED STEELS

Precipitation Hardened Ferritic-Pearlitic Steel

Chemical Composition

Steel Name	Material No.	% C	% Mn	% Si	% S	% V	% Cr	% Mo	Other
19MnVS6	1.1301	0.15/0.22	1.20/1.60	0.15/0.80	0.020/0.060	0.08/0.20	<0.30	<0.08	N=100-200 ppm
27MnSiVS6	1.5232	0.25/0.30	1.30/1.60	0.50/0.80	0.030/0.050	0.08/0.13			
30MnVS6	1.1302	0.26/0.33	1.20/1.60	0.15/0.80	0.020/0.060	0.08/0.20	<0.30	<0.08	N=100-200 ppm
38MnVS6	1.1303	0.34/0.41	1.20/1.60	0.15/0.80	0.020/0.060	0.08/0.20	<0.30	<0.08	N=100-200 ppm
38MnSiVS5	1.5231	0.35/0.40	1.20/1.50	0.50/0.80	0.030/0.065	0.08/0.13			
44MnSiVS5	1.5233	0.42/0.47	1.30/1.60	0.50/0.80	0.020/0.035	0.10/0.15			
46MnVS3	1.1305	0.42/0.49	0.60/1.00	1.15/0.80	0.020/0.060	0.08/0.20	<0.30	<0.08	N=100-200 ppm
46MnVS6	1.1304	0.42/0.49	1.20/1.60	0.15/0.80	0.020/0.060	0.08/0.20	<0.30	<0.08	N=100-200 ppm
49MnVS3	1.1199	0.44/0.50	0.70/1.00	≤0.50	0.030/0.065	0.08/0.13			

Mechanical Properties

Steel Name	Material No.	Diameter or Section Size (mm)	Yield Point R_C (N/mm^2)	Tensile R_m (N/mm^2)	Elongation A% min.	Reduction of Area Z% min.	Hardness Surface/Core (Brinell)
19MnVS6	1.1301	30-120	390	600-750	16	32	<255 HB
27MnSiVS6	1.5232	30-150	500	800-950	14	30	<255 HB
30MnVS6	1.1302	30-120	450	700-900	14	30	<255 HB
38MnVS6	1.1303	30-120	520	800-950	12	25	<255 HB
38MnSiVS5	1.5231	30-150	550	820-1000	12	25	<255 HB
44MnSiVS5	1.5233	30-150	600	950-1100	10	20	<255 HB
46MnVS3	1.1305	30-120	450	700-900	14	30	<255 HB
46MnVS6	1.1304	30-120	580	900-1050	10	20	<255 HB
49MnVS3	1.1199	30-150	450	750-900	8	20	<255 HB

STANDARD ALLOY STEELS

Chemical Composition Ranges and Limits

SAE No.	C	Mn	Cr	Ni	Mo	Si	Other
1330	.28/.33	1.60/1.90	—	—	—	—	—
1335	.33/.38	1.60/1.90	—	—	—	—	—
1340	.38/.43	1.60/1.90	—	—	—	—	—
4023	.20/.25	.70/.90	—	—	.20/.30	—	—
4027	.25/.30	.70/.90	—	—	.20/.30	—	—
4028*	.25/.30	.70/.90	—	—	.20/.30	—	—
4037	.35/.40	.70/.90	—	—	.20/.30	—	—
4047	.45/.50	.70/.90	—	—	.20/.30	—	—
4118	.18/.23	.70/.90	.40/.60	—	.08/.15	—	—
4120[a]	.18/.23	.90/1.20	.40/.60	—	.13/.20	—	—
4121[b]	.18/.23	.75/1.00	.45/.65	—	.20/.30	—	—
4130	.28/.33	.40/.60	.80/1.10	—	.15/.25	—	—
4131	.28/.33	.50/.70	.90/1.20	—	.15/.25	—	—
4137	.35/.40	.70/.90	.80/1.10	—	.15/.25	—	—
4140	.38/.43	.75/1.00	.80/1.10	—	.15/.25	—	—
4142	.40/.45	.75/1.00	.80/1.10	—	.15/.25	—	—
4145	.43/.48	.75/1.00	.80/1.10	—	.15/.25	—	—
4147	.45/.50	.75/1.00	.80/1.10	—	.15/.25	—	—
4150	.48/.53	.75/1.00	.80/1.10	—	.15/.25	—	—
4320	.17/.22	.45/.65	.40/.60	1.65/2.00	.20/.30	—	—
4340	.38/.43	.60/.80	.70/.90	1.65/2.00	.20/.30	—	—
E4340	.38/.43	.65/.85	.70/.90	1.65/2.00	.20/.30	—	—
4620	.17/.22	.45/.65	—	1.65/2.00	.20/.30	—	—
4715[c]	.13/.18	.70/.90	.45/.65	.70/1.00	.45/.65	—	—
4720	.17/.22	.50/.70	.35/.55	.90/1.20	.15/.25	—	—
4815	.13/.18	.40/.60	—	3.25/3.75	.20/.30	—	—

continued on next page...

STANDARD ALLOY STEELS - *CONTINUED*

Chemical Composition Ranges and Limits

SAE No.	C	Mn	Cr	Ni	Mo	Si	Other
4820	.18/.23	.50/.70	—	3.25/3.75	.20/.30	—	—
5120	.17/.22	.70/.90	.70/.90	—	—	—	—
5130	.28/.33	.70/.90	.80/1.10	—	—	—	—
5132	.30/.35	.60/.80	.75/1.00	—	—	—	—
5140	.38/.43	.70/.90	.70/.90	—	—	—	—
5150	.48/.53	.70/.90	.70/.90	—	—	—	—
5160	.56/.64	.75/1.00	.70/.90	—	—	—	—
51100	.98/1.10	.25/.45	.90/1.15	—	—	—	—
52100	.98/1.10	.25/.45	1.30/1.60	—	—	—	—
6150	.48/.53	.70/.90	.80/1.10	—	—	—	.15 min V
8615	.13/.18	.70/.90	.40/.60	.40/.70	.15/.25	—	—
8617	.15/.20	.70/.90	.40/.60	.40/.70	.15/.25	—	—
8620	.18/.23	.70/.90	.40/.60	.40/.70	.15/.25	—	—
8622	.20/.25	.70/.90	.40/.60	.40/.70	.15/.25	—	—
8630	.28/.33	.70/.90	.40/.60	.40/.70	.15/.25	—	—
8637	.35/.40	.75/1.00	.40/.60	.40/.70	.15/.25	—	—
8640	.38/.43	.75/1.00	.40/.60	.40/.70	.15/.25	—	—
8645	.43/.48	.75/1.00	.40/.60	.40/.70	.15/.25	—	—
8720	.18/.23	.70/.90	.40/.60	.40/.70	.20/.30	—	—
8822	.20/.25	.75/1.00	.40/.60	.40/.70	.30/.40	—	—
9259	.56/.64	.75/1.00	.45/.65	—	—	.70/1.10	—
9260	.56/.64	.75/1.00	—	—	—	1.80/2.20	—

NOTE: *Unless specified: Si = .15/.35, P = .025 max, S = .025 max, Ni = .25 max, Cr = .20 max, Mo = .06 max. These standard grades can have modifications in chemistry when agreed upon by user and supplier.*

* *Sulfur content is .035/.050.*

a *Formerly PS 15.*

b *Formerly PS 24.*

c *Formerly PS 30.*

PS GRADES (FORMERLY EX GRADES)

Chemical Composition Ranges and Limits

PS No.	C	Mn	Cr	Ni	Mo	B	V
10	.19/.24	.95/1.25	.25/.40	.20/.40	.05/.10	—	—
16	.20/.25	.90/1.20	.40/.60	—	.13/.20	—	—
17	.23/.28	.90/1.20	.40/.60	—	.13/.20	—	—
18	.25/.30	.90/1.20	.40/.60	—	.13/.20	—	—
19	.18/.23	.90/1.20	.40/.60	—	.08/.15	.0005-.003	—
20	.13/.18	.90/1.20	.40/.60	—	.13/.20	—	—
21	.15/.20	.90/1.20	.40/.60	—	.13/.20	—	—
31	.15/.20	.70/.90	.45/.65	.70/1.00	.45/.60	—	—
32	.18/.23	.70/.90	.45/.65	.70/1.00	.45/.60	—	—
33	.17/.24	.85/1.25	.20 min	.20 min	.05 min	—	—
34	.28/.33	.90/1.20	.40/.60	—	.13/.20	—	—
36	.38/.43	.90/1.20	.45/.65	—	.13/.20	—	—
38	.43/.48	.90/1.20	.45/.65	—	.13/.20	—	—
39	.48/.53	.90/1.20	.45/.65	—	.13/.20	—	—
40	.51/.59	.90/1.20	.45/.65	—	.13/.20	—	—
54	.19/.25	.70/1.05	.40/.70	—	.05 min	—	—
55	.15/.20	.70/1.00	.45/.65	1.65/2.00	.65/.80	—	—
56	.08/.13	.70/1.00	.45/.65	1.65/2.00	.65/.80	—	—
58	.16/.21	1.00/1.30	.45/.65	—	—	—	—
59	.18/.23	1.00/1.30	.70/.90	—	—	—	—
61	.23/.28	1.00/1.30	.70/.90	—	—	—	—
63	.31/.38	.75/1.10	.45/.65	—	—	.0005-.003	—
64	.16/.21	1.00/1.30	.70/.90	—	—	—	—
65	.21/.26	1.00/1.30	.70/.90	—	—	—	—
66	.16/.21	.40/.70	.45/.75	1.65/2.00	.08/.15	—	.10/.15
67	.42/.49	.80/1.20	.85/1.20	—	.25/.35	—	—

NOTE: *Unless specified: Si = .15/.35, P = .025 max, S = .025 max.*
PS No.s 15, 24 and 30 are now standard grades. (See SAE No.s 4120, 4121 and 4715.)

STANDARD H STEELS

	Chemical Composition Ranges and Limits						
SAE No.	C	Mn	Cr	Ni	Mo	V	Si
1330H	.27/.33	1.45/2.05	—	—	—	—	—
1335H	.32/.38	1.45/2.05	—	—	—	—	—
1340H	.37/.44	1.45/2.05	—	—	—	—	—
1345H	.42/.49	1.45/2.05	—	—	—	—	—
4027H	.24/.30	.60/1.00	—	—	.20/.30	—	—
4028H[a]	.24/.30	.60/1.00	—	—	.20/.30	—	—
4032H	.29/.35	.60/1.00	—	—	.20/.30	—	—
4037H	.34/.41	.60/1.00	—	—	.20/.30	—	—
4042H	.39/.46	.60/1.00	—	—	.20/.30	—	—
4047H	.44/.51	.60/1.00	—	—	.20/.30	—	—
4118H	.17/.23	.60/1.00	.30/.70	—	.08/.15	—	—
4130H	.27/.33	.30/.70	.75/1.20	—	.15/.25	—	—
4135H	.32/.38	.60/1.00	.75/1.20	—	.15/.25	—	—
4137H	.34/.41	.60/1.00	.75/1.20	—	.15/.25	—	—
4140H	.37/.44	.65/1.10	.75/1.20	—	.15/.25	—	—
4142H	.39/.46	.65/1.10	.75/1.20	—	.15/.25	—	—
4145H	.42/.49	.65/1.10	.75/1.20	—	.15/.25	—	—
4147H	.44/.51	.65/1.10	.75/1.20	—	.15/.25	—	—
4150H	.47/.54	.65/1.10	.75/1.20	—	.15/.25	—	—
4161H	.55/.65	.65/1.10	.65/.95	—	.25/.35	—	—
4320H	.17/.23	.40/.70	.35/.65	1.55/2.00	.20/.30	—	—
4340H	.37/.44	.55/.90	.65/.95	1.55/2.00	.20/.30	—	—
E4340H	.37/.44	.60/.95	.65/.95	1.55/2.00	.20/.30	—	—
4620H	.17/.23	.35/.75	—	1.55/2.00	.20/.30	—	—
4718H	.15/.21	.60/.95	.30/.60	.85/1.25	.30/.40	—	—
4720H	.17/.23	.45/.75	.30/.60	.85/1.25	.15/.25	—	—

STANDARD H STEELS - *CONTINUED*

Chemical Composition Ranges and Limits

SAE No.	C	Mn	Cr	Ni	Mo	V	Si
4815H	.12/.18	.30/.70	—	3.20/3.80	.20/.30	—	—
4817H	.14/.20	.30/.70	—	3.20/3.80	.20/.30	—	—
4820H	.17/.23	.40/.80	—	3.20/3.80	.20/.30	—	—
5046H	.43/.50	.65/1.10	.13/.43	—	—	—	—
5120H	.17/.23	.60/1.00	.60/1.00	—	—	—	—
5130H	.27/.33	.60/1.00	.75/1.20	—	—	—	—
5132H	.29/.35	.50/.90	.65/1.10	—	—	—	—
5135H	.32/.38	.50/.90	.70/1.15	—	—	—	—
5140H	.37/.44	.60/1.00	.60/1.00	—	—	—	—
5147H	.45/.52	.60/1.05	.80/1.25	—	—	—	—
5150H	.47/.54	.60/1.00	.60/1.00	—	—	—	—
5155H	.50/.60	.60/1.00	.60/1.00	—	—	—	—
5160H	.55/.65	.65/1.10	.60/1.00	—	—	—	—
6118H	.15/.21	.40/.80	.40/.80	—	—	—	.10/.15
6150H	.47/.54	.60/1.00	.75/1.20	—	—	.15 min	—
8617H	.14/.20	.60/.95	.35/.65	.35/.75	.15/.25	—	—
8620H	.17/.23	.60/.95	.35/.65	.35/.75	.15/.25	—	—
8622H	.19/.25	.60/.95	.35/.65	.35/.75	.15/.25	—	—
8625H	.22/.28	.60/.95	.35/.65	.35/.75	.15/.25	—	—
8627H	.24/.30	.60/.95	.35/.65	.35/.75	.15/.25	—	—
8630H	.27/.33	.60/.95	.35/.65	.35/.75	.15/.25	—	—
8637H	.34/.41	.70/1.05	.35/.65	.35/.75	.15/.25	—	—
8640H	.37/.44	.70/1.05	.35/.65	.35/.75	.15/.25	—	—
8642H	.39/.46	.70/1.05	.35/.65	.35/.75	.15/.25	—	—
8645H	.42/.49	.70/1.05	.35/.65	.35/.75	.15/.25	—	—
8650H	.47/.54	.70/1.05	.35/.65	.35/.75	.15/.25	—	—

continued on next page...

STANDARD H STEELS - *CONTINUED*

Chemical Composition Ranges and Limits

SAE No.	C	Mn	Cr	Ni	Mo	V	Si
8655H	.50/.60	.70/1.05	.35/.65	.35/.75	.15/.25	—	—
8660H	.55/.65	.70/1.05	.35/.65	.35/.75	.15/.25	—	—
8720H	.17/.23	.60/.95	.35/.65	.35/.75	.20/.30	—	—
8740H	.37/.44	.70/1.05	.35/.65	.35/.75	.20/.30	—	—
8822H	.19/.25	.70/1.05	.35/.65	.35/.75	.30/.40	—	—
9260H	.55/.65	.65/1.10	—	—	—	—	1.70/2.20
9310H	.07/.13	.40/.70	1.00/1.45	2.95/3.55	.08/.15	—	—

NOTE: *Unless specified: Si = .15/.35, P = .025 max, S = .025 max, Cu = .35 max, Ni = .25 max, Cr = .20 max, Mo = .06 max.*

a *Sulfur content is .035/.050.*

STANDARD CARBON AND CARBON BORON H STEELS

Chemical Composition Ranges and Limits

SAE No.	C	Mn	P Max	S Max	Si	SAE No.	C	Mn	P Max	S Max	Si
1038H	.34/.43	.50/1.00	.040	.050	.15/.35	**15B21H***	.17/.24	.70/1.20	.040	.050	.15/.35
1045H	.42/.51	.50/1.00	.040	.050	.15/.35	**15B35H***	.31/.39	.70/1.20	.040	.050	.15/.35
1522H	.17/.25	1.00/1.50	.040	.050	.15/.35	**15B37H***	.30/.39	1.00/1.50	.040	.050	.15/.35
1524H	.18/.26	1.25/1.75	.040	.050	.15/.35	**15B41H***	.35/.45	1.25/1.75	.040	.050	.15/.35
1526H	.21/.30	1.00/1.50	.040	.050	.15/.35	**15B48H***	.43/.53	1.00/1.50	.040	.050	.15/.35
1541H	.35/.45	1.25/1.75	.040	.050	.15/.35	**15B62H***	.54/.67	1.00/1.50	.040	.050	.40/.60

NOTE: *For electric furnace steels P & S = .025 max and the prefix "E" is added.*

* *Boron content is .0005 to .003.*

STANDARD ALLOY BORON STEELS[B]

Chemical Composition Ranges and Limits

Grade Designation	Carbon	Manganese	Phosphorous, Max	Sulfur, Max	Silicon[A]	Nickel	Chromium	Molybdenum
50B44	.43/.48	.75/1.00	.035	.040	.15/.35	—	.20/.60	—
50B46	.44/.49	.75/1.00	.035	.040	.15/.35	—	.20/.35	—
50B50	.48/.53	.75/1.00	.035	.040	.15/.35	—	.40/.60	—
50B60	.56/.64	.75/1.00	.035	.040	.15/.35	—	.40/.60	—
51B60	.56/.64	.75/1.00	.035	.040	.15/.35	—	.70/.90	—
81B45	.43/.48	.75/1.00	.035	.040	.15/.35	.20/.40	.35/.55	.08/.15
94B17	.15/.20	.75/1.00	.035	.040	.15/.35	.30/.60	.30/.50	.08/.15
94B30	.28/.33	.75/1.00	.035	.040	.15/.35	.30/.60	.30/.50	.08/.15

A *Silicon may be specified by the purchaser as 0.10% maximum. The need for 0.10% maximum generally relates to severe cold-formed parts.*

B *These steels can be expected to contain 0.0005 to 0.003% boron. If the usual titanium additive is not permitted, the steels can be expected to contain up to 0.005% boron.*

RESTRICTED HARDENABILITY STEELS

Chemical Composition Ranges and Limits

SAE No.	C	Mn	Si	Ni	Cr	Mo
15B21RH*	.17/.22	.80/1.10	.15/.35	—	—	—
15B35RH*	.33/.38	.80/1.10	.15/.35	—	—	—
3310RH	.08/.13	.40/.60	.15/.35	3.25/3.75	1.40/1.75	—
4027RH	.25/.30	.70/.90	.15/.35	—	—	.20/.30
4118RH	.18/.23	.70/.90	.15/.35	—	.40/.60	.08/.15
4120RH	.18/.23	.90/1.20	.15/.35	—	.40/.60	.13/.20
4130RH	.28/.33	.40/.60	.15/.35	—	.80/1.10	.15/.25
4140RH	.38/.43	.75/1.00	.15/.35	—	.80/1.10	.15/.25
4145RH	.43/.48	.75/1.00	.15/.35	—	.80/1.10	.15/.25
4161RH	.56/.64	.75/1.00	.15/.35	—	.70/.90	.25/.35
4320RH	.17/.22	.45/.65	.15/.35	1.65/2.00	.40/.60	.20/.30
4620RH	.17/.22	.45/.65	.15/.35	1.65/2.00	—	.20/.30
4820RH	.18/.23	.50/.70	.15/.35	3.25/3.75	—	.20/.30
50B40RH*	.38/.43	.75/1.00	.15/.35	—	.40/.60	—
5130RH	.28/.33	.70/.90	.15/.35	—	.80/1.10	—
5140RH	.38/.43	.70/.90	.15/.35	—	.70/.90	—
5160RH	.56/.64	.75/1.00	.15/.35	—	.70/.90	—
8620RH	.18/.23	.70/.90	.15/.35	.40/.70	.40/.60	.15/.25
8622RH	.20/.25	.70/.90	.15/.35	.40/.70	.40/.60	.15/.25
8720RH	.18/.23	.70/.90	.15/.35	.40/.70	.40/.60	.20/.30
8822RH	.20/.25	.75/1.00	.15/.35	.40/.70	.40/.60	.30/.40
9310RH	.08/.13	.45/.65	.15/.35	3.00/3.50	1.00/1.40	.08/.15

NOTE: *Unless specified: Cu = .35 max, Ni = .25 max, Cr = .20 max, Mo = .06 max.*

* *Boron content is .0005 to .003.*

FORMERLY STANDARD STEELS

Chemical Composition Ranges and Limits

SAE No.	C	Mn	P Max	S Max	Cr	Ni	Mo	V	W
1009	.15 max	.60 max	.040	.050	—	—	—	—	—
1013	.11/.16	.50/.80	.040	.050	—	—	—	—	—
1033	.30/.36	.70/1.00	.040	.050	—	—	—	—	—
1034	.32/.38	.50/.80	.040	.050	—	—	—	—	—
1037	.32/.38	.70/1.00	.040	.050	—	—	—	—	—
1059	.55/.65	.50/.80	.040	.050	—	—	—	—	—
1062	.54/.65	.85/1.15	.040	.050	—	—	—	—	—
1064	.60/.70	.50/.80	.040	.050	—	—	—	—	—
1069	.65/.75	.40/.70	.040	.050	—	—	—	—	—
1075	.70/.80	.40/.70	.040	.050	—	—	—	—	—
1084	.80/.93	.60/.90	.040	.050	—	—	—	—	—
1085	.80/.93	.70/1.00	.040	.050	—	—	—	—	—
1086	.80/.94	.30/.50	.040	.050	—	—	—	—	—
1108	.08/.13	.50/.80	.040	.08/.13	—	—	—	—	—
1109	.08/.13	.60/.90	.040	.08/.13	—	—	—	—	—
1111	.13 max	.60/.90	.07/.12	.10/.15	—	—	—	—	—
1112	.13 max	.70/1.00	.07/.12	.16/.23	—	—	—	—	—
1113	.13 max	.70/1.00	.07/.12	.24/.33	—	—	—	—	—
1114	.10/.16	1.00/1.30	.040	.08/.13	—	—	—	—	—
1115	.13/.18	.60/.90	.040	.08/.13	—	—	—	—	—
1116	.14/.20	1.10/1.40	.040	.16/.23	—	—	—	—	—
1119	.14/.20	1.00/1.30	.040	.24/.33	—	—	—	—	—
1120	.18/.23	.70/1.00	.040	.08/.13	—	—	—	—	—
1126	.23/.29	.70/1.00	.040	.08/.13	—	—	—	—	—
1132	.27/.34	1.35/1.65	.040	.08/.13	—	—	—	—	—
1138	.34/.40	.70/1.00	.040	.08/.13	—	—	—	—	—

continued on next page...

FORMERLY STANDARD STEELS - *CONTINUED*

	Chemical Composition Ranges and Limits								
SAE No.	**C**	**Mn**	**P Max**	**S Max**	**Cr**	**Ni**	**Mo**	**V**	**W**
1139	.35/.43	1.35/1.65	.040	.13/.20	—	—	—	—	—
1145	.42/.49	.70/1.00	.040	.04/.07	—	—	—	—	—
1151	.48/.55	.70/1.00	.040	.08/.13	—	—	—	—	—
1211	.13 max	.60/.90	.07/.12	.10/.15	—	—	—	—	—
1320	.18/.23	1.60/1.90	.040	.040	—	—	—	—	—
1345	.43/.48	1.60/1.90	.035	.040	—	—	—	—	—
1518	.15/.21	1.10/1.40	.040	.050	—	—	—	—	—
1525	.23/.29	.80/1.10	.040	.050	—	—	—	—	—
1536	.30/.37	1.20/1.50	.040	.050	—	—	—	—	—
1547	.43/.51	1.35/1.65	.040	.050	—	—	—	—	—
1551	.45/.56	.85/1.15	.040	.050	—	—	—	—	—
1561	.55/.65	.75/1.05	.040	.050	—	—	—	—	—
1572	.65/.76	1.00/1.30	.040	.050	—	—	—	—	—
2317	.15/.20	.40/.60	—	—	—	3.25/3.75	—	—	—
2330	.28/.33	.60/.80	—	—	—	3.25/3.75	—	—	—
2340	.38/.43	.70/.90	—	—	—	3.25/3.75	—	—	—
2345	.43/.48	.70/.90	—	—	—	3.25/3.75	—	—	—
2512	.09/.14	.45/.60	—	—	—	4.75/5.25	—	—	—
2515	.12/.17	.40/.60	—	—	—	4.75/5.25	—	—	—
2517	.15/.20	.45/.60	—	—	—	4.75/5.25	—	—	—
3115	.13/.18	.40/.60	—	—	.55/.75	1.10/1.40	—	—	—
3120	.17/.22	.60/.80	—	—	.55/.75	1.10/1.40	—	—	—
3130	.28/.33	.60/.80	—	—	.55/.75	1.10/1.40	—	—	—
3135	.33/.38	.60/.80	—	—	.55/.75	1.10/1.40	—	—	—
X3140	.38/.43	.70/.90	—	—	.70/.90	1.10/1.40	—	—	—
3140	.38/.43	.70/.90	—	—	.55/.75	1.10/1.40	—	—	—

FORMERLY STANDARD STEELS - *CONTINUED*

Chemical Composition Ranges and Limits

SAE No.	C	Mn	P Max	S Max	Cr	Ni	Mo	V	W
3145	.43/.48	.70/.90	—	—	.70/.90	1.10/1.40	—	—	—
3150	.48/.53	.70/.90	—	—	.70/.90	1.10/1.40	—	—	—
3215	.10/.20	.30/.60	—	—	.90/1.25	1.50/2.00	—	—	—
3220	.15/.25	.30/.60	—	—	.90/1.25	1.50/2.00	—	—	—
3230	.25/.35	.30/.60	—	—	.90/1.25	1.50/2.00	—	—	—
3240	.35/.45	.30/.60	—	—	.90/1.25	1.50/2.00	—	—	—
3245	.40/.50	.30/.60	—	—	.90/1.25	1.50/2.00	—	—	—
3250	.45/.55	.30/.60	—	—	.90/1.25	1.50/2.00	—	—	—
3310	.08/.13	.45/.60	—	—	1.40/1.75	3.25/3.75	—	—	—
3311	.10/.16	.30/.50	—	—	1.30/1.60	3.25/3.75	.15 max	—	—
3312	.08/.13	.45/.60	—	—	1.40/1.75	3.25/3.75	—	—	—
3316	.14/.19	.45/.60	—	—	1.40/1.75	3.25/3.75	—	—	—
3325	.20/.30	.30/.60	—	—	1.25/1.75	3.25/3.75	—	—	—
3335	.30/.40	.30/.60	—	—	1.25/1.75	3.25/3.75	—	—	—
3340	.35/.45	.30/.60	—	—	1.25/1.75	3.25/3.75	—	—	—
3415	.10/.20	.30/.60	—	—	.60/.95	2.75/3.25	—	—	—
3435	.30/.40	.30/.60	—	—	.60/.95	2.75/3.25	—	—	—
3450	.45/.55	.30/.60	—	—	.60/.95	2.75/3.25	—	—	—
4012	.09/.14	.75/1.00	—	—	—	—	—	—	—
4024†	.20/.25	.70/.90	—	—	—	—	.20/.30	—	—
4032	.30/.35	.70/.90	—	—	—	—	.20/.30	—	—
4042	.40/.45	.70/.90	—	—	—	—	.20/.30	—	—
4053	.50/.56	.75/1.00	—	—	—	—	.20/.30	—	—
4063	.60/.67	.75/1.00	—	—	—	—	.20/.30	—	—
4068	.63/.70	.75/1.00	—	—	—	—	.20/.30	—	—
4119	.17/.22	.70/.90	—	—	.40/.60	—	.20/.30	—	—

continued on next page...

FORMERLY STANDARD STEELS - *CONTINUED*

	Chemical Composition Ranges and Limits								
SAE No.	**C**	**Mn**	**P Max**	**S Max**	**Cr**	**Ni**	**Mo**	**V**	**W**
4125	.23/.28	.70/.90	—	—	.40/.60	—	.20/.30	—	—
4135	.33/.38	.70/.90	—	—	.80/1.10	—	.15/.25	—	—
4161	.56/.64	.75/1.00	—	—	.70/.90	—	.25/.35	—	—
4317	.15/.20	.45/.65	—	—	.40/.60	1.65/2.00	.20/.30	—	—
4337	.35/.40	.60/.80	—	—	.70/.90	1.65/2.00	.20/.30	—	—
4419	.18/.23	.45/.65	—	—	—	—	.45/.60	—	—
4419H	.17/.23	.35/.75	—	—	—	—	.45/.60	—	—
4422	.20/.25	.70/.90	—	—	—	—	.35/.45	—	—
4427	.24/.29	.70/.90	—	—	—	—	.35/.45	—	—
4608	.06/.11	.25/.45	—	—	—	1.40/1.75	.15/.25	—	—
46B12*	.10/.15	.45/.65	—	—	—	1.65/2.00	.20/.30	—	—
4615	.13/.18	.45/.65	—	—	—	1.65/2.00	.20/.30	—	—
4617	.15/.20	.45/.65	—	—	—	1.65/2.00	.20/.30	—	—
X4620	.18/.23	.50/.70	—	—	—	1.65/2.00	.20/.30	—	—
4621	.18/.23	.70/.90	—	—	—	1.65/2.00	.20/.30	—	—
4621H	.17/.23	.60/1.00	—	—	—	1.55/2.00	.20/.30	—	—
4626	.24/.29	.45/.65	—	—	—	.70/1.00	.15/.25	—	—
4640	.38/.43	.60/.80	—	—	—	1.65/2.00	.20/.30	—	—
4718	.16/.21	.70/.90	—	—	.35/.55	.90/1.20	.30/.40	—	—
4812	.10/.15	.40/.60	—	—	—	3.25/3.75	.20/.30	—	—
4817	.15/.20	.40/.60	—	—	—	3.25/3.75	.20/.30	—	—
5015	.12/.17	.30/.50	—	—	.30/.50	—	—	—	—
50B40*	.38/.43	.75/1.00	—	—	.40/.60	—	—	—	—
50B44*	.43/.48	.75/1.00	—	—	.40/.60	—	—	—	—
5045	.43/.48	.70/.90	—	—	.55/.75	—	—	—	—
5046	.43/.48	.75/1.00	—	—	.20/.35	—	—	—	—

FORMERLY STANDARD STEELS - *CONTINUED*

Chemical Composition Ranges and Limits

SAE No.	C	Mn	P Max	S Max	Cr	Ni	Mo	V	W
50B50*	.48/.53	.75/1.00	—	—	.40/.60	—	—	—	—
5060	.56/.64	.75/1.00	—	—	.40/.60	—	—	—	—
50B60*	.56/.64	.75/1.00	—	—	.40/.60	—	—	—	—
5115	.13/.18	.70/.90	—	—	.70/.90	—	—	—	—
5117	.15/.20	.70/.90	—	—	.70/.90	—	—	—	—
5135	.33/.38	.60/.80	—	—	.80/1.05	—	—	—	—
5145	.43/.48	.70/.90	—	—	.70/.90	—	—	—	—
5145H	.42/.49	.60/1.00	—	—	.60/1.00	—	—	—	—
5147	.46/.51	.70/.95	—	—	.85/1.15	—	—	—	—
5152	.48/.55	.70/.90	—	—	.90/1.20	—	—	—	—
5155	.51/.59	.70/.90	—	—	.70/.90	—	—	—	—
50100	.98/1.10	.25/.45	—	—	.40/.60	—	—	—	—
6115	.10/.20	.30/.60	—	—	.80/1.10	—	—	.15 min	—
6117	.15/.20	.70/.90	—	—	.70/.90	—	—	.10 min	—
6118	.16/.21	.50/.70	—	—	.50/.70	—	—	.10/.15	—
6120	.17/.22	.70/.90	—	—	.70/.90	—	—	.10 min	—
6125	.20/.30	.60/.90	—	—	.80/1.10	—	—	.15 min	—
6130	.25/.35	.60/.90	—	—	.80/1.10	—	—	.15 min	—
6135	.30/.40	.60/.90	—	—	.80/1.10	—	—	.15 min	—
6140	.35/.45	.60/.90	—	—	.80/1.10	—	—	.15 min	—
6145	.43/.48	.70/.90	—	—	.80/1.10	—	—	.15 min	—
6195	.90/1.05	.20/.45	—	—	.80/1.10	—	—	.15 min	—
71360	.50/.70	.30 max	—	—	3.00/4.00	—	—	—	12.00/15.00
71660	.50/.70	.30 max	—	—	3.00/4.00	—	—	—	15.00/18.00
7260	.50/.70	.30 max	—	—	.50/1.00	—	—	—	1.05/2.00
8115	.13/.18	.70/.90	—	—	.30/.50	.20/.40	.08/.15	—	—

continued on next page...

FORMERLY STANDARD STEELS - *CONTINUED*

Chemical Composition Ranges and Limits

SAE No.	C	Mn	P Max	S Max	Cr	Ni	Mo	V	W
81B45*	.43/.48	.75/1.00	—	—	.35/.55	.20/.40	.08/.15	—	—
8625	.23/.28	.70/.90	—	—	.40/.60	.40/.70	.15/.25	—	—
8627	.25/.30	.70/.90	—	—	.40/.60	.40/.70	.15/.25	—	—
8632	.30/.35	.70/.90	—	—	.40/.60	.40/.70	.15/.25	—	—
8635	.33/.38	.75/1.00	—	—	.40/.60	.40/.70	.15/.25	—	—
8641§	.38/.43	.75/1.00	—	—	.40/.60	.40/.70	.15/.25	—	—
8642	.40/.45	.75/1.00	—	—	.40/.60	.40/.70	.15/.25	—	—
86B45*	.43/.48	.75/1.00	—	—	.40/.60	.40/.70	.15/.25	—	—
8647	.45/.50	.75/1.00	—	—	.40/.60	.40/.70	.15/.25	—	—
8650	.48/.53	.75/1.00	—	—	.40/.60	.40/.70	.15/.25	—	—
8653	.50/.56	.75/1.00	—	—	.50/.80	.40/.70	.15/.25	—	—
8655	.51/.59	.75/1.00	—	—	.40/.60	.40/.70	.15/.25	—	—
8660	.56/.64	.75/1.00	—	—	.40/.60	.40/.70	.15/.25	—	—
8715	.13/.18	.70/.90	—	—	.40/.60	.40/.70	.20/.30	—	—
8717	.15/.20	.70/.90	—	—	.40/.60	.40/.70	.20/.30	—	—
8719	.18/.23	.60/.80	—	—	.40/.60	.40/.70	.20/.30	—	—
8735	.33/.38	.75/1.00	—	—	.40/.60	.40/.70	.20/.30	—	—
8740	.38/.43	.75/1.00	—	—	.40/.60	.40/.70	.20/.30	—	—
8742	.40/.45	.75/1.00	—	—	.40/.60	.40/.70	.20/.30	—	—
8745	.43/.48	.75/1.00	—	—	.40/.60	.40/.70	.20/.30	—	—
8750	.48/.53	.75/1.00	—	—	.40/.60	.40/.70	.20/.30	—	—
9250[1]	.45/.55	.60/.90	—	—	—	—	—	—	—
9254[2]	.51/.59	.60/.80	—	—	.60/.80	—	—	—	—
9255[1]	.51/.59	.70/.95	—	—	—	—	—	—	—
9261[1]	.55/.65	.75/1.00	—	—	.10/.25	—	—	—	—
9262[1]	.55/.65	.75/1.00	—	—	.25/.40	—	—	—	—

FORMERLY STANDARD STEELS - *CONTINUED*

Chemical Composition Ranges and Limits

SAE No.	C	Mn	P Max	S Max	Cr	Ni	Mo	V	W
9310	.08/.13	.45/.65	—	—	1.00/1.40	3.00/3.50	.08/.15	—	—
9315	.13/.18	.45/.65	—	—	1.00/1.40	3.00/3.50	.08/.15	—	—
9317	.15/.20	.45/.65	—	—	1.00/1.40	3.00/3.50	.08/.15	—	—
94B15	.13/.18	.75/1.00	—	—	.30/.50	.30/.60	.08/.15	—	—
94B17	.15/.20	.75/1.00	—	—	.30/.50	.30/.60	.08/.15	—	—
94B30*	.28/.33	.75/1.00	—	—	.30/.50	.30/.60	.08/.15	—	—
9437	.35/.40	.90/1.20	—	—	.30/.50	.30/.60	.08/.15	—	—
9440	.38/.43	.90/1.20	—	—	.30/.50	.30/.60	.08/.15	—	—
94B40*	.38/.43	.75/1.00	—	—	.30/.60	.30/.60	.08/.15	—	—
9442	.40/.45	.90/1.20	—	—	.30/.50	.30/.60	.08/.15	—	—
9445	.43/.48	.90/1.20	—	—	.30/.50	.30/.60	.08/.15	—	—
9447	.45/.50	.90/1.20	—	—	.30/.50	.30/.60	.08/.15	—	—
9747	.45/.50	.50/.80	—	—	.10/.25	.40/.70	.15/.25	—	—
9763	.60/.67	.50/.80	—	—	.10/.25	.40/.70	.15/.25	—	—
9840	.38/.43	.70/.90	—	—	.70/.90	.85/1.15	.20/.30	—	—
9845	.43/.48	.70/.90	—	—	.70/.90	.85/1.15	.20/.30	—	—
9850	.48/.53	.70/.90	—	—	.70/.90	.85/1.15	.20/.30	—	—
43BV12*	.08/.13	.75/1.00	—	—	.40/.60	1.65/2.00	.20/.30	.03 min	—
43BV14*	.10/.15	.45/.65	—	—	.40/.60	1.65/2.00	.08/.15	.03 min	—

* *Boron content is .0005 to .003.*
§ *Sulfur content is .04/.60.*
1 *Silicon = 1.80/2.20.*
2 *Silicon = 1.20/1.60.*

SELECTED MILITARY SPECIFICATIONS

Chemical Composition Ranges and Limits

MIL	C	Mn	P Max	S Max	Si	Cr	Ni	Mo	Nearest Equivalent AMS	Nearest Equivalent SAE No.
S-5000	.38/.43	.65/.85	.025	.025	.15/.35	.70/.90	1.65/2.00	.20/.30	6415	E4340
S-50783[1]	1.00/1.15	1.60/1.90	.035	.040	.70/1.00	.20 max	.25 max	.06 max	—	—
S-5626	.38/.43	.75/1.00	.025	.025	.20/.35	.80/1.10	.25 max	.15/.25	6382	4140
S-6049	.38/.43	.75/1.00	.025	.025	.20/.35	.40/.60	.40/.70	.20/.30	638740	—
S-6050	.28/.33	.70/.90	.025	.025	.20/.35	.40/.60	.40/.70	.15/.25	6280	8630
S-6709[2]	.38/.43	.50/.70	.025	.025	.20/.40	1.40/1.80	—	.30/.40	6470	—
S-6758	.28/.33	.40/.60	.025	.025	.20/.35	.80/1.10	.25 max	.15/.25	637	4130
S-7108[3]	.23/.28	1.20/1.50	.040	.040	1.30/1.70	.40 max	1.65/2.00	.35/.45	6418	4625M4
S-7393	.08/.13	.45/.60	.015	.015	.20/.35	1.25/1.75	3.25/3.75	—	6250	3310
	.14/.19	.45/.60	.025	.025	.20/.35	1.25/1.75	3.25/4.00	—	—	3316
	.07/.13	.40/.70	.025	.025	.20/.35	1.00/1.40	3.00/3.50	.08/.15	—	9310
S-7420	.95/1.10	.25/.45	.025	.025	.20/.35	1.30/1.60	—	—	6440	52100
S-8503[5]	.48/.53	.70/.90	.025	.025	.20/.35	.75/1.20	—	—	6448	6150
S-8690[4]	.18/.23	.70/1.00	.025	.025	.20/.35	.40/.60	.40/.70	.15/.25	6274	8620
S-8695[3]	.34/.41	.60/1.00	.040	.040	.20/.35	—	—	.20/.30	6300	4037
S-8699[3,6]	.28/.33	.80/1.00	.040	.040	.20/.35	.75/.95	1.65/2.00	.35/.50	6427	4330M4V1
S-8707	.38/.43	.70/.90	.040	.040	.20/.35	.70/.90	.85/1.15	.20/.30	6342	9840
S-8844-1	.38/.43	.65/.90	.010	.010	.15/.35	.70/.90	1.65/2.00	.20/.30	—	4340
S-8844-3[6]	.40/.45	.65/.90	.010	.010	1.45/1.80	.70/.95	1.65/2.00	.35/.45	—	300M
T-5066	.22/.28	.30/.60	.025	.025	.30 max	—	—	—	—	1025
S-11595[7]	.48/.55	.75/1.00	.040	.040	.20/.35	.80/1.10	—	.15/.25	—	4150
S-11595[7]	.47/.55	.70/1.00	.040	.05/.09	.20/.35	.80/1.15	—	.15/.25	—	41R50
S-11595[7,8]	.41/.49	.60/.90	.040	.040	.20/.35	.80/1.15	—	.30/.40	—	4142M3V2
S-46047[8]	.38/.45	.75/1.00	.025	.020	.20/.35	.95/1.25	—	.55/.70	—	—

NOTE: *Aircraft quality steels except where indicated. Cu = .35 max unless specified.*

1 *Al = .020 max.* **2** *Al = .95/1.35.* **3** *P & S = .025 max if Basic Electric Furnace Steel is specified.* **4** *P & S = .015 max if consumable vacuum melted steel is specified.* **5** *V = .15 min.* **6** *V = .05/.10.* **7** *Al = .040 max.* **8** *V = .20/.30.*

SELECTED AMS ALLOY STEEL SPECIFICATIONS

Chemical Composition Ranges and Limits

AMS No.	C	Mn	Si	Cr	Ni	Mo	V	Other Designations
6250	.07/.13	.40/.70	.15/.35	1.25/1.75	3.25/3.75	.06 max	—	3310
6260[1]	.07/.13	.40/.70	.15/.35	1.00/1.40	3.00/3.50	.08/.15	—	9310
6263	.11/.17	.40/.70	.15/.35	1.00/1.40	3.00/3.50	.08/.15	—	9315
6264	.14/.20	.40/.70	.15/.35	1.00/1.40	3.00/3.50	.08/.15	—	9317
6265[2]	.07/.13	.40/.70	.15/.35	1.00/1.40	3.00/3.50	.08/.15	—	9310
6266[3]	.08/.13	.75/1.00	.20/.40	.40/.60	1.65/2.00	.20/.30	.03/.08	43BV12
6270	.11/.17	.70/1.00	.15/.35	.40/.60	.40/.70	.15/.25	—	8615
6272	.15/.20	.70/1.00	.15/.35	.40/.60	.40/.70	.15/.25	—	8617
6274	.17/.23	.75/1.00	.15/.35	.35/.65	.35/.75	.15/.25	—	8620
6275[3]	.15/.20	.60/.95	.15/.35	.30/.50	.30/.60	.08/.15	—	94B17
6280	.28/.33	.70/.90	.15/.35	.40/.60	.40/.70	.15/.25	—	8630
6281	.28/.33	.70/.90	.15/.35	.40/.60	.40/.70	.15/.25	—	8630
6282	.33/.38	.75/1.00	.15/.35	.40/.60	.40/.70	.20/.30	—	8735
6290	.11/.17	.45/.65	.15/.35	.20 max	1.65/2.00	.20/.30	—	4615
6292	.15/.20	.45/.65	.15/.35	.20 max	1.65/2.00	.20/.30	—	4617
6294	.17/.22	.45/.65	.15/.35	.20 max	1.65/2.00	.20/.30	—	4620
6299	.17/.23	.40/.70	.15/.35	.35/.65	1.55/2.00	.20/.30	—	4320
6300[4]	.35/.40	.70/.90	.15/.35	.20 max	.25 max	.20/.30	—	4037
6302	.28/.33	.45/.65	.55/.75	1.00/1.50	.25 max	.40/.60	.20/.30	17-22-AS®
6303[5]	.25/.30	.60/.90	.55/.75	1.00/1.50	.50 max	.40/.60	.75/.95	17-22-AV®
6304	.40/.50	.40/.70	.15/.35	.80/1.10	.25 max	.45/.65	.25/.35	—
6312	.38/.43	.60/.80	.15/.35	.20 max	1.65/2.00	.20/.30	—	4640
6320	.33/.38	.75/1.00	.15/.35	.40/.60	.40/.70	.20/.30	—	8735
6321[3]	.38/.43	.75/1.00	.15/.35	.30/.55	.20/.40	.08/.15	—	81B40
6322	.38/.43	.75/1.00	.15/.35	.40/.60	.40/.70	.20/.30	—	8740

continued on next page...

SELECTED AMS ALLOY STEEL SPECIFICATIONS - *CONTINUED*

Chemical Composition Ranges and Limits

AMS No.	C	Mn	Si	Cr	Ni	Mo	V	Other Designations
6323	.38/.43	.75/1.00	.15/.35	.40/.60	.40/.70	.20/.30	—	8740
6324	.38/.43	.75/1.00	.15/.35	.55/.75	.55/.85	.20/.30	—	8740 Mod
6328	.48/.53	.75/1.00	.15/.35	.40/.60	.40/.70	.20/.30	—	8750
6342	.38/.43	.70/.90	.15/.35	.70/.90	.85/1.15	.20/.30	—	9840
6371	.28/.33	.40/.60	.15/.35	.80/1.10	.25 max	.15/.25	—	4130
6372	.33/.38	.70/.90	.15/.35	.80/1.10	.25 max	.15/.25	—	4135
6381	.38/.43	.75/1.00	.15/.35	.80/1.10	.25 max	.15/.25	—	4140
6382	.38/.43	.75/1.00	.15/.35	.80/1.10	.25 max	.15/.25	—	4140
6407	.27/.33	.60/.80	.40/.70	1.00/1.35	1.85/2.25	.35/.55	—	HS220-07
6409[6]	.38/.43	.65/.85	.15/.35	.70/.90	1.65/2.00	.20/.30	—	4340*
6412	.35/.40	.65/.85	.15/.35	.70/.90	1.65/2.00	.20/.30	—	4337
6414[2]	.38/.43	.60/.90	.15/.35	.70/.90	1.65/2.00	.20/.30	—	CV4340
6415	.38/.43	.65/.85	.15/.35	.70/.90	1.65/2.00	.20/.30	—	4340
6418	.23/.28	1.20/1.50	1.30/1.70	.20/.40	1.65/2.00	.35/.45	—	4625M4
6419[7]	.40/.45	.60/.90	1.45/1.80	.70/.95	1.65/2.00	.30/.50	.05/.10	300M
6421[3]	.35/.40	.65/.85	.15/.35	.70/.90	.70/1.00	.15/.25	—	98B37 Mod
6422[3]	.38/.43	.65/.85	.15/.35	.70/.90	.70/1.00	.15/.25	.01/.06	98B40 Mod
6427	.28/.33	.75/1.00	.15/.35	.75/1.00	1.65/2.00	.35/.50	.05/.10	4330M4V1
6428	.32/.38	.60/.80	.15/.35	.65/.90	1.65/2.00	.30/.40	.17/.23	—
6430[2]	.32/.38	.60/.90	.40/.60	.65/.90	1.65/2.00	.30/.40	.17/.23	4335M4V2
6431[7]	.45/.50	.60/.90	.15/.30	.90/1.20	.40/.70	.90/1.10	.08/.15	D6-AC
6440	.98/1.10	.25/.45	.15/.35	1.30/1.60	.25 max	.10 max	—	52100
6444[2]	.98/1.10	.25/.45	.15/.35	1.30/1.60	.25 max	.08 max	—	CV52100
6445[2]	.92/1.02	.95/1.25	.50/.70	.90/1.15	.25 max	.08 max	—	51100
6448	.48/.53	.70/.90	.15/.35	.80/1.10	.25 max	.06 max	.15/.30	6150

NOTE: *P & S = .025 max, Cu = .35 max unless specified.*

* *Special Aircraft Quality.*

1 *Boron = .001 max.* **2** *P & S = .015 max.* **3** *Boron = .0005/.005.* **4** *P & S = .040 max.* **5** *Cu = .50 max.* **6** *P = .015 max, S = .008 max.* **7** *P & S = .010 max.*

NOTES

SELECTED ASTM SPECIFICATIONS

Chemical Composition Ranges and Limits

ASTM No.	Grade	C	Mn	Si	Cr	Ni	Mo	V	Others
A106*	A	.25 max	.27/.93	.10 min	.40 max	.40 max	.15 max	.08 max	—
	B	.30 max	.29/1.06	.10 min	.40 max	.40 max	.15 max	.08 max	—
	C	.35 max	.29/1.06	.10 min	.40 max	.40 max	.15 max	.08 max	—
A182	F11	.10/.20	.30/.80	.50/1.00	1.00/1.50	—	.44/.65	—	—
	F12	.10/.20	.30/.80	.10/.60	.80/1.25	—	.44/.65	—	—
A192	A	.06/.18	.27/.63	.25 max	—	—	—	—	—
A200	T4	.05/.15	.30/.60	.50/1.00	2.15/2.85	—	.44/.65	—	—
	T5†	.15 max	.30/.60	.50 max	4.00/6.00	—	.44/.65	—	—
	T7†	.15 max	.30/.60	.50/1.00	6.00/8.00	—	.44/.65	—	—
	T9†	.15 max	.30/.60	.25/1.00	8.00/10.00	—	.90/1.10	—	—
	T11†	.05/.15	.30/.60	.50/1.00	1.00/1.50	—	.44/.65	—	—
	T21†	.05/.15	.30/.60	.50 max	2.65/3.65	—	.80/1.06	—	—
	T22†	.05/.15	.30/.60	.50 max	1.90/2.60	—	.87/1.13	—	—
	T91**	.08/.12	.30/.60	.20/.50	8.00/9.00	.40 max	.85/1.05	.18/.25	—
A209	T1	.10/.20	.30/.80	.10/.50	—	—	.44/.65	—	—
	T1b	.14 max	.30/.80	.10/.50	—	—	.44/.65	—	—
A210	A1	.27 max	.93 max	.10 min	—	—	—	—	—
	C	.35 max	.29/1.06	.10 min	—	—	—	—	—
A213	T5b	.15 max	.30/.60	1.00/2.00	4.90/6.00	—	.44/.65	—	—
	T5c	.12 max	.30/.60	.50 max	4.00/6.00	—	.44/.65	—	Ti = 4 x C min, .70 max

NOTE: *See current ASTM Specifications for P & S limitations.*

* *The combined elements of Cr, Ni, Mo, V and Cu must not exceed 1%.*

† *These grades also included in ASTM Specifications A213 and A335.*

** *Cb = .06/.10, N = .03/.07, Al = .04 max.*

ASTM GRADES A213/A213M

FERRITIC STEEL[A]

Composition, %

Grade	C	Mn	P Max	S Max	Si	Cr	Mo	Ti	V	Nb	N	Ni	Al
T2[c]	.10/.20	.30/.61	.025	.025	.10/.30	.50/.81	.44/.65	—	—	—	—	—	—
T5	.15 max	.30/.60	.025	.025	.50 max	4.00/6.00	.45/.65	—	—	—	—	—	—
T5[b]	.15 max	.30/.60	.025	.025	1.00/2.00	4.00/6.00	.45/.65	—	—	—	—	—	—
T5[c]	.12 max	.30/.60	.025	.025	.50 max	4.00/6.00	.45/.65	A	—	—	—	—	—
T9	.15 max	.30/.60	.025	.025	.25/1.00	8.00/10.00	.90/1.10	—	—	—	—	—	—
T11	.05 min/15 max	.30/.60	.025	.025	.50/1.00	1.00/1.50	.44/.65	—	—	—	—	—	—
T12[c]	.05 min/15 max	.30/.61	.025	.025	.50 max	.80/1.25	.44/.65	—	—	—	—	—	—
T17	.15/.25	.30/.61	.025	.025	.15/.35	.80/1.25	—	—	.15	—	—	—	—
T21	.05 min/15 max	.30/.60	.025	.025	.50 max	2.65/3.35	.80/1.06	—	—	—	—	—	—
T22	.05 min/15 max	.30/.60	.025	.025	.50 max	1.90/2.60	.87/1.13	—	—	—	—	—	—
T91	.08/.12	.30/.60	.020	.010	.20/.50	8.00/9.50	.85/1.05	—	.18/.25	.06/.10	.030/.070	.40 max	.04 max
13Cr	.15/.22	.25/1.00	.020	.010	1.00 max	12.00/14.00	—	—	—	—	—	—	—

A *Grade T5c shall have a titanium content of not less than four times the carbon content and not more than 0.70%.*
b *Grade 18Cr-2Mo shall have Ti + Nb = 0.20 + 4 (C + N) min., 0.80 max.*
c *It is permissible to order T2 and T12 with 0.045 max. Sulfur.*

GERMAN INDUSTRIAL STANDARDS
CARBON STEELS AND ALLOY STEELS

DIN 17200

Chemical Composition, %

Steel Grade	C	Si Max	Mn	P Max	S Max	Cr	Mo	Ni	V
C 10	.07/.13	.40	.30/.60	.045	.045	—	—	—	—
C 15	.12/.18	.40	.30/.60	.045	.045	—	—	—	—
C 20	.17/.23	.40	.30/.60	.045	.045	—	—	—	—
C 22*	.17/.24	.40	.30/.60	.045	.045	—	—	—	—
C 25*	.22/.29	.40	.40/.70	.045	.045	—	—	—	—
C 30*	.27/.34	.40	.50/.80	.045	.045	—	—	—	—
C 35*	.32/.39	.40	.50/.80	.045	.045	—	—	—	—
C 40*	.37/.44	.40	.50/.80	.045	.045	—	—	—	—
C 45*	.42/.50	.40	.50/.80	.045	.045	—	—	—	—
C 50*	.47/.55	.40	.60/.90	.045	.045	—	—	—	—
C 55*	.52/.60	.40	.60/.90	.045	.045	—	—	—	—
C 60*	.57/.65	.40	.60/.90	.045	.045	—	—	—	—
28 Mn 6	.25/.35	.40	1.30/1.65	.035	.03	—	—	—	—
32 Cr 2	.28/.35	.40	.50/.80	.035	.03	.40/.60	—	—	—
32 CrS 2	.28/.35	.40	.50/.80	.035	.020/.035	.40/.60	—	—	—
38 Cr 2	.35/.42	.40	.50/.80	.035	.03	.40/.60	—	—	—
38 CrS 2	.35/.42	.40	.50/.80	.035	.020/.035	.40/.60	—	—	—
46 Cr 2	.42/.50	.40	.50/.80	.035	.03	.40/.60	—	—	—
46 CrS 2	.42/.50	.40	.50/.80	.035	.020/.035	.40/.60	—	—	—

**Ck has same chemical composition except %S is .03 max.*

Cm has same chemical composition except %S is .020/.035 max.

GERMAN INDUSTRIAL STANDARDS
CARBON STEELS AND ALLOY STEELS - *CONTINUED*

DIN 17200

Chemical Composition, %

Steel Grade	C	Si Max	Mn	P Max	S Max	Cr	Mo	Ni	V
28 Cr 4	.24/.31	.40	.60/.90	.035	.03	.90/1.20	—	—	—
28 CrS 4	.24/.31	.40	.60/.90	.035	.020/.035	.90/1.20	—	—	—
34 Cr 4	.30/.37	.40	.60/.90	.035	.03	.90/1.20	—	—	—
34 CrS4	.30/.37	.40	.60/.90	.035	.020/.035	.90/1.20	—	—	—
37 Cr 4	.34/.41	.40	.60/.90	.035	.03	.90/1.20	—	—	—
37 CrS 4	.34/.41	.40	.60/.90	.035	.020/.035	.90/1.20	—	—	—
41 Cr 4	.38/.45	.40	.60/.90	.035	.03	.90/1.20	—	—	—
41 CrS 4	.38/.45	.40	.60/.90	.035	.020/.035	.90/1.20	—	—	—
25 CrMo 4	.22/.29	.40	.60/.90	.035	.03	.90/1.20	.15/.30	—	—
25 CrMoS 4	.22/.29	.40	.60/.90	.035	.020/.035	.90/1.20	.15/.30	—	—
34 CrMo 4	.30/.37	.40	.60/.90	.035	.03	.90/1.20	.15/.30	—	—
34 CrMoS 4	.30/.37	.40	.60/.90	.035	.020/.035	.90/1.20	.15/.30	—	—
42 CrMo 4	.38/.45	.40	.60/.90	.035	.03	.90/1.20	.15/.30	—	—
42 CrMoS 4	.38/.45	.40	.60/.90	.035	.020/.035	.90/1.20	.15/.30	—	—
50 CrMo 4	.46/.54	.40	.50/.80	.035	.03	.90/1.20	.15/.30	—	—
36 CrNiMo 4	.32/.40	.40	.50/.80	.035	.03	.90/1.20	.15/.30	.90/1.20	—
34 CrNiMo 6	.30/.38	.40	.40/.70	.035	.03	1.40/1.70	.15/.30	1.40/1.70	—
30 CrNiMo 8	.26/.34	.40	.30/.60	.035	.03	1.80/2.20	.30/.50	1.80/2.20	—
50 CrV 4	.47/.55	.40	.70/1.10	.035	.03	.90/1.20	—	—	.10/.20
30 CrMoV 9	.26/.34	.40	.40/.70	.035	.03	2.30/2.70	.15/.25	—	.10/.20

continued on next page...

GERMAN INDUSTRIAL STANDARDS
CARBON STEELS AND ALLOY STEELS

DIN 17210

Chemical Composition, %*

Steel Grade	C	Si Max	Mn	P Max	S Max	Cr	Mo	Ni
C 10	.07/.13	.15/.35	.30/.60	.045	.045	—	—	—
C 15	.12/.18	.15/.35	.30/.60	.045	.045	—	—	—
Ck 10	.07/.13	.15/.35	.30/.60	.035	.035	—	—	—
Ck 15	.12/.18	.15/.35	.30/.60	.035	.035	—	—	—
15 Cr 3	.12/.18	.15/.40	.40/.60	.035	.035	.40/.70	—	—
16 MnCr 5	.14/.19	.15/.40	1.00/1.30	.035	.035	.80/1.10	—	—
20 MnCr 5	.17/.22	.15/.40	1.10/1.40	.035	.035	1.00/1.30	—	—
20 MoCr 4	.17/.22	.15/.40	.60/.90	.035	.035	.30/.50	.40/.50	—
25 MoCr 4	.23/.29	.15/.40	.60/.90	.035	.035	.40/.60	.40/.50	—
15 CrNi 6	.12/.17	.15/.40	.40/.60	.035	.035	1.40/1.70	—	1.40/1.70
17 CrNiMo 6	.14/.19	.15/.40	.40/.60	.035	.035	1.50/1.80	.25/.35	1.40/1.70

* *Alloy steels intended for direct quenching shall contain at least 0.02% by weight. of metallic (acid soluble) aluminum.*

GERMAN INDUSTRIAL STANDARDS
THROUGH HARDENING BEARING STEELS

DIN 17230								
	Chemical Composition, %							
Steel Grade	**C**	**Si**	**Mn**	**P Max**	**S Max**	**Cr**	**Mo**	**Ni Max**
100 Cr2	.90/1.05	.15/.35	.25/.44	.030	.025	.40/.60	.10 max	.30
100 Cr6	.90/1.05	.15/.36	.25/.45	.030	.025	1.35/1.60	.10 max	.30
100 CrMn6	.90/1.05	.50/.70	1.00/1.20	.030	.025	1.40/1.65	.10 max	.30
100 CrMo7	.90/1.05	.20/.40	.25/.45	.030	.025	1.65/1.95	.15/.25	.30
100 CrMo7 3	.90/1.05	.20/.40	.60/.80	.030	.025	1.65/1.95	.20/.35	.30
100 CrMnMo 8	.90/1.05	.40/.60	.80/1.10	.030	.025	1.80/2.05	.50/.60	.30

USA - GERMAN - JAPANESE
NEAR EQUIVALENT GRADES

USA	German	Japanese
1330	30Mn5	SCMn2
1335	36Mn5	SMn2
4118	20CrMo5	SCM418
4130	25CrMo4	SCM430
4140	42CrMo4	SCM440
4340	40NiCrMo6	SNCM439
8620	21NiCrMo2	SNCM220
8640	40NiCrMo22	SNCM240
5120	20Cr4	SCr420
5130	28Cr4	SCr430
5140	41Cr4	SCr440
52100	100Cr6	SUJ2

JAPANESE INDUSTRIAL STANDARDS
CARBON STEELS

JIS G 4051

Chemical Composition, %

Steel Grade	C	Si	Mn	P	S	Steel Grade	C	Si	Mn	P	S
S 10 C	.08/.13	.15/.35	.30/.60	.030 max	.035 max	**S 40 C**	.37/.43	.15/.35	.60/.90	.030 max	.035 max
S 12 C	.10/.15	.15/.35	.30/.60	.030 max	.035 max	**S 43 C**	.40/.46	.15/.35	.60/.90	.030 max	.035 max
S 15 C	.13/.18	.15/.35	.30/.60	.030 max	.035 max	**S 45 C**	.42/.48	.15/.35	.60/.90	.030 max	.035 max
S 17 C	.15/.20	.15/.35	.30/.60	.030 max	.035 max	**S 48 C**	.45/.51	.15/.35	.60/.90	.030 max	.035 max
S 20 C	.18/.23	.15/.35	.30/.60	.030 max	.035 max	**S 50 C**	.47/.53	.15/.35	.60/.90	.030 max	.035 max
S 22 C	.20/.25	.15/.35	.30/.60	.030 max	.035 max	**S 53 C**	.50/.56	.15/.35	.60/.90	.030 max	.035 max
S 25 C	.22/.28	.15/.35	.30/.60	.030 max	.035 max	**S 55 C**	.52/.58	.15/.35	.60/.90	.030 max	.035 max
S 28 C	.25/.31	.15/.35	.60/.90	.030 max	.035 max	**S 58 C**	.55/.61	.15/.35	.60/.90	.030 max	.035 max
S 30 C	.27/.33	.15/.35	.60/.90	.030 max	.035 max	**S 09 CK**	.07/.12	.10/.35	.30/.60	.025 max	.025 max
S 33 C	.30/.36	.15/.35	.60/.90	.030 max	.035 max	**S 15 CK**	.13/.18	.15/.35	.30/.60	.025 max	.025 max
S 35 C	.32/.38	.15/.35	.60/.90	.030 max	.035 max	**S 20 CK**	.18/.23	.15/.35	.30/.60	.025 max	.025 max
S 38 C	.35/.41	.15/.35	.60/.90	.030 max	.035 max						

NOTE: *As impurities, Cu, Ni, Cr and Ni + Cr for grades S 09 CK, S 15 CK, S 20 CK shall not exceed respectively 0.25%, 0.20%, 0.20% and 0.30%, and Cu, Ni, Cr and Ni + Cr for other grades shall not exceed respectively 0.30%, 0.20%, 0.20% and 0.35%.*

JAPANESE INDUSTRIAL STANDARDS
MANGANESE STEELS AND MANGANESE CHROMIUM STEELS

JIS G 4106

Chemical Composition, %

Steel Grade	C	Si	Mn	P	S	Cr
SMn 420	.17/.23	.15/.35	1.20/1.50	.030 max	.030 max	—
SMn 433	.30/.36	.15/.35	1.20/1.50	.030 max	.030 max	—
SMn 438	.35/.41	.15/.35	1.35/1.65	.030 max	.030 max	—
SMn 443	.40/.46	.15/.35	1.35/1.65	.030 max	.030 max	—
SMnC 420	.17/.23	.15/.35	1.20/1.50	.030 max	.030 max	.35/.70
SMnC 443	.40/.46	.15/.35	1.35/1.65	.030 max	.030 max	.35/.70

NOTE: *As impurities Ni and Cu shall not exceed 0.25% and 0.30%, respectively, for all grades. SMn 420, SMn433, SMn438 and SMn 443 shall not contain Cr exceeding 0.35%.*

JAPANESE INDUSTRIAL STANDARDS
CHROMIUM STEELS

JIS G 4104

Chemical Composition, %

Steel Grade	C	Si	Mn	P	S	Cr
SCr 415	.13/.18	.15/.35	.60/.85	.030 max	.030 max	.90/1.20
SCr 420	.18/.23	.15/.35	.60/.85	.030 max	.030 max	.90/1.20
SCr 430	.28/.33	.15/.35	.60/.85	.030 max	.030 max	.90/1.20
SCr 435	.33/.38	.15/.35	.60/.85	.030 max	.030 max	.90/1.20
SCr 440	.38/.43	.15/.35	.60/.85	.030 max	.030 max	.90/1.20
SCr 445	.43/.48	.15/.35	.60/.85	.030 max	.030 max	.90/1.20

NOTE: *As impurities, Ni and Cu shall not exceed 0.25% and 0.30%, respectively, for all grades.*

JAPANESE INDUSTRIAL STANDARDS
CHROMIUM MOLYBDENUM STEELS

JIS G 4105

Chemical Composition, %

Steel Grade	C	Si	Mn	P	S	Cr	Mo
SCM 415	.13/.18	.15/.35	.60/.85	.030 max	.030 max	.90/1.20	.15/.30
SCM 418	.16/.21	.15/.35	.60/.85	.030 max	.030 max	.90/1.20	.15/.30
SCM 420	.18/.23	.15/.35	.60/.85	.030 max	.030 max	.90/1.20	.15/.30
SCM 421	.17/.23	.15/.35	.70/1.00	.030 max	.030 max	.90/1.20	.15/.30
SCM 430	.28/.33	.15/.35	.60/.85	.030 max	.030 max	.90/1.20	.15/.30
SCM 432	.27/.37	.15/.35	.30/.60	.030 max	.030 max	1.00/1.50	.15/.30
SCM 435	.33/.38	.15/.35	.60/.85	.030 max	.030 max	.90/1.20	.15/.30
SCM 440	.38/.43	.15/.35	.60/.85	.030 max	.030 max	.90/1.20	.15/.30
SCM 445	.43/.48	.15/.35	.60/.85	.030 max	.030 max	.90/1.20	.15/.30
SCM 822	.20/.25	.15/.35	.60/.85	.030 max	.030 max	.90/1.20	.35/.45

NOTE: *As impurities, Ni and Cu shall not exceed 0.25% and 0.30%, respectively, for all grades.*

JAPANESE INDUSTRIAL STANDARDS
NICKEL MOLYBDENUM CHROMIUM STEELS

JIS G 4103

Chemical Composition, %

Steel Grade	C	Si	Mn	P	S	Ni	Cr	Mo
SNCM 220	.17/.23	.15/.35	.60/.90	.030 max	.030 max	.40/.70	.40/.65	.15/.30
SNCM 240	.38/.43	.15/.35	.70/1.00	.030 max	.030 max	.40/.70	.40/.65	.15/.30
SNCM 415	.12/.18	.15/.35	.40/.70	.030 max	.030 max	1.60/2.00	.40/.65	.15/.30
SNCM 420	.17/.23	.15/.35	.40/.70	.030 max	.030 max	1.60/2.00	.40/.65	.15/.30
SNCM 431	.27/.35	.15/.35	.60/.90	.030 max	.030 max	1.60/2.00	.60/1.00	.15/.30
SNCM 439	.36/.43	.15/.35	.60/.90	.030 max	.030 max	1.60/2.00	.60/1.00	.15/.30
SNCM 447	.44/.50	.15/.35	.60/.90	.030 max	.030 max	1.60/2.00	.60/1.00	.15/.30
SNCM 616	.13/.20	.15/.35	.80/1.20	.030 max	.030 max	2.80/3.20	1.40/1.80	.40/.60
SNCM 625	.20/.30	.15/.35	.35/.60	.030 max	.030 max	3.00/3.50	1.00/1.50	.15/.30
SNCM 630	.25/.35	.15/.35	.35/.60	.030 max	.030 max	2.50/3.50	2.50/3.50	.50/.70
SNCM 815	.12/.18	.15/.35	.30/.60	.030 max	.030 max	4.00/4.50	.70/1.00	.15/.30

NOTE: *As impurities, Cu shall not exceed 0.30% for all grades.*

JAPANESE INDUSTRIAL STANDARDS
HIGH CARBON CHROMIUM BEARING STEELS

JIS G 4805							
	Chemical Composition, %						
Symbol	C	Si	Mn	P	S	Cr	Mo
SUJ 1	.95/1.10	.15/.35	.50 max	.025 max	.025 max	.90/1.20	—
SUJ 2	.95/1.10	.15/.35	.50 max	.025 max	.025 max	1.30/1.60	—
SUJ 3	.95/1.10	.40/.70	.90/1.15	.025 max	.025 max	.90/1.20	—
SUJ 4	.95/1.10	.15/.35	.50 max	.025 max	.025 max	1.30/1.60	.10/.25
SUJ 5	.95/1.10	.40/.70	.90/1.15	.025 max	.025 max	.90/1.20	.10/.25

JAPANESE AUTOMOBILE STANDARDS
CARBON STEELS AND BORON STEELS

No.	Steel Grade	Chemical Composition, % C	Si	Mn	P	S	B	Cu	Ni	Cr	Ni + Cr
1	S 10 C	.08/.13	.15/.35	.30/.60	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
2	S 12 C	.10/.15	.15/.35	.30/.60	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
3	S 15 C	.13/.18	.15/.35	.30/.60	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
4	S 17 C	.15/.20	.15/.35	.30/.60	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
5	S 20 C	.18/.23	.15/.35	.30/.60	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
6	S 22 C	.20/.25	.15/.35	.30/.60	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
7	S 25 C	.22/.28	.15/.35	.30/.60	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
8	S 28 C	.25/.31	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
9	S 30 C	.27/.33	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
10	S 33 C	.30/.36	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
11	S 35 C	.32/.38	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
12	S 38 C	.35/.41	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
13	S 40 C	.37/.43	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
14	S 43 C	.40/.46	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
15	S 45 C	.42/.48	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
16	S 48 C	.45/.51	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
17	S 50 C	.47/.53	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
18	S 53 C	.50/.56	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
19	S 55 C	.52/.58	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
20	S 58 C	.55/.61	.15/.35	.60/.90	.030 max	.035 max	—	.30 max	.20 max	.20 max	.35 max
21	ASBo 20	.18/.23	.15/.35	.30/.60	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max
22	ASBo 25	.22/.28	.15/.35	.30/.60	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max
23	ASBo 28	.25/.31	.15/.35	.60/.90	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max
24	ASBo 30	.27/.33	.15/.35	.60/.90	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max

JAPANESE AUTOMOBILE STANDARDS
CARBON STEELS AND BORON STEELS - *CONTINUED*

		Chemical Composition, %									
No.	Steel Grade	C	Si	Mn	P	S	B	Cu	Ni	Cr	Ni + Cr
25	ASBo 33	.30/.36	.15/.35	.60/.90	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max
26	ASBo 35	.32/.38	.15/.35	.60/.90	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max
27	ASBo 38	.35/.41	.15/.35	.60/.90	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max
28	ASBo 40	.37/.43	.15/.35	.60/.90	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max
29	ASBo 43	.40/.46	.15/.35	.60/.90	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max
30	ASBo 45	.42/.48	.15/.35	.60/.90	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max
31	ASBo 48	.45/.51	.15/.35	.60/.90	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max
32	ASBo 50	.47/.53	.15/.35	.60/.90	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max
33	ASBo 53	.50/.56	.15/.35	.60/.90	.030 max	.035 max	.0005 min	.30 max	.20 max	.20 max	.35 max

JAPANESE AUTOMOBILE STANDARDS — H STEELS

		Chemical Composition, %									
No.	Steel Grade	C	Si	Mn	P	S	Ni	Cr	Mo	B	Cu
34	ASMn420H	.17/.23	.15/.35	1.15/1.55	.030 max	.030 max	.25 max	.35 max	—	—	.30 max
35	ASMn425H	.22/.28	.15/.35	1.15/1.55	.030 max	.030 max	.25 max	.35 max	—	—	.30 max
36	ASMn430H	.27/.34	.15/.35	1.15/1.55	.030 max	.030 max	.25 max	.35 max	—	—	.30 max
37	SMn433H	.29/.36	.15/.35	1.15/1.55	.030 max	.030 max	.25 max	.35 max	—	—	.30 max
38	ASMn435H	.32/.39	.15/.35	1.15/1.55	.030 max	.030 max	.25 max	.35 max	—	—	.30 max
39	SMn438H	.34/.41	.15/.35	1.30/1.70	.030 max	.030 max	.25 max	.35 max	—	—	.30 max
40	ASMn440H	.37/.44	.15/.35	1.30/1.70	.030 max	.030 max	.25 max	.35 max	—	—	.30 max
41	ASMn443H	.40/.47	.15/.35	1.30/1.70	.030 max	.030 max	.25 max	.35 max	—	—	.30 max
42	ASMn448H	.45/.52	.15/.35	1.30/1.70	.030 max	.030 max	.25 max	.35 max	—	—	.30 max
43	ASMn453H	.50/.57	.15/.35	1.30/1.70	.030 max	.030 max	.25 max	.35 max	—	—	.30 max
44	ASMnB220H	.17/.23	.15/.35	1.10/1.40	.030 max	.030 max	.25 max	.35 max	—	.0005 min	.30 max
45	ASMnB233H	.29/.36	.15/.35	1.10/1.40	.030 max	.030 max	.25 max	.35 max	—	.0005 min	.30 max
46	ASMnB422H	.19/.25	.15/.35	1.20/1.50	.030 max	.030 max	.25 max	.35 max	—	.0005 min	.30 max
47	ASMnB425H	.22/.28	.15/.35	1.20/1.50	.030 max	.030 max	.25 max	.35 max	—	.0005 min	.30 max
48	ASMnB433H	.29/.36	.15/.35	1.20/1.50	.030 max	.030 max	.25 max	.35 max	—	.0005 min	.30 max
49	ASMnB443H	.40/.47	.15/.35	1.20/1.50	.030 max	.030 max	.25 max	.35 max	—	.0005 min	.30 max
50	ASMnC420H	.17/.23	.15/.35	1.15/1.55	.030 max	.030 max	.25 max	.35/.70	—	—	.30 max
51	SMnC443H	.39/.46	.15/.35	1.30/1.70	.030 max	.030 max	.25 max	.35/.70	—	—	.30 max
52	ASMnC520H	.17/.23	.15/.35	1.15/1.55	.030 max	.030 max	.25 max	.85/1.25	—	—	.30 max
53	ASMnC543H	.39/.46	.15/.35	1.30/1.70	.030 max	.030 max	.25 max	.85/1.25	—	—	.30 max
54	ASMnCB440H	.37/.44	.15/.35	.80/1.20	.030 max	.030 max	.25 max	.30/.70	—	.0005 min	.30 max
55	SCr415H	.12/.18	.15/.35	.80/1.20	.030 max	.030 max	.25 max	.85/1.25	—	—	.30 max
56	ASCr418H	.15/.21	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	—	—	.30 max
57	SCr420H	.17/.23	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	—	—	.30 max
58	ASCr423H	.20/.26	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	—	—	.30 max
59	ASCr425H	.22/.28	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	—	—	.30 max

JAPANESE AUTOMOBILE STANDARDS — H STEELS - *CONTINUED*

		Chemical Composition, %									
No.	**Steel Grade**	**C**	**Si**	**Mn**	**P**	**S**	**Ni**	**Cr**	**Mo**	**B**	**Cu**
60	SCr430H	.27/.34	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	—	—	.30 max
61	SCr435H	.32/.39	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	—	—	.30 max
62	SCr440H	.37/.44	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	—	—	.30 max
63	ASCr445H	.42/.49	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	—	—	.30 max
64	ASCB435H	.32/.39	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	—	.0005 min	.30 max
65	ASCB440H	.37/.44	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	—	.0005 min	.30 max
66	ASCM115H	.12/.18	.15/.35	.60/.90	.030 max	.030 max	.25 max	.35/.65	.08/.15	—	.30 max
67	ASCM118H	.15/.21	.15/.35	.60/.90	.030 max	.030 max	.25 max	.35/.65	.08/.15	—	.30 max
68	ASCM120H	.17/.23	.15/.35	.60/.90	.030 max	.030 max	.25 max	.35/.65	.08/.15	—	.30 max
69	ASCM125H	.22/.28	.15/.35	.60/.90	.030 max	.030 max	.25 max	.35/.65	.08/.15	—	.30 max
70	ASCM315H	.12/.18	.15/.35	.65/1.00	.030 max	.030 max	.25 max	.85/1.25	.08/.15	—	.30 max
71	ASCM318H	.15/.21	.15/.35	.65/1.00	.030 max	.030 max	.25 max	.85/1.25	.08/.15	—	.30 max
72	ASCM320H	.17/.23	.15/.35	.65/1.00	.030 max	.030 max	.25 max	.85/1.25	.08/.15	—	.30 max
73	ASCM325H	.22/.28	.15/.35	.65/1.00	.030 max	.030 max	.25 max	.85/1.25	.08/.15	—	.30 max
74	SCM415H	.12/.18	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	.15/.35	—	.30 max
75	SCM418H	.15/.21	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	.15/.35	—	.30 max
76	SCM420H	.17/.23	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	.15/.35	—	.30 max
77	ASCM430H	.27/.34	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	.15/.35	—	.30 max
78	SCM435H	.32/.39	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	.15/.35	—	.30 max
79	SCM440H	.37/.44	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	.15/.35	—	.30 max
80	SCM445H	.42/.49	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	.15/.35	—	.30 max
81	SCM822H	.19/.25	.15/.35	.55/.90	.030 max	.030 max	.25 max	.85/1.25	.35/.45	—	.30 max
82	SNCM220H	.17/.23	.15/.35	.60/.95	.030 max	.030 max	.35/.75	.35/.65	.15/.30	—	.30 max
83	SNCM420H	.17/.23	.15/.35	.40/.70	.030 max	.030 max	1.55/2.00	.35/.65	.15/.30	—	.30 max

END-QUENCH HARDENABILITY BANDS — 1038 H TO 15B21 H

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE													
	1038 H		1045 H		1522 H		1524 H		1526 H		1541 H		15B21 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	58	51	62	55	50	41	51	42	53	44	60	53	48	41
1.5	56	42	61	52	48	41	49	42	50	42	59	52	48	41
2	55	34	59	42	47	32	48	38	49	38	59	50	47	40
2.5	53	29	56	34	46	27	47	34	47	33	58	47	47	39
3	49	26	52	31	45	22	45	29	46	26	57	44	46	38
3.5	43	24	46	29	42	21	43	25	42	25	56	41	45	36
4	37	23	38	28	39	20	39	22	39	21	55	38	44	30
4.5	33	22	34	27	37	—	38	20	37	20	53	35	42	23
5	30	22	33	26	34	—	35	—	33	—	52	32	40	20
5.5	29	21	32	26	32	—	34	—	31	—	50	29	38	—
6	28	21	32	25	30	—	32	—	30	—	48	27	32	—
6.5	27	20	31	25	28	—	30	—	28	—	46	26	27	—
7	27	—	31	25	27	—	29	—	27	—	44	25	22	—
7.5	26	—	30	24	—	—	28	—	26	—	41	24	20	—
8	26	—	30	24	—	—	27	—	26	—	39	23	—	—
9	25	—	29	23	—	—	26	—	24	—	35	23	—	—
10	25	—	29	22	—	—	25	—	24	—	33	22	—	—
12	23	—	28	21	—	—	23	—	23	—	32	21	—	—
14	21	—	27	20	—	—	22	—	—	—	31	20	—	—
16	—	—	26	—	—	—	—	—	—	—	30	—	—	—
18	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24	—	—	—	—	—	—	—	—	—	—	—	—	—	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 1038 H TO 15B21 H

Metric

Tabulations of Band Limits

"J" Distance Millimeters	GRADE													
	1038 H		1045 H		1522 H		1524 H		1526 H		1541 H		15B21 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.5	58	51	62	55	50	41	51	42	53	44	60	53	48	41
3	56	37	60	45	48	35	49	39	50	39	59	50	48	40
5	49	25	53	31	45	23	44	26	44	24	57	43	46	36
7	33	22	36	27	39	20	38	21	37	20	56	36	43	27
9	29	20	32	25	32	—	34	—	32	—	49	29	38	—
11	27	—	31	24	27	—	30	—	28	—	44	25	30	—
13	26	—	30	23	—	—	27	—	25	—	38	23	—	—
15	25	—	29	22	—	—	25	—	24	—	35	22	—	—
20	24	—	28	20	—	—	23	—	—	—	32	20	—	—
25	22	—	27	—	—	—	—	—	—	—	30	—	—	—
30	—	—	—	—	—	—	—	—	—	—	—	—	—	—
35	—	—	—	—	—	—	—	—	—	—	—	—	—	—
40	—	—	—	—	—	—	—	—	—	—	—	—	—	—
45	—	—	—	—	—	—	—	—	—	—	—	—	—	—
50	—	—	—	—	—	—	—	—	—	—	—	—	—	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 15B28 H TO 1330 H

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE															
	15B28 H		15B30 H		15B35 H		15B37 H		15B41 H		15B48 H		15B62 H		1330 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	53	47	55	48	56	50	58	50	60	53	63	56	—	60	56	49
2	53	47	53	47	55	49	56	50	59	52	62	56	—	60	56	47
3	52	46	52	46	54	48	55	49	59	52	62	55	—	60	55	44
4	51	45	51	44	53	39	54	48	58	51	61	54	—	60	53	40
5	51	42	50	32	51	28	53	43	58	51	60	53	65	59	52	35
6	50	32	48	22	47	24	52	37	57	50	59	52	65	58	50	31
7	49	25	43	20	41	22	51	33	57	49	58	42	64	57	48	28
8	48	21	38	—	—	—	50	26	56	48	57	34	64	52	45	26
9	46	20	33	—	—	—	—	—	55	44	56	31	64	43	43	25
10	43	—	29	—	30	20	45	22	55	37	55	30	63	39	42	23
11	40	—	27	—	—	—	—	—	54	32	53	29	63	37	40	22
12	37	—	26	—	27	—	40	21	53	28	51	28	63	35	39	21
13	34	—	25	—	—	—	—	—	52	26	48	27	62	35	38	20
14	31	—	24	—	26	—	33	20	51	25	45	27	62	34	37	—
15	30	—	23	—	—	—	—	—	50	25	41	26	61	33	36	—
16	29	—	22	—	25	—	29	—	49	24	38	26	60	33	35	—
18	27	—	20	—	—	—	—	—	46	23	34	25	58	32	34	—
20	25	—	—	—	24	—	27	—	42	22	32	24	54	31	33	—
22	25	—	—	—	—	—	—	—	39	21	31	23	48	30	32	—
24	24	—	—	—	22	—	25	—	36	21	30	22	43	30	31	—
26	23	—	—	—	—	—	—	—	34	20	29	21	40	29	31	—
28	22	—	—	—	20	—	23	—	33	—	29	20	37	28	31	—
30	21	—	—	—	—	—	—	—	31	—	28	—	35	27	30	—
32	20	—	—	—	—	—	—	—	31	—	28	—	34	26	30	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 15B28 H TO 1330 H

Metric

Tabulations of Band Limits

"J" Distance Millimeters	GRADE															
	15B28 H		15B30 H		15B35 H		15B37 H		15B41 H		15B48 H		15B62 H		1330 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.5	53	47	55	48	58	51	58	50	60	53	63	56	—	60	56	49
3	53	47	54	47	57	50	57	50	60	52	63	55	—	60	56	47
5	53	46	53	45	56	49	56	49	59	52	62	55	65	60	55	44
7	52	43	52	38	54	45	54	46	58	51	61	54	65	59	53	38
9	51	35	49	25	52	32	53	39	58	50	60	53	65	58	51	32
11	50	24	45	20	47	24	51	31	57	49	59	45	65	56	48	28
13	48	21	38	—	39	21	50	26	56	47	57	33	64	50	45	25
15	45	20	31	—	32	20	47	23	55	41	56	30	64	42	43	24
20	35	—	26	—	27	—	38	20	53	26	49	27	63	34	39	20
25	29	—	23	—	25	—	30	—	50	24	39	25	60	32	35	—
30	26	—	20	—	24	—	28	—	45	23	33	24	56	31	33	—
35	25	—	—	—	23	—	26	—	39	21	31	23	48	30	32	—
40	24	—	—	—	22	—	25	—	35	20	30	22	42	29	31	—
45	23	—	—	—	20	—	23	—	32	—	29	—	37	27	31	—
50	20	—	—	—	—	—	—	—	31	—	28	—	34	26	30	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 1335 H TO 4037 H

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE															
	1335 H		1340 H		1345 H		3310 H*		3316 H*		4028 H		4032 H		4037 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	58	51	60	53	63	56	43	36	47	40	52	45	57	50	59	52
2	57	49	60	52	63	56	43	36	47	39	50	40	54	45	57	49
3	56	47	59	51	62	55	42	35	47	38	46	31	51	36	54	42
4	55	44	58	49	61	54	42	35	46	38	40	25	46	29	51	35
5	54	38	57	46	61	51	42	34	46	37	34	22	39	25	45	30
6	52	34	56	40	60	44	42	33	46	37	30	20	34	23	38	26
7	50	31	55	35	60	38	41	32	45	36	28	—	31	22	34	23
8	48	29	54	33	59	35	41	31	45	35	26	—	29	21	32	22
9	46	27	52	31	58	33	41	30	45	34	25	—	28	20	30	21
10	44	26	51	29	57	32	40	30	45	33	25	—	26	—	29	20
11	42	25	50	28	56	31	40	29	45	33	24	—	26	—	28	—
12	41	24	48	27	55	30	40	29	45	32	23	—	25	—	27	—
13	40	23	46	26	54	29	39	28	45	32	23	—	24	—	26	—
14	39	22	44	25	53	29	39	28	44	32	22	—	24	—	26	—
15	38	22	42	25	52	28	38	27	44	31	22	—	23	—	26	—
16	37	21	41	24	51	28	38	27	44	31	21	—	23	—	25	—
18	35	20	39	23	49	27	37	26	44	31	21	—	23	—	25	—
20	34	—	38	23	48	27	37	26	43	31	20	—	22	—	25	—
22	33	—	37	23	47	26	37	26	43	31	—	—	22	—	25	—
24	32	—	36	22	46	26	36	26	43	31	—	—	21	—	24	—
26	31	—	35	21	45	25	36	25	42	31	—	—	21	—	24	—
28	31	—	35	21	45	25	36	25	42	30	—	—	20	—	24	—
30	30	—	34	20	45	24	35	25	42	30	—	—	—	—	23	—
32	30	—	34	20	45	24	35	25	41	30	—	—	—	—	23	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 1335 H TO 4037 H

Metric

Tabulations of Band Limits

"J" Distance Millimeters	GRADE															
	1335 H		1340 H		1345 H		3310 H*		3316 H*		4028 H		4032 H		4037 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.5	58	51	60	53	63	56	—	—	—	—	52	45	57	50	59	52
3	58	49	60	52	63	56	—	—	—	—	51	41	55	46	57	50
5	57	46	59	50	63	54	—	—	—	—	45	32	51	34	54	42
7	55	42	58	48	62	52	—	—	—	—	40	23	44	27	49	32
9	53	36	57	42	61	46	—	—	—	—	32	20	36	24	41	27
11	50	31	56	36	60	38	—	—	—	—	29	—	32	22	35	24
13	47	28	54	32	59	35	—	—	—	—	26	—	29	20	32	21
15	45	27	52	30	58	31	—	—	—	—	25	—	27	—	30	20
20	41	23	47	26	55	29	—	—	—	—	23	—	24	—	27	—
25	37	21	41	24	51	27	—	—	—	—	22	—	23	—	26	—
30	35	—	39	23	48	26	—	—	—	—	21	—	23	—	25	—
35	33	—	37	22	47	25	—	—	—	—	—	—	22	—	25	—
40	32	—	36	21	46	24	—	—	—	—	—	—	21	—	25	—
45	31	—	35	20	45	24	—	—	—	—	—	—	20	—	24	—
50	30	—	34	20	45	24	—	—	—	—	—	—	—	—	23	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 4042 H TO 4142 H

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE															
	4042 H		4047 H		4118 H		4130 H		4135 H		4137 H		4140 H		4142 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	62	55	64	57	48	41	56	49	58	51	59	52	60	53	62	55
2	60	52	62	55	46	36	55	46	58	50	59	51	60	53	62	55
3	58	48	60	50	41	27	53	42	57	49	58	50	60	52	62	54
4	55	40	58	42	35	23	51	38	56	48	58	49	59	51	61	53
5	50	33	55	35	31	20	49	34	56	47	57	49	59	51	61	53
6	45	29	52	32	28	—	47	31	55	45	57	48	58	50	61	52
7	39	27	47	30	27	—	44	29	54	42	56	45	58	48	60	51
8	36	26	43	28	25	—	42	27	53	40	55	43	57	47	60	50
9	34	25	40	28	24	—	40	26	52	38	55	40	57	44	60	49
10	33	24	38	27	23	—	38	26	51	36	54	39	56	42	59	47
11	32	24	37	26	22	—	36	25	50	34	53	37	56	40	59	46
12	31	23	35	26	21	—	35	25	33	49	52	36	55	39	58	44
13	30	23	34	25	21	—	34	24	48	32	51	35	55	38	58	42
14	30	23	33	25	20	—	34	24	47	31	50	34	54	37	57	41
15	29	22	33	25	—	—	33	23	46	30	49	33	54	36	57	40
16	29	22	32	25	—	—	33	23	45	30	48	33	53	35	56	39
18	28	22	31	24	—	—	32	22	44	29	46	32	52	34	55	37
20	28	21	30	24	—	—	32	21	42	28	45	31	51	33	54	36
22	28	20	30	23	—	—	32	20	41	27	44	30	49	33	53	35
24	27	20	30	23	—	—	31	—	40	27	43	30	48	32	53	34
26	27	—	30	22	—	—	31	—	39	27	42	30	47	32	52	34
28	27	—	29	22	—	—	30	—	38	26	42	29	46	31	51	34
30	26	—	29	21	—	—	30	—	38	26	41	29	45	31	51	33
32	26	—	29	21	—	—	29	—	37	26	41	29	44	30	50	33

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 4042 H TO 4142 H

Metric

Tabulations of Band Limits

"J" Distance Millimeters	GRADE															
	4042 H		4047 H		4118 H		4130 H*		4135 H*		4137 H		4140 H		4142 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.5	62	55	64	57	48	41	56	49	58	51	59	52	60	53	62	55
3	61	53	63	55	46	37	55	46	58	50	59	51	60	52	62	54
5	58	47	60	49	40	27	53	40	57	49	58	50	60	52	62	54
7	54	36	57	39	34	22	51	36	56	48	58	49	59	51	62	53
9	48	30	53	33	29	—	48	32	56	46	57	48	59	50	61	52
11	40	27	48	30	27	—	44	28	55	42	56	45	58	48	61	51
13	36	25	43	28	25	—	41	26	53	39	55	42	57	46	60	49
15	33	24	39	27	24	—	39	25	52	37	55	39	57	43	60	48
20	31	23	34	25	21	—	34	24	49	32	52	35	55	38	58	43
25	29	22	33	24	—	—	33	23	45	30	48	33	53	35	56	39
30	28	21	31	24			33	22	43	28	46	31	51	33	55	36
35	28	20	30	23			32	20	41	27	44	30	49	32	53	35
40	27	—	30	23			31	—	40	27	43	29	48	32	52	34
45	27	—	29	22			31	—	39	26	42	29	46	31	51	33
50	26	—	29	21			30	—	37	26	41	29	45	30	50	33

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 4145 H TO 4620 H

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE															
	4145 H		4147 H		4150 H		4161 H		4320 H		4340 H		E 4340 H		4620 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	63	56	64	57	65	59	65	60	48	41	60	53	60	53	48	41
2	63	55	64	57	65	59	65	60	47	38	60	53	60	53	45	35
3	62	55	64	56	65	59	65	60	45	35	60	53	60	53	42	27
4	62	54	64	56	65	58	65	60	43	32	60	53	60	53	39	24
5	62	53	63	55	65	58	65	60	41	29	60	53	60	53	34	21
6	61	53	63	55	65	57	65	60	38	27	60	53	60	53	31	—
7	61	52	63	55	65	57	65	60	36	25	60	53	60	53	29	—
8	61	52	63	54	64	56	65	60	34	23	60	52	60	53	27	—
9	60	51	63	54	64	56	65	59	33	22	60	52	60	53	26	—
10	60	50	62	53	64	55	65	59	31	21	60	52	60	53	25	—
11	60	49	62	52	64	54	65	59	30	20	59	51	60	53	24	—
12	59	48	62	51	63	53	64	59	29	20	59	51	60	52	23	—
13	59	46	61	49	63	51	64	58	28	—	59	50	60	52	22	—
14	59	45	61	48	62	50	64	58	27	—	58	49	59	52	22	—
15	58	43	60	46	62	48	64	57	27	—	58	49	59	52	22	—
16	58	42	60	45	62	47	64	56	26	—	58	48	59	51	21	—
18	57	40	59	42	61	45	64	55	25	—	58	47	58	51	21	—
20	57	38	59	40	60	43	63	53	25	—	57	46	58	50	20	—
22	56	37	58	39	59	41	63	50	24	—	57	45	58	49	—	—
24	55	36	57	38	59	40	63	48	24	—	57	44	57	48	—	—
26	55	35	57	37	58	39	63	45	24	—	57	43	57	47	—	—
28	55	35	57	37	58	38	63	43	24	—	56	42	57	46	—	—
30	55	34	56	37	58	38	63	42	24	—	56	41	57	45	—	—
32	54	34	56	36	58	38	63	41	24	—	56	40	57	44	—	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 4145 H TO 4620 H

Metric

Tabulations of Band Limits

"J" Distance Millimeters	GRADE															
	4145 H		4147 H		4150 H		4161 H		4320 H		4340 H		E 4340 H		4620 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.5	63	56	64	57	65	59	65	60	48	41	60	53	60	53	48	41
3	63	55	64	57	65	59	65	60	47	39	60	53	60	53	46	37
5	63	55	64	56	65	58	65	60	45	35	60	53	60	53	42	28
7	62	54	64	55	65	58	65	60	42	30	60	53	60	53	37	23
9	62	53	63	55	65	57	65	60	39	27	60	53	60	53	33	—
11	61	52	63	55	65	57	65	60	36	25	60	53	60	53	30	—
13	61	51	63	54	65	56	65	60	34	23	60	52	60	53	27	—
15	60	50	63	53	64	55	65	60	32	22	60	52	60	53	26	—
20	59	47	62	50	63	51	65	58	28	—	59	50	60	52	23	—
25	58	42	60	45	62	47	64	56	26	—	58	48	59	51	22	—
30	57	39	59	42	61	44	63	53	25	—	58	46	58	50	21	—
35	56	37	58	39	60	41	63	50	25	—	57	44	58	49	—	—
40	55	35	57	37	59	39	63	46	24	—	57	43	57	47	—	—
45	55	34	57	36	58	38	63	43	24	—	56	42	57	46	—	—
50	55	34	56	36	58	38	63	41	24	—	56	40	57	44	—	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 4626 H TO 50B44 H

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE															
	4626 H*		4718 H		4720 H		4815 H		4817 H		4820 H		50B40 H		50B44 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	51	45	47	40	48	41	45	38	46	39	48	41	60	53	63	56
2	48	36	47	40	47	39	44	37	46	38	48	40	60	53	63	56
3	41	29	45	38	43	31	44	34	45	35	47	39	59	52	62	55
4	33	24	43	33	39	27	42	30	44	32	46	38	59	51	62	55
5	29	21	40	29	35	23	41	27	42	29	45	34	58	50	61	54
6	27	—	37	27	32	21	39	24	41	27	43	31	58	48	61	52
7	25	—	35	25	29	—	37	22	39	25	42	29	57	44	60	48
8	24	—	33	24	28	—	35	21	37	23	40	27	57	39	60	43
9	23	—	32	23	27	—	33	20	35	22	39	26	56	34	59	38
10	22	—	31	22	26	—	31	—	33	21	37	25	55	31	58	34
11	22	—	30	22	25	—	30	—	32	20	36	24	53	29	57	31
12	21	—	29	21	24	—	29	—	31	20	35	23	51	28	56	30
13	21	—	29	21	24	—	28	—	30	—	34	22	49	27	54	29
14	20	—	28	21	23	—	28	—	29	—	33	22	47	26	52	29
15	—	—	27	20	23	—	27	—	28	—	32	21	44	25	50	28
16	—	—	27	20	22	—	27	—	28	—	31	21	41	25	48	27
18	—	—	27	—	21	—	26	—	27	—	29	20	38	23	44	26
20	—	—	26	—	21	—	25	—	26	—	28	20	36	21	40	24
22	—	—	26	—	21	—	24	—	25	—	28	—	35	—	38	23
24	—	—	25	—	20	—	24	—	25	—	27	—	34	—	37	21
26	—	—	25	—	—	—	24	—	25	—	27	—	33	—	36	20
28	—	—	24	—	—	—	23	—	25	—	26	—	32	—	35	—
30	—	—	24	—	—	—	23	—	24	—	26	—	30	—	34	—
32	—	—	24	—	—	—	23	—	24	—	25	—	29	—	33	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

* *Formerly Standard Steel*

END-QUENCH HARDENABILITY BANDS — 4626 H TO 50B44 H

Metric

Tabulations of Band Limits

"J" Distance Millimeters	GRADE															
	4626 H*		4718 H		4720 H		4815 H		4817 H		4820 H		50B40 H		50B44 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.5	—	—	47	40	48	41	45	38	46	39	48	41	60	53	63	56
3	—	—	47	40	47	39	45	36	46	38	48	40	60	53	63	56
5	—	—	46	38	43	32	44	33	45	35	48	39	60	52	63	56
7	—	—	43	31	38	25	42	28	44	31	46	36	59	51	62	54
9	—	—	39	28	33	22	40	25	42	28	45	32	59	49	61	52
11	—	—	36	25	30	20	37	22	39	25	43	29	58	44	61	49
13	—	—	34	23	28	—	35	20	37	23	40	27	57	38	60	42
15	—	—	32	22	27	—	32	—	34	21	39	25	56	33	59	36
20	—	—	29	21	24	—	29	—	31	—	35	22	50	27	55	30
25	—	—	27	20	23	—	27	—	28	—	32	21	43	24	49	27
30	—	—	26	—	22	—	26	—	27	—	29	20	37	22	42	25
35	—	—	26	—	21	—	25	—	26	—	28	—	35	—	38	23
40	—	—	25	—	20	—	24	—	25	—	27	—	34	—	37	21
45	—	—	25	—	—	—	24	—	25	—	26	—	32	—	35	—
50	—	—	24	—	—	—	23	—	25	—	26	—	30	—	34	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

* *Formerly Standard Steel*

END-QUENCH HARDENABILITY BANDS — 5046 H TO 5135 H

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE															
	5046 H		50B46 H		50B50 H		50B60 H		5120 H		5130 H		5132 H		5135 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	63	56	63	56	65	59	—	60	48	40	56	49	57	50	58	51
2	62	55	62	54	65	59	—	60	46	34	55	46	56	47	57	49
3	60	45	61	52	64	58	—	60	41	28	53	42	54	43	56	47
4	56	32	60	50	64	57	—	60	36	23	51	39	52	40	55	43
5	52	28	59	41	63	56	—	60	33	20	49	35	50	35	54	38
6	46	27	58	32	63	55	—	59	30	—	47	32	48	32	52	35
7	39	26	57	31	62	52	—	57	28	—	45	30	45	29	50	32
8	35	25	56	30	62	47	65	53	27	—	42	28	42	27	47	30
9	34	24	54	29	61	42	65	47	25	—	40	26	40	25	45	28
10	33	24	51	28	60	37	64	42	24	—	38	25	38	24	43	27
11	33	23	47	27	60	35	64	39	23	—	37	23	37	23	41	25
12	32	23	43	26	59	33	64	37	22	—	36	22	36	22	40	24
13	32	22	40	26	58	32	63	36	21	—	35	21	35	21	39	23
14	31	22	38	25	57	31	63	35	21	—	34	20	34	20	38	22
15	31	21	37	25	56	30	63	34	20	—	34	—	34	—	37	21
16	30	21	36	24	54	29	62	34	—	—	33	—	33	—	37	21
18	29	20	35	23	50	28	60	33	—	—	32	—	32	—	36	20
20	28	—	34	22	47	27	58	31	—	—	31	—	31	—	35	—
22	27	—	33	21	44	26	55	30	—	—	30	—	30	—	34	—
24	26	—	32	20	41	25	53	29	—	—	29	—	29	—	33	—
26	25	—	31	—	39	24	51	28	—	—	27	—	28	—	32	—
28	24	—	30	—	38	22	49	27	—	—	26	—	27	—	32	—
30	23	—	29	—	37	21	47	26	—	—	25	—	26	—	31	—
32	23	—	28	—	36	—	44	25	—	—	24	—	25	—	30	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 5046 H TO 5135 H

Metric

Tabulations of Band Limits

"J" Distance Millimeters	GRADE															
	5046 H		50B46 H		50B50 H		50B60 H		5120 H		5130 H		5132 H		5135 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.5	63	56	63	56	65	59	—	60	48	40	56	49	57	50	58	51
3	62	54	62	55	65	59	—	60	46	34	55	46	56	47	58	49
5	59	40	61	53	65	59	—	60	41	27	53	42	54	43	56	46
7	54	30	60	47	64	57	—	60	34	22	51	37	52	38	54	41
9	48	27	59	35	63	55	—	59	31	20	48	33	49	33	53	36
11	39	26	58	31	63	52	—	57	29	—	45	30	45	29	50	32
13	35	25	56	29	62	46	65	41	27	—	42	27	42	26	47	30
15	34	25	53	28	62	39	65	44	25	—	39	25	39	25	44	27
20	32	22	42	26	59	32	65	36	22	—	35	21	35	21	40	23
25	30	20	37	24	54	29	62	34	—	—	33	—	33	—	37	21
30	29	—	35	22	49	27	59	32	—	—	31	—	32	—	35	—
35	27	—	34	21	44	26	56	30	—	—	30	—	31	—	34	—
40	26	—	32	—	40	24	52	28	—	—	28	—	29	—	33	—
45	24	—	31	—	38	22	48	27	—	—	26	—	27	—	32	—
50	23	—	29	—	37	20	45	25	—	—	24	—	25	—	31	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 5140 H TO 6150 H

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE															
	5140 H		5147 H		5150 H		5155 H		5160 H		51B60 H		6118 H		6150 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	60	53	64	57	65	59	—	60	—	60	—	60	46	39	65	59
2	59	52	64	56	65	58	65	59	—	60	—	60	44	36	65	58
3	58	50	63	55	64	57	64	58	—	60	—	60	38	28	64	57
4	57	48	62	54	63	56	64	57	65	59	—	60	33	24	64	56
5	56	43	62	53	62	53	63	55	65	58	—	60	30	22	63	55
6	54	38	61	52	61	49	63	52	64	56	—	59	28	20	63	53
7	52	35	61	49	60	42	62	47	64	52	—	58	27	—	62	50
8	50	33	60	45	59	38	62	41	63	47	—	57	26	—	61	47
9	48	31	60	40	58	36	61	37	62	42	—	54	26	—	61	43
10	46	30	59	37	56	34	60	36	61	39	—	50	25	—	60	41
11	45	29	59	35	55	33	59	35	60	37	—	44	25	—	59	39
12	43	28	58	34	53	32	57	34	59	36	65	41	24	—	58	38
13	42	27	58	33	51	31	55	34	58	35	65	40	24	—	57	37
14	40	27	57	32	50	31	52	33	56	35	64	39	23	—	55	36
15	39	26	57	32	48	30	51	33	54	34	64	38	23	—	54	35
16	38	25	56	31	47	30	49	32	52	34	63	37	22	—	52	35
18	37	24	55	30	45	29	47	31	48	33	61	36	22	—	50	34
20	36	23	54	29	43	28	45	31	47	32	59	34	21	—	48	32
22	35	21	53	27	42	27	44	30	46	31	57	33	21	—	47	31
24	34	20	52	26	41	26	43	29	45	30	55	31	20	—	46	30
26	34	—	51	25	40	25	42	28	44	29	53	30	—	—	45	29
28	33	—	50	24	39	24	41	27	43	28	51	28	—	—	44	27
30	33	—	49	22	39	23	41	26	43	28	49	27	—	—	43	26
32	32	—	48	21	38	22	40	25	42	27	47	25	—	—	42	25

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 5140 H TO 6150 H

Metric

Tabulations of Band Limits

"J" Distance Millimeters	GRADE															
	5140 H		5147 H		5150 H		5155 H		5160 H		51B60 H		6118 H		6150 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.5	60	53	64	57	65	59	—	60	—	60	—	60	46	39	65	59
3	59	52	64	56	65	58	65	60	—	60	—	60	44	36	65	58
5	58	50	64	55	64	57	65	59	—	60	—	60	39	28	65	57
7	57	45	63	53	63	54	64	56	—	59	—	60	32	23	64	55
9	55	40	62	52	62	50	64	53	65	57	—	59	30	20	63	53
11	53	35	61	49	60	43	63	48	64	32	—	58	28	—	63	50
13	50	32	60	44	58	37	61	40	64	46	—	55	27	—	61	46
15	47	30	60	39	57	35	60	37	62	40	—	51	25	—	60	42
20	42	28	58	33	52	31	56	34	58	36	65	40	24	—	58	37
25	39	25	57	31	47	29	50	32	53	34	63	37	23	—	53	35
30	36	23	55	29	44	28	46	30	49	32	61	35	22	—	50	33
35	35	21	53	27	42	27	44	29	46	30	57	32	21	—	47	31
40	34	—	52	25	40	26	43	28	44	28	54	30	20	—	45	29
45	33	—	50	23	39	24	42	27	42	27	51	28	—	—	44	27
50	32	—	49	21	38	22	41	25	41	27	47	25	—	—	43	25

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 81B45 H TO 86B30 H

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE															
	81B45 H		8617 H		8620 H		8622 H		8625 H		8627 H		8630 H		86B30 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	63	56	46	39	48	41	50	43	52	45	54	47	56	49	56	49
2	63	56	44	33	47	37	49	39	51	41	52	43	55	46	55	49
3	63	56	41	27	44	32	47	34	48	36	50	38	54	43	55	48
4	63	56	38	24	41	27	44	30	46	32	48	35	52	39	55	48
5	63	55	34	20	37	23	40	26	43	29	45	32	50	35	54	48
6	63	54	31	—	34	21	37	24	40	27	43	29	47	32	54	48
7	62	53	28	—	32	—	34	22	37	25	40	27	44	29	53	48
8	62	51	27	—	30	—	32	20	35	23	38	26	41	28	53	47
9	61	48	26	—	29	—	31	—	33	22	36	24	39	27	52	46
10	60	44	25	—	28	—	30	—	32	21	34	24	37	26	52	44
11	60	41	24	—	27	—	29	—	31	20	33	23	35	25	52	42
12	59	39	23	—	26	—	28	—	30	—	32	22	34	24	51	40
13	58	38	23	—	25	—	27	—	29	—	31	21	33	23	51	39
14	57	37	22	—	25	—	26	—	28	—	30	21	33	22	50	38
15	57	36	22	—	24	—	26	—	28	—	30	20	32	22	50	36
16	56	35	21	—	24	—	25	—	27	—	29	20	31	21	49	35
18	55	34	21	—	23	—	25	—	27	—	28	—	30	21	48	34
20	53	32	20	—	23	—	24	—	26	—	28	—	30	20	47	32
22	52	31	—	—	23	—	24	—	26	—	28	—	29	20	45	31
24	50	30	—	—	23	—	24	—	26	—	27	—	29	—	44	29
26	49	29	—	—	23	—	24	—	26	—	27	—	29	—	43	28
28	47	28	—	—	22	—	24	—	25	—	27	—	29	—	41	27
30	45	28	—	—	22	—	24	—	25	—	27	—	29	—	40	26
32	43	27	—	—	22	—	24	—	25	—	27	—	29	—	39	25

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 81B45 H TO 86B30 H

Metric

Tabulations of Band Limits

"J" Distance Millimeters	GRADE															
	81B45 H		8617 H		8620 H		8622 H		8625 H		8627 H		8630 H		86B30 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.5	63	56	46	39	48	41	50	43	52	45	54	47	56	49	56	49
3	63	56	44	33	47	37	50	39	51	40	53	43	55	46	56	49
5	63	56	42	27	44	31	47	34	48	35	50	38	54	42	55	48
7	63	56	37	23	40	25	43	28	45	31	47	34	51	38	55	48
9	63	55	32	20	35	22	39	25	41	28	44	31	48	33	54	48
11	63	53	29	—	33	20	35	22	38	25	41	27	44	29	54	47
13	62	49	27	—	30	—	32	20	35	23	38	25	41	27	53	46
15	61	47	25	—	29	—	31	—	33	21	35	24	38	26	53	44
20	59	38	23	—	26	—	28	—	29	—	32	21	34	23	52	39
25	57	35	22	—	24	—	26	—	28	—	30	20	31	21	50	35
30	55	33	20	—	23	—	25	—	27	—	28	—	30	20	48	33
35	52	31	—	—	23	—	24	—	26	—	27	—	29	—	46	30
40	50	29	—	—	23	—	24	—	26	—	27	—	29	—	43	28
45	47	28	—	—	22	—	24	—	26	—	27	—	29	—	41	27
50	44	27	—	—	22	—	24	—	25	—	27	—	29	—	40	25

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 8637 H TO 8660 H

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE															
	8637 H		8640 H		8642 H		8645 H		86B45 H		8650 H		8655 H		8660 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	59	52	60	53	62	55	63	56	63	56	65	59	—	60	—	60
2	58	51	60	53	62	54	63	56	63	56	65	58	—	59	—	60
3	58	50	60	52	62	53	63	55	62	55	65	57	—	59	—	60
4	57	48	59	51	61	52	63	54	62	54	64	57	—	58	—	60
5	56	45	59	49	61	50	62	52	62	54	64	56	—	57	—	60
6	55	42	58	46	60	48	61	50	61	53	63	54	—	56	—	59
7	54	39	57	42	59	45	61	48	61	52	63	53	—	55	—	58
8	53	36	55	39	58	42	60	45	60	52	62	50	—	54	—	57
9	51	34	54	36	57	39	59	41	60	51	61	47	—	52	—	55
10	49	32	52	34	55	37	58	39	60	51	60	44	65	49	—	53
11	47	31	50	32	54	34	56	37	59	50	60	41	65	46	—	50
12	46	30	49	31	52	33	55	35	59	50	59	39	64	43	—	47
13	44	29	47	30	50	32	54	34	59	49	58	37	64	41	—	45
14	43	28	45	29	49	31	52	33	59	48	58	36	63	40	—	44
15	41	27	44	28	48	30	51	32	58	46	57	35	63	39	—	43
16	40	26	42	28	46	29	49	31	58	45	56	34	62	38	65	42
18	39	25	41	26	44	28	47	30	58	42	55	33	61	37	64	40
20	37	25	39	26	42	28	45	29	58	39	53	32	60	35	64	39
22	36	24	38	25	41	27	43	28	57	37	52	31	59	34	63	38
24	36	24	38	25	40	27	42	28	57	35	50	31	58	34	62	37
26	35	24	37	24	40	26	42	27	57	34	49	30	57	33	62	36
28	35	24	37	24	39	26	41	27	57	32	47	30	56	33	61	36
30	35	23	37	24	39	26	41	27	56	32	46	29	55	32	60	35
32	35	23	37	24	39	26	41	27	56	31	45	29	53	32	60	35

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 6837 H TO 8660 H

Metric

Tabulations of Band Limits

"J" Distance Millimeters	GRADE															
	8637 H		8640 H		8642 H		8645 H		86B45 H		8650 H		8655 H		8660 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.5	59	52	60	53	62	55	63	56	63	56	65	59	—	60	—	60
3	59	51	60	53	62	54	63	56	63	56	65	59	—	60	—	60
5	58	49	60	52	62	53	63	55	63	55	65	58	—	59	—	60
7	57	47	60	50	61	51	63	53	62	54	65	56	—	57	—	60
9	55	43	58	47	60	49	62	51	62	53	64	55	—	56	—	59
11	54	39	57	42	59	46	61	48	61	52	63	53	—	55	—	58
13	52	36	55	38	58	42	59	45	61	51	62	50	—	53	—	56
15	50	33	54	36	56	38	58	41	60	51	61	46	65	51	—	53
20	45	29	48	31	52	32	54	34	59	49	59	38	64	42	—	46
25	41	27	43	27	47	29	49	31	58	45	57	34	64	39	—	42
30	38	25	40	26	44	28	46	29	58	40	54	32	62	36	65	39
35	36	24	39	25	41	27	43	28	57	36	52	31	60	34	64	38
40	35	24	38	24	40	27	42	27	57	33	49	30	58	34	62	37
45	35	23	37	24	39	26	42	27	56	32	47	29	56	33	61	36
50	35	23	37	24	39	26	41	27	56	31	46	29	54	32	60	35

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 8720 H TO 94B30 H

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE															
	8720 H		8740 H		8822 H		9260 H		9310 H		94B15 H		94B17 H		94B30 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	48	41	60	53	50	43	—	60	43	36	45	38	46	39	56	49
2	47	38	60	53	49	42	—	60	43	35	45	38	46	39	56	49
3	45	35	60	52	48	39	65	57	43	35	44	37	45	38	55	48
4	42	30	60	51	46	33	64	53	42	34	44	36	45	37	55	48
5	38	26	59	49	43	29	63	46	42	32	43	32	44	34	54	47
6	35	24	58	46	40	27	62	41	42	31	42	28	43	29	54	46
7	33	22	57	43	37	25	60	38	42	30	40	25	42	26	53	44
8	31	21	56	40	35	24	58	36	41	29	38	23	41	24	53	42
9	30	20	55	37	34	24	55	36	40	28	36	21	40	23	52	39
10	29	—	53	35	33	23	52	35	40	27	34	20	38	21	52	37
11	28	—	52	34	32	23	49	34	39	27	33	—	36	20	51	34
12	27	—	50	32	31	22	47	34	38	26	31	—	34	—	51	32
13	26	—	49	31	31	22	45	33	37	26	30	—	33	—	50	30
14	26	—	48	31	30	22	43	33	36	26	29	—	32	—	49	29
15	25	—	46	30	30	21	42	32	36	26	28	—	31	—	48	28
16	25	—	45	29	29	21	40	32	35	26	27	—	30	—	46	27
18	24	—	43	28	29	20	38	31	35	26	26	—	28	—	44	25
20	24	—	42	28	28	—	37	31	35	25	25	—	27	—	42	24
22	23	—	41	27	27	—	36	30	34	25	24	—	26	—	40	23
24	23	—	40	27	27	—	36	30	34	25	23	—	25	—	38	23
26	23	—	39	27	27	—	35	29	34	25	23	—	24	—	37	22
28	23	—	39	27	27	—	35	29	34	25	22	—	24	—	35	21
30	22	—	38	26	27	—	35	28	33	24	22	—	23	—	34	21
32	22	—	38	26	27	—	34	28	33	24	22	—	23	—	34	20

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS — 8720 H TO 94B30 H

Metric

Tabulations of Band Limits

"J" Distance Millimeters	GRADE															
	8720 H		8740 H		8822 H		9260 H		9310 H		94B15 H		94B17 H		94B30 H	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1.5	48	41	60	53	50	43	—	60	43	36	45	38	46	39	56	49
3	47	39	60	52	49	42	—	60	43	35	45	38	46	39	56	49
5	45	35	60	51	47	38	65	58	43	34	45	37	46	38	56	48
7	41	29	60	49	45	31	63	50	43	33	44	34	45	36	55	47
9	37	25	59	46	41	28	62	42	43	31	42	30	44	31	55	46
11	33	22	58	43	38	26	60	38	42	30	40	26	43	26	54	44
13	31	21	56	39	35	24	58	36	41	28	38	22	41	24	53	41
15	29	—	54	36	33	23	54	35	40	27	36	20	39	22	53	38
20	27	—	50	31	31	21	47	33	38	26	31	—	34	—	51	31
25	25	—	45	29	29	20	40	32	36	25	28	—	30	—	47	26
30	24	—	43	28	29	—	38	31	35	25	26	—	28	—	43	24
35	23	—	41	27	28	—	37	30	35	25	24	—	26	—	40	23
40	23	—	40	27	27	—	36	29	34	25	23	—	25	—	37	22
45	23	—	39	26	27	—	35	28	34	24	22	—	24	—	36	21
50	22	—	38	26	27	—	35	28	33	24	22	—	23	—	34	20

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

RESTRICTED END-QUENCH HARDENABILITY BANDS — 15B21 RH TO 4130 RH

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE													
	15B21 RH		15B35 RH		3310 RH		4027 RH		4118 RH		4120 RH		4130 RH	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	47	42	57	52	42	37	51	46	47	42	47	42	55	50
2	46	41	55	51	42	37	48	42	44	38	45	39	54	48
3	44	39	54	50	42	37	43	34	38	30	41	35	52	44
4	42	33	53	49	41	36	37	28	33	25	38	30	49	40
5	37	24	50	41	41	36	32	24	29	22	34	26	46	36
6	30	20	46	33	41	35	28	22	27	20	31	24	44	34
7	24	—	42	28	40	33	26	20	25	—	29	22	41	32
8	22	—	36	24	40	33	24	—	24	—	28	21	39	30
9	20	—	32	23	39	32	23	—	23	—	26	20	37	28
10	—	—	28	21	39	32	22	—	22	—	25	—	35	27
11	—	—	—	—	39	31	22	—	21	—	24	—	33	26
12	—	—	25	—	39	31	21	—	20	—	23	—	32	26
13	—	—	—	—	38	30	21	—	—	—	23	—	32	26
14	—	—	24	—	38	30	20	—	—	—	22	—	31	25
15	—	—	—	—	37	29	—	—	—	—	22	—	31	25
16	—	—	23	—	37	29	—	—	—	—	21	—	31	25
18	—	—	—	—	36	28	—	—	—	—	20	—	30	24
20	—	—	22	—	36	28	—	—	—	—	—	—	30	23
22	—	—	—	—	35	27	—	—	—	—	—	—	30	23
24	—	—	20	—	35	27	—	—	—	—	—	—	29	22
26	—	—	—	—	35	27	—	—	—	—	—	—	29	22
28	—	—	—	—	34	26	—	—	—	—	—	—	28	21
30	—	—	—	—	34	26	—	—	—	—	—	—	28	21
32	—	—	—	—	34	26	—	—	—	—	—	—	27	20

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

RESTRICTED END-QUENCH HARDENABILITY BANDS — 4140 RH TO 50B40 RH

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE													
	4140 RH		4145 RH		4161 RH		4320 RH		4620 RH		4820 RH		50B40 RH	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	59	54	62	57	65	60	47	42	47	42	47	42	59	54
2	59	54	62	57	65	60	46	40	44	37	47	42	59	54
3	59	54	61	56	65	60	44	37	40	30	46	41	58	53
4	59	53	61	56	65	60	41	34	37	27	45	40	58	53
5	58	52	60	55	65	60	39	31	32	24	43	36	57	52
6	57	51	60	55	65	60	36	29	29	21	41	33	56	50
7	56	50	59	54	65	60	34	27	27	20	40	32	55	47
8	55	49	59	53	65	60	32	25	25	—	38	30	54	43
9	54	48	58	52	65	60	31	24	24	—	36	28	52	38
10	53	46	58	52	65	60	29	23	23	—	35	27	50	35
11	52	44	58	51	65	60	28	22	22	—	34	26	49	33
12	52	43	57	50	64	59	26	21	21	—	33	25	47	32
13	51	42	57	49	64	59	25	20	20	—	32	24	45	31
14	50	41	56	48	64	59	24	—	—	—	31	24	44	30
15	50	40	56	47	63	58	24	—	—	—	30	23	41	29
16	49	39	55	46	63	57	23	—	—	—	29	23	38	28
18	48	38	54	44	62	56	22	—	—	—	28	22	36	26
20	47	37	53	43	62	54	22	—	—	—	27	22	34	24
22	46	37	52	42	61	53	21	—	—	—	26	21	33	23
24	45	36	51	40	60	51	21	—	—	—	25	20	32	22
26	44	35	51	40	59	49	21	—	—	—	25	20	31	21
28	43	35	50	39	58	47	21	—	—	—	25	—	30	20
30	42	34	50	38	57	46	21	—	—	—	24	—	29	—
32	41	33	49	37	57	45	21	—	—	—	23	—	28	—

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

RESTRICTED END-QUENCH HARDENABILITY BANDS — 5130 RH TO 9310 RH

Tabulations of Band Limits

"J" Distance Sixteenths of an Inch	GRADE															
	5130 RH		5140 RH		5160 RH		8620 RH		8622 RH		8720 RH		8822 RH		9310 RH	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	55	50	59	54	65	60	47	42	49	44	47	42	49	44	42	37
2	53	47	58	53	65	60	45	39	47	41	45	39	48	43	42	36
3	51	44	57	51	65	60	41	35	45	37	43	37	47	40	42	36
4	49	41	55	49	65	59	38	30	41	32	40	32	43	35	41	35
5	46	37	53	45	64	58	34	26	38	29	36	28	40	31	41	34
6	44	35	51	41	63	57	31	24	35	27	33	26	37	29	40	33
7	42	33	48	38	62	54	29	22	32	24	31	24	35	27	40	32
8	39	31	46	36	60	50	28	21	30	22	29	23	33	26	39	31
9	37	29	44	34	58	45	26	20	29	21	28	22	32	25	38	30
10	35	27	43	33	56	42	25	—	28	20	27	21	31	25	37	29
11	34	26	41	32	55	40	24	—	27	—	26	20	30	24	37	29
12	33	25	40	31	53	39	23	—	26	—	25	—	30	23	36	28
13	32	24	39	30	51	38	23	—	25	—	25	—	29	23	35	28
14	31	23	37	29	50	37	22	—	24	—	24	—	28	23	34	28
15	30	22	36	28	48	36	22	—	24	—	24	—	28	22	34	28
16	29	21	35	27	47	36	21	—	23	—	23	—	27	22	33	27
18	28	20	34	26	44	35	20	—	23	—	23	—	27	21	33	27
20	27	—	33	25	43	34	—	—	22	—	22	—	26	20	32	26
22	26	—	32	24	42	33	—	—	22	—	22	—	26	—	32	26
24	25	—	31	23	41	32	—	—	22	—	21	—	26	—	32	26
26	24	—	30	22	40	31	—	—	22	—	20	—	26	—	32	26
28	23	—	30	21	39	30	—	—	22	—	—	—	25	—	32	26
30	22	—	29	20	39	29	—	—	22	—	—	—	25	—	31	25
32	21	—	29	—	38	29	—	—	22	—	—	—	25	—	31	25

NOTE: *These values were adjusted to the nearest Rockwell "C" point, and are used when points are selected and specified.*

END-QUENCH HARDENABILITY BANDS FOR SELECTED DIN SPECIFICATIONS

Metric

Steel Grade		Temperature of Heat Treatment for End Quench Tests (°C)			Distance From Quenched End in Millimeters, Hardness in HRC																			
Symbol	Material Number	Normal -izing	Harden -ing	Band Limits	1.5	1	2	3	4	5	6	7	8	9	10	11	13	15	20	25	30	35	40	45	50
Ck 35	1.1181	—	—	max	—	58	57	55	53	49	41	34	31	28	27	26	25	24	23	20	—	—	—	—	—
Cm 35	1.1180	—	—	min	—	48	40	33	24	22	20	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ck 40	1.1186	—	—	max	—	60	60	59	57	53	47	39	34	31	30	29	28	27	26	25	24	—	—	—	—
Cm 40	1.1189	—	—	min	—	51	46	35	27	25	24	23	22	21	20	—	—	—	—	—	—	—	—	—	—
Ck 45	1.1191	—	—	max	—	62	61	61	60	57	51	44	37	34	33	32	31	30	29	28	27	—	—	—	—
Cm 45	1.1201	—	—	min	—	55	51	37	30	28	27	26	25	24	23	22	21	20	—	—	—	—	—	—	—
Ck 50	1.1206	—	—	max	—	63	62	61	60	58	55	50	43	36	35	34	33	32	31	29	28	—	—	—	—
Cm 50	1.1241	—	—	min	—	56	53	44	34	31	30	30	29	28	27	26	25	24	23	20	—	—	—	—	—
Ck 55	1.1203	—	—	max	—	65	64	63	62	60	57	52	45	37	36	35	34	33	32	30	29	—	—	—	—
Cm 55	1.1209	—	—	min	—	58	55	47	37	33	32	31	30	29	28	27	26	25	24	22	20	—	—	—	—
Ck 60	1.1221	—	—	max	—	67	66	65	63	62	59	54	47	39	37	36	35	34	33	31	30	—	—	—	—
Cm 60	1.1223	—	—	min	—	60	57	50	39	35	33	32	31	30	29	28	27	26	25	23	21	—	—	—	—
28 Mn 6	1.1170	—	—	max	55	—	—	54	—	51	—	48	—	44	—	41	38	35	31	29	27	26	25	25	24
28 Mn 6	1.1170	—	—	min	46	—	—	43	—	37	—	27	—	21	—	—	—	—	—	—	—	—	—	—	—
32 Cr 2	1.7020	—	—	max	57	—	—	55	—	52	—	47	—	41	—	37	35	33	30	28	25	23	22	21	20
32 CrS 2	1.7021	—	—	min	49	—	—	44	—	35	—	27	—	23	—	20	—	—	—	—	—	—	—	—	—
38 Cr 2	1.7003	—	—	max	59	—	—	57	—	54	—	49	—	43	—	39	37	35	32	30	27	25	24	23	22
38 CrS 2	1.7023	—	—	min	51	—	—	46	—	37	—	29	—	25	—	22	20	—	—	—	—	—	—	—	—
46 Cr 2	1.7006	—	—	max	63	—	—	61	—	59	—	57	—	53	—	47	42	39	36	33	32	31	30	29	29
46 CrS 2	1.7025	—	—	min	54	—	—	49	—	40	—	32	—	28	—	25	23	22	20	—	—	—	—	—	—

continued on next page...

END-QUENCH HARDENABILITY BANDS FOR SELECTED DIN SPECIFICATIONS - *CONTINUED*

Metric

Steel Grade		Temperature of Heat Treatment for End Quench Tests (°C)			Distance From Quenched End in Millimeters, Hardness in HRC																			
Symbol	Material Number	Normal -izing	Harden -ing	Band Limits	1.5	1	2	3	4	5	6	7	8	9	10	11	13	15	20	25	30	35	40	45	50
28 Cr 4	1.7036	—	—	max	53	—	—	52	—	51	—	49	—	45	—	42	39	36	33	30	29	28	27	27	27
28 CrS 4	1.7036	—	—	min	45	—	—	43	—	39	—	29	—	25	—	22	20	—	—	—	—	—	—	—	—
34 Cr 4	1.7033	—	—	max	57	—	—	57	—	56	—	54	—	52	—	49	46	44	39	37	35	34	33	32	31
34 CrS 4	1.7037	—	—	min	49	—	—	48	—	45	—	41	—	35	—	32	29	27	23	21	20	—	—	—	—
37 Cr 4	1.7034	—	—	max	59	—	—	59	—	58	—	57	—	55	—	52	50	48	42	39	37	36	35	34	33
37 CrS 4	1.7038	—	—	min	51	—	—	50	—	48	—	44	—	39	—	36	33	31	26	24	22	20	—	—	—
41 Cr 4	1.7035	—	—	max	61	—	—	61	—	60	—	59	—	58	—	56	54	52	46	42	40	38	37	36	35
41 CrS 4	1.7039	—	—	min	53	—	—	52	—	50	—	47	—	41	—	37	34	33	29	26	23	21	—	—	—
25 CrMo 4	1.7218	—	—	max	52	—	—	52	—	51	—	50	—	48	—	46	43	41	37	35	33	32	31	31	31
25 CrMoS 4	1.7213	—	—	min	44	—	—	43	—	40	—	37	—	34	—	32	29	27	23	21	20	—	—	—	—
34 CrMo 4	1.7220	—	—	max	57	—	—	57	—	57	—	56	—	55	—	54	53	52	48	45	43	41	40	40	39
34 CrMoS 4	1.7226	—	—	min	49	—	—	49	—	48	—	45	—	42	—	39	36	34	30	28	27	26	25	24	24
42 CrMo 4	1.7225	—	—	max	61	—	—	61	—	61	—	60	—	60	—	59	59	58	56	53	51	48	47	46	45
42 CrMoS 4	1.7227	—	—	min	53	—	—	53	—	52	—	51	—	49	—	43	40	37	34	32	31	30	30	29	29
50 CrMo 4	1.7228	—	—	max	65	—	—	65	—	64	—	64	—	63	—	63	63	62	61	60	58	57	55	54	54
50 CrMo 4	1.7228	—	—	min	58	—	—	58	—	57	—	55	—	54	—	53	51	48	45	41	39	38	37	36	36
36 CrNiMo 4	1.6511	—	—	max	59	—	—	59	—	58	—	58	—	57	—	57	57	56	55	54	53	52	51	50	49
36 CrNiMo 4	1.6511	—	—	min	51	—	—	50	—	49	—	49	—	48	—	47	46	45	43	41	39	38	36	34	33
34 CrNiMo 6	1.6582	—	—	max	58	—	—	58	—	58	—	58	—	57	—	57	57	57	57	57	57	57	57	57	57
34 CrNiMo 6	1.6582	—	—	min	50	—	—	50	—	50	—	50	—	49	—	48	48	48	48	47	47	47	46	45	44

END-QUENCH HARDENABILITY BANDS FOR SELECTED DIN SPECIFICATIONS - *CONTINUED*

Metric

Steel Grade		Temperature of Heat Treatment for End Quench Tests (°C)			Distance From Quenched End in Millimeters, Hardness in HRC																			
Symbol	Material Number	Normal -izing	Harden -ing	Band Limits	1.5	1	2	3	4	5	6	7	8	9	10	11	13	15	20	25	30	35	40	45	50
30 CrNiMo 8	1.6580	—	—	max	56	—	—	56	—	56	—	56	—	55	—	55	55	55	55	54	54	54	54	54	54
30 CrNiMo 8	1.6580	—	—	min	48	—	—	48	—	48	—	48	—	47	—	47	47	46	46	45	45	44	44	43	43
50 CrV 4	1.8159	—	—	max	65	—	—	65	—	64	—	64	—	63	—	63	63	62	62	62	61	60	60	59	58
50 CrV 4	1.8159	—	—	min	57	—	—	56	—	56	—	55	—	53	—	52	50	48	44	41	37	35	34	33	32
30 CrMoV 9	1.7707	—	—	max	56	—	—	56	—	56	—	56	—	56	—	56	55	55	54	53	52	51	50	49	48
30 CrMoV 9	1.7707	—	—	min	48	—	—	48	—	47	—	47	—	46	—	46	45	44	41	39	38	37	36	35	34
17 Cr 3	1.7016	—	880	max	—	45	45	44	41	38	32	26	21	—	—	—	—	—	—	—	—	—	—	—	—
17 Cr 3	1.7016	—	880	min	—	34	30	25	20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20 Cr 4	1.7027	—	870	max	49	—	—	48	—	46	—	43	—	40	—	37	35	33	28	25	22	—	—	—	—
20 CrS 4	1.7028	—	870	min	41	—	—	39	—	30	—	25	—	22	—	—	—	—	—	—	—	—	—	—	—
16 MnCr 5	1.7131	—	870	max	47	—	—	46	—	44	—	41	—	37	—	35	34	33	31	30	29	28	27	—	—
16 MnCrS 5	1.7139	—	870	min	39	—	—	35	—	31	—	28	—	24	—	22	20	—	—	—	—	—	—	—	—
20 MnCr 5	1.7147	—	870	max	49	—	—	49	—	48	—	46	—	44	—	42	41	40	37	35	34	33	31	—	—
20 MnCrS 5	1.7149	—	870	min	41	—	—	39	—	36	—	33	—	31	—	29	27	25	23	21	—	—	—	—	—
20 MoCr 4	1.7321	—	910	max	49	—	—	47	—	44	—	41	—	38	—	35	33	31	28	26	25	24	24	—	—
20 MoCrS 4	1.7323	—	910	min	41	—	—	37	—	31	—	27	—	34	—	22	—	—	—	—	—	—	—	—	—
22 CrMoS 35	1.7333	—	910	max	50	—	—	49	—	48	—	47	—	45	—	43	41	40	37	35	34	33	32	—	—
22 CrMoS 35	1.7333	—	910	min	42	—	—	41	—	37	—	33	—	31	—	28	26	25	23	22	21	20	—	—	—
21 NiCrMo 2	1.6523	—	925	max	49	—	—	48	—	46	—	43	—	39	—	35	33	31	28	27	26	25	24	—	—
21 NiCrMoS 2	1.6526	—	925	min	41	—	—	37	—	32	—	25	—	22	—	20	—	—	—	—	—	—	—	—	—

continued on next page...

END-QUENCH HARDENABILITY BANDS FOR SELECTED DIN SPECIFICATIONS - *CONTINUED*

Metric

Steel Grade		Temperature of Heat Treatment for End Quench Tests (°C)			Distance From Quenched End in Millimeters, Hardness in HRC																			
Symbol	Material Number	Normal -izing	Harden -ing	Band Limits	1.5	1	2	3	4	5	6	7	8	9	10	11	13	15	20	25	30	35	40	45	50
15 CrNi 6	1.5919	—	860	max	47	—	—	47	—	46	—	45	—	43	—	42	41	39	37	35	34	34	33	—	—
15 CrNi 6	1.5919	—	860	min	39	—	—	38	—	36	—	35	—	32	—	30	28	26	24	22	21	20	20	—	—
17 CrNiMo 6	1.6587	—	860	max	48	—	—	48	—	48	—	48	—	47	—	47	46	46	44	43	42	41	41	—	—
17 CrNiMo 6	1.6587	—	860	min	40	—	—	40	—	39	—	38	—	37	—	36	35	34	32	31	30	29	29	—	—
SMn 420 H (21)	—	925	925	max	48	—	—	46	—	42	—	36	—	30	—	27	25	24	21	—	—	—	—	—	—
SMn 420 H (21)	—	925	925	min	40	—	—	36	—	21	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SMn 433 H (1)	—	900	870	max	57	—	—	56	—	53	—	49	—	42	—	36	33	30	27	25	24	23	22	21	21
SMn 433 H (1)	—	900	870	min	50	—	—	46	—	34	—	26	—	23	—	20	—	—	—	—	—	—	—	—	—
SMn 438 H (2)	—	870	845	max	59	—	—	59	—	57	—	54	—	51	—	46	41	39	35	33	31	30	29	28	27
SMn 438 H (2)	—	870	845	min	52	—	—	49	—	43	—	34	—	28	—	24	22	21	—	—	—	—	—	—	—
SMn 443 H (3)	—	870	845	max	62	—	—	61	—	60	—	59	—	57	—	54	50	45	37	34	32	31	30	29	28
SMn 443 H (3)	—	870	845	min	55	—	—	53	—	49	—	39	—	33	—	29	27	26	23	22	20	—	—	—	—
SMnC 420 H (21)	—	925	925	max	48	—	—	48	—	45	—	41	—	37	—	33	31	29	26	24	23	—	—	—	—
SMnC 420 H (21)	—	925	925	min	40	—	—	39	—	33	—	27	—	23	—	20	—	—	—	—	—	—	—	—	—
SMnC 443 H (3)	—	870	845	max	62	—	—	62	—	61	—	60	—	59	—	58	56	55	50	46	42	41	40	39	38
SMnC 443 H (3)	—	870	845	min	55	—	—	54	—	53	—	51	—	48	—	44	39	35	29	26	25	24	23	22	21
SCr 415 H (21)	—	925	925	max	46	—	—	45	—	41	—	35	—	31	—	28	27	26	23	20	—	—	—	—	—
SCr 415 H (21)	—	925	925	min	39	—	—	34	—	26	—	21	—	—	—	—	—	—	—	—	—	—	—	—	
SCr 420 H (22)	—	925	925	max	48	—	—	48	—	46	—	40	—	36	—	34	32	31	29	27	26	24	23	23	22
SCr 420 H (22)	—	925	925	min	40	—	—	37	—	32	—	28	—	25	—	22	21	—	—	—	—	—	—	—	—

END-QUENCH HARDENABILITY BANDS FOR SELECTED DIN SPECIFICATIONS - *CONTINUED*

Metric

Steel Grade		Temperature of Heat Treatment for End Quench Tests (°C)			Distance From Quenched End in Millimeters, Hardness in HRC																			
Symbol	Material Number	Normal -izing	Harden -ing	Band Limits	1.5	1	2	3	4	5	6	7	8	9	10	11	13	15	20	25	30	35	40	45	50
SCr 430 H (2)	—	900	870	max	56	—	—	55	—	53	—	51	—	48	—	45	42	39	35	33	31	30	28	26	25
SCr 430 H (2)	—	900	870	min	49	—	—	46	—	42	—	37	—	33	—	30	28	26	21	—	—	—	—	—	—
SCr 435 H (3)	—	870	845	max	58	—	—	57	—	56	—	55	—	53	—	51	47	44	39	37	35	34	33	32	31
SCr 435 H (3)	—	870	845	min	51	—	—	49	—	46	—	42	—	37	—	32	29	27	23	21	—	—	—	—	—
SCr 440 H (4)	—	870	845	max	60	—	—	60	—	59	—	58	—	57	—	55	54	52	46	41	39	37	37	36	35
SCr 440 H (4)	—	870	845	min	53	—	—	52	—	50	—	48	—	45	—	41	37	34	29	26	24	22	—	—	—
SCM 415 H (21)	—	925	925	max	46	—	—	45	—	42	—	38	—	34	—	31	29	28	26	25	24	24	23	23	22
SCM 415 H (21)	—	925	925	min	39	—	—	36	—	29	—	24	—	21	—	20	—	—	—	—	—	—	—	—	—
SCM 418 H	—	925	925	max	47	—	—	47	—	45	—	41	—	38	—	35	33	32	30	28	27	27	26	26	25
SCM 418 H	—	925	925	min	39	—	—	37	—	31	—	27	—	24	—	22	21	20	—	—	—	—	—	—	—
SCM 415 H (21)	—	925	925	max	46	—	—	45	—	42	—	38	—	34	—	31	29	28	26	25	24	24	23	23	22
SCM 415 H (21)	—	925	925	min	39	—	—	36	—	29	—	24	—	21	—	20	—	—	—	—	—	—	—	—	—
SCM 418 H	—	925	925	max	47	—	—	47	—	45	—	41	—	38	—	35	33	32	30	28	27	27	26	26	25
SCM 418 H	—	925	925	min	39	—	—	37	—	31	—	27	—	24	—	22	21	20	—	—	—	—	—	—	—
SCM 420 H (22)	—	925	925	max	48	—	—	48	—	47	—	44	—	42	—	39	37	35	33	31	30	30	29	29	28
SCM 420 H (22)	—	925	925	min	40	—	—	39	—	35	—	31	—	28	—	25	24	23	20	20	—	—	—	—	—
SCM 435 H (3)	—	870	845	max	58	—	—	58	—	57	—	56	—	55	—	54	53	51	48	45	43	41	39	38	37
SCM 435 H (3)	—	870	845	min	51	—	—	50	—	49	—	47	—	45	—	42	39	37	32	30	28	27	27	26	26
SCM 440 H (4)	—	870	845	max	60	—	—	60	—	60	—	59	—	58	—	58	57	56	55	53	51	49	47	46	44
SCM 440 H (4)	—	870	845	min	53	—	—	53	—	52	—	51	—	50	—	48	46	43	38	35	33	33	32	31	30

continued on next page...

END-QUENCH HARDENABILITY BANDS FOR SELECTED DIN SPECIFICATIONS - *CONTINUED*

Metric

Steel Grade		Temperature of Heat Treatment for End Quench Tests (°C)			Distance From Quenched End in Millimeters, Hardness in HRC																			
Symbol	Material Number	Normal -izing	Harden -ing	Band Limits	1.5	1	2	3	4	5	6	7	8	9	10	11	13	15	20	25	30	35	40	45	50
SCM 445 H (5)	—	870	845	max	56	—	—	63	—	62	—	62	—	61	—	61	61	60	59	58	57	56	55	55	54
SCM 445 H (5)	—	870	845	min	56	—	—	55	—	55	—	54	—	53	—	52	52	51	47	43	39	37	35	35	34
SCM 882 H (24)	—	925	925	max	50	—	—	50	—	50	—	49	—	48	—	46	43	41	39	38	37	36	36	36	36
SCM 882 H (24)	—	925	925	min	43	—	—	42	—	41	—	39	—	36	—	32	29	27	24	24	23	22	22	21	21
SNC 415 H (21)	—	925	925	max	45	—	—	44	—	39	—	35	—	31	—	28	26	24	21	—	—	—	—	—	—
SNC 415 H (21)	—	925	925	min	37	—	—	32	—	24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SNC 631 H (2)	—	900	870	max	57	—	—	57	—	56	—	56	—	55	—	55	55	54	53	51	49	47	45	44	43
SNC 631 H (2)	—	900	870	min	49	—	—	48	—	47	—	46	—	45	—	43	41	39	35	31	29	28	27	26	26
SNC 815 H (22)	—	925	845	max	46	—	—	46	—	46	—	46	—	45	—	44	43	41	38	35	34	34	33	33	32
SNC 815 H (22)	—	925	845	min	38	—	—	37	—	36	—	34	—	31	—	29	27	26	24	22	22	22	21	21	21
SNCM 220 H (21)	—	925	925	max	48	—	—	47	—	44	—	40	—	35	—	32	30	29	26	24	23	23	23	22	22
SNCM 220 H (21)	—	925	925	min	41	—	—	37	—	30	—	25	—	22	—	20	—	—	—	—	—	—	—	—	—
SNCM 420 H (23)	—	925	925	max	48	—	—	47	—	46	—	42	—	39	—	36	34	32	29	26	25	24	24	24	24
SNCM 420 H (23)	—	925	925	min	41	—	—	38	—	34	—	30	—	27	—	25	23	22	—	—	—	—	—	—	—

HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF CARBON STEEL BARS

Chemical Ranges and Limits, Percent			
Element	**Maximum of Specified Element**	**Range**	**Lowest Maximum**
Carbon[a]	—	—	0.06
	to 0.12 incl.	—	—
	over 0.12/0.25 incl.	0.05	—
	over 0.25/0.40 incl.	0.06	—
	over 0.40/0.55 incl.	0.07	—
	over 0.55/0.80 incl.	0.10	—
	over 0.80	0.13	—
Manganese	—	—	0.35
	to 0.40 incl.	0.15	—
	over 0.40/0.50 incl.	0.20	—
	over 0.50/1.65 incl.	0.30	—
Phosphorus	to 0.40 incl.	—	0.040[d]
	over 0.40/0.80 incl.	0.03	—
	over 0.08/0.13 incl.	0.05	—
Sulfur	to 0.50 incl.	—	0.050[d]
	over 0.050/0.09 incl.	0.03	—
	over 0.09/0.15 incl.	0.05	—
	over 0.15/0.23 incl.	0.07	—
	over 0.23/0.50 incl.	0.09	—
Silicon[b]	—	—	0.050[d]
	to 0.10 incl.	0.03	—
	over 0.10/0.15 incl.	0.05	—
	over 0.15/0.20 incl.	0.07	—
	over 0.23/0.50 incl.	0.09	—
Copper	when copper is required, 0.20 min is generally used	—	—
Lead[c]	when lead is required, a range of 0.15/0.35 is specified	—	—
Bismuth[e]	—	—	—
Calcium[e]	—	—	—
Selenium[e]	—	—	—
Tellunum[e]	—	—	—

a *The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1/10 percent. When the maximum manganese limit exceeds 1/10 percent, add 0.01 to the carbon ranges shown above.*

b *It is not common practice to produce a rephosphorized and resulfurized carbon steel to specified limits for silicon because of its adverse effect on machinability.*

c *A cast or heat analysis is not determinable when lead is added to the ladle stream.*

d *For steels produced in merchant quality, the phosphorus maximum is 0.04 percent and the sulfur maximum is 0.05 percent.*

e *Element specification range as agreed upon between purchaser and supplier.*

HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF ALLOY STEEL BARS

Chemical Ranges and Limits, Percent				
Element	Maximum of Specified Element	Open-Hearth or Basic-Oxygen Steel	Electric-Furnace Steel	Maximum Limit Percent[a]
Carbon	to 0.55 incl.	0.05	0.05	—
	over 0.55/0.70 incl.	0.08	0.07	—
	over 0.70/0.80 incl.	0.10	0.09	—
	over 0.80/0.95 incl.	0.12	0.11	—
	over 0.95/1.35 incl.	0.13	0.12	—
Manganese	to 0.60 incl.	0.20	0.15	—
	over 0.60/0.90 incl.	0.20	0.20	—
	over 0.90/1.05 incl.	0.25	0.25	—
	over 1.05/1.90 incl.	0.30	0.30	—
	over 1.90/2.10 incl.	0.40	0.35	—
Phosphorus	basic open-hearth or basic-oxygen steel	—	—	0.035[c]
	acid open-hearth steel	—	—	0.050
	basic electric-furnace steel	—	—	0.025
	acid electric-furnace steel	—	—	0.050
Sulfur	to 0.50 incl.	0.015	0.015	—
	over 0.050/0.07 incl.	0.02	0.02	—
	over 0.07/0.10 incl.	0.04	0.04	—
	basic open-hearth or basic-oxygen steel	—	—	0.040[c]
	acid open-hearth steel	—	—	0.050
	basic electric-furnace steel	—	—	0.025
	acid electric-furnace steel	—	—	0.050
Silicon	to 0.20 incl.	0.08	0.08	—
	over 0.20/0.30 incl.	0.15	0.15	—
	over 0.30/0.60 incl.	0.20	0.20	—
	over 0.60/1.00 incl.	0.30	0.30	—
	over 1.00/2.20 incl.	0.40	0.35	—
	acid steels[b]	—	—	—
Nickel	to 0.50 incl.	0.20	0.20	—
	over 0.50/1.50 incl.	0.30	0.30	—
	over 1.50/2.00 incl.	0.35	0.35	—
	over 2.00/3.00 incl.	0.40	0.40	—
	over 3.00/5.30 incl.	0.50	0.50	—
	over 5.30/10.00 incl.	1.00	1.00	—
Chromium	to 0.40 incl.	0.15	0.15	—
	over 0.40/0.90 incl.	0.20	0.20	—
	over 0.90/1.05 incl.	0.25	0.25	—
	over 1.05/1.60 incl.	0.30	0.30	—
	over 1.60/1.75 incl.	[b]	0.35	—
	over 1.75/2.10 incl.	[b]	0.40	—
	over 2.10/3.99 incl.	[b]	0.50	—

HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF ALLOY STEEL BARS - *CONTINUED*

Chemical Ranges and Limits, Percent				
Element	**Maximum of Specified Element**	**Open-Hearth or Basic-Oxygen Steel**	**Electric-Furnace Steel**	**Maximum Limit Percent[a]**
Molybdenum	to 0.10 incl.	0.05	0.05	—
	over 0.10/0.20 incl.	0.07	0.07	—
	over 0.20/0.50 incl.	0.10	0.10	—
	over 0.50/0.80 incl.	0.15	0.15	—
	over 0.80/1.15 incl.	0.20	0.20	—
Tungsten	to 0.50 incl.	0.20	0.20	—
	over 0.50/1.00 incl.	0.30	0.30	—
	over 1.00/2.00 incl.	0.50	0.50	—
	over 2.00/4.00 incl.	0.60	0.60	—
Vanadium	to 0.25 incl.	0.25	0.25	—
	over 0.25/0.50 incl.	0.10	0.10	—
Aluminum	up to 0.10 incl.	0.05	0.05	—
	over 0.10/0.20 incl.	0.10	0.10	—
	over 0.20/0.30 incl.	0.15	0.15	—
	over 0.30/0.80 incl.	0.25	0.25	—
	over 0.80/1.30 incl.	0.35	0.35	—
	over 1.30/1.80 incl.	0.45	0.45	—
Copper	to 0.60 incl.	0.20	0.20	—
	over 0.60/1.50 incl.	0.30	0.30	—
	over 1.50/2.00 incl.	0.35	0.35	—

NOTE 1: *Boron steels can be expected to have 0.0005 percent minimum boron content.*

NOTE 2: *Alloy steels can be produced with a lead range of 0.15/0.35 percent. A cast or heat analysis is not determinable when lead is added to the ladle stream.*

NOTE 3: *Small quantities of certain elements are present in alloy steels that are specified or required. These elements are considered incidental and may be present to the following maximum amounts: Cu = 0.35 percent, Ni = 0.25 percent, Cr = 0.20 percent, Mo = 0.06 percent*

a *Applies to only nonrephosphorized and nonresulfurized steels.*

b *Minimum silicon limit for acid open-hearth or acid electric furnace alloy steels is 0.15 percent.*

c *Not normally produced in open-hearth.*

PERMISSIBLE VARIATIONS FOR PRODUCT ANALYSIS OF CARBON STEEL

Element	Limit or Maximum of Specified Range, Percent	Over Maximum Limit, Percent	Under Maximum Limit, Percent[a]
Carbon[a]	0.25 and under	0.02	0.02
	over 0.25/0.55 incl.	0.03	0.03
	over 0.55	0.04	0.04
Manganese	0.90 and under	0.03	0.03
	over 0.90/1.65 incl.	0.06	0.06
Phosphorus[a,b]	basic steels	0.008	—
	acid Bessemer steel	0.01	0.01
Sulfur[a,b]	—	0.008	—
Silicon	0.35 and under	0.02	0.02
	over 0.35/0.60 incl.	0.05	0.05
Copper	under minimum only	—	0.02
Lead[c]	0.15/0.35 incl.	0.03	0.03

a *Rimmed and capped steels are not subject to rejection on product analysis unless misapplication is clearly indicated.*

b *Resulfurized or rephosphorized steels are not subject to rejection on product analysis for these elements unless misapplication is clearly indicated.*

c *Product analysis tolerance for lead applies both over and under to a spedfied range of 0.15/0.35 percent.*

PRODUCT ANALYSIS TOLERANCES FOR ALLOY STEELS

Bars, Blooms, Billets and Slabs

Element	Limit or Maximum of Specified Range, Percent	Tolerance, in Percent, Over Maximum Limit or Under Minimum Limit for Size Ranges Shown	
		To 100 in² (64,516 mm²) Incl.	Over 100 in² (64,516 mm²)
Carbon	0.30 and under	0.01	0.02
	over 0.30/0.75 incl.	0.02	0.03
	over 0.75	0.03	0.04
Manganese	0.90 and under	0.03	0.04
	over 0.90/2.10 incl.	0.04	0.05
Phosphorus	over maximum only	0.005	0.010
Sulfur	over maximum only[a]	0.005	0.010
Silicon	0.40 and under	0.02	0.02
	over 0.40/2.20 incl.	0.05	0.06
Nickel	1.00 and under	0.03	0.03
	over 1.00/2.00 incl.	0.05	0.05
	over 2.00/5.30 incl.	0.07	0.07
	over 5.30/10.00 incl.	0.10	0.10
Chromium	0.90 and under	0.03	0.04
	over 0.90/2.10 incl.	0.05	0.06
	over 2.10/3.99 incl.	0.10	0.10
Molybdenum	0.20 and under	0.01	0.01
	over 0.20/0.40 incl.	0.02	0.03
	over 0.40/1.15 incl.	0.03	0.04
Tungsten	1.00 and under	0.04	0.05
	over 1.00/4.00 incl.	0.08	0.09
Vanadium	0.10 and under	0.01	0.01
	over 0.10/0.25 incl.	0.02	0.02
	over 0.25/0.50 incl.	0.03	0.03
	min. value specified, under min. limit only[d]	0.01	—
Aluminum[b]	0.10 and under	0.03	—
	over 0.10/0.20 incl.	0.04	—
	over 0.20/0.30 incl.	0.05	—
	over 0.30/0.80 incl.	0.07	—
	over 0.80/1.80 incl.	0.10	—
Lead[b]	0.15/0.35 incl.	0.03[c]	—
Copper[b]	to 1.00 incl.	0.03	—
	over 1.00/2.00 incl.	0.05	—
Titanium[b]	to 0.10 incl.	0.01[d]	—
Columbium[b]	to 0.10 incl.	0.01[d]	—
Zirconium[b]	to 0.15 incl.	0.03	—
Nitrogen[b]	to 0.030 incl.	0.005	—

NOTE: *Boron is not subject to product analysis tolerances.*

a *Resulfurized steels are not subject to product analysis limits for sulfur.*

b *Tolerances shown apply only to 100 in² (64,516 mm²) or less.*

c *Tolerance is over and under.*

d *If the minimum of the range is 0.01 percent, the under tolerance is 0.005 percent.*

RECOMMENDED COLD SHEARING LIMITATIONS FOR HOT ROLLED ALLOY AND CARBON STEEL BILLETS AND BARS (Standard AISI & SAE Grades and Formerly Standard SAE Grades)

Maximum Square or Equivalent Cross-Sectional Area[a] Without Heat Treatment

Grade Series Designation	When Maximum of Specified Carbon Range is, Percent							
	To 0.20 Incl.	Over 0.20 To 0.25 Incl.	Over 0.25 To 0.33 Incl.	Over 0.33 To 0.44 Incl.	Over 0.44 To 0.49 Incl.	Over 0.49 To 0.55 Incl.	Over 0.55 To 0.76 Incl.	Over 0.76 To 1.05 Incl.
10XX, 12XX and 11XX thru 1.00 max Mn	4 ½	4 ½	4	3	2 ½	2	1 ½	1
11XX over 1.00 max Mn and 15XX	4 ¼	4	3 ½	2 ½	2	1 ½	1	—
13XX	—	4	3 ½	2 ½	2[b]	—	—	—
23XX	4	4	3 ½	3	2[b]	—	—	—
25XX	4	—	—	—	—	—	—	—
31XX	4	4	3 ½	3	2 ½[b]	—	—	—
32XX	3 ½	3	2 ½	2[b]	[c]	—	—	—
33XX	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]
34XX	4	—	—	2 ½[b]	—	—	—	—
40XX	4	4	4	3	2 ½[b]	2	[c]	—
41XX	4	4	3 ½	2 ½[b]	[c]	[c]	—	—
43XX	4	4	—	1 ½[b]	—	—	—	—
44XX	—	4	4	—	—	—	—	—
46XX	4	4	3 ½	2[b]	—	—	—	—
47XX	—	4	—	—	—	—	—	—
48XX	4	3	—	—	—	—	—	—
50XX	4	—	—	—	2	—	—	—
50BXX	—	—	—	2	2[b]	[c]	[c]	—
51XX	4	4	4	3	2	[c]	—	—

RECOMMENDED COLD SHEARING LIMITATIONS FOR HOT ROLLED ALLOY AND CARBON STEEL BILLETS AND BARS (Standard AISI & SAE Grades and Formerly Standard SAE Grades) - *CONTINUED*

Grade Series Designation	Maximum Square or Equivalent Cross-Sectional Area[a] Without Heat Treatment — When Maximum of Specified Carbon Range is, Percent							
	To 0.20 Incl.	Over 0.20 To 0.25 Incl.	Over 0.25 To 0.33 Incl.	Over 0.33 To 0.44 Incl.	Over 0.44 To 0.49 Incl.	Over 0.49 To 0.55 Incl.	Over 0.55 To 0.76 Incl.	Over 0.76 To 1.05 Incl.
51BXX	—	—	—	—	—	—	[c]	—
61XX	4	4	3	2 ½	2[b]	[c]	—	[c]
81XX	4	—	—	—	—	—	—	—
81BXX	—	—	—	—	2 ½	—	—	—
86XX	4	4	3	2 ½	2[b]	[c]	[c]	—
86BXX	—	—	3	—	2[b]	—	—	—
87XX	4	4	—	2 ½	2[b]	[c]	—	—
88XX	—	3 ½	—	—	—	—	—	—
92XX	—	—	—	—	—	[c]	[c]	—
93XX	[c]	—	—	—	—	—	—	—
94XX	—	—	—	2 ½	[c]	[c]	—	—
94BXX	4	—	4	2 ½	—	—	—	—
97XX	—	—	—	—	—	[c]	[c]	—
98XX	—	—	—	[c]	[c]	[c]	—	—
43BVXX	4	—	—	—	—	—	—	—

NOTE: *For standard H grades, the maximum carbon content of the comparable standard steel is used when considering cold shearing limitations.*

a *Refer to Table 1-4 for cross-sectional area and metric equivalents.*

b *Sizes 1 inch² and smaller should be cold shearing quality or thermally treated before cold shearing. Producers should be consulted for flat sizes under 3/4 inch thickness.*

c *All sizes in this carbon range should be cold shearing quality or thermally treated before cold shearing.*

RECOMMENDED COLD SHEARING LIMITATIONS FOR COLD SHEARING QUALITY HOT ROLLED ALLOY AND CARBON STEEL BILLETS AND BARS (Standard AISI & SAE Grades and Formerly Standard SAE Grades)

Grade Series Designation	Maximum Square or Equivalent Cross-Sectional Area[a] After Cold Shear Annealing — When Maximum of Specified Carbon Range is, Percent							
	To 0.20 Incl.	Over 0.20 To 0.25 Incl.	Over 0.25 To 0.33 Incl.	Over 0.33 To 0.44 Incl.	Over 0.44 To 0.49 Incl.	Over 0.49 To 0.55 Incl.	Over 0.55 To 0.76 Incl.	Over 0.76 To 1.05 Incl.
10XX, 12XX and 11XX thru 1.00 max Mn	6 ½	6 ½	6	5	4 ½	4	3 ½	2 ½
11XX over 1.00 max Mn and 15XX	6 ½	6	5 ½	4 ½	4	3	2 ¼	—
13XX	—	5	4 ¾	4 ½	4	—	—	—
23XX	5	5	4 ¾	4 ¼	3 ½	—	—	—
25XX	5	—	—	—	—	—	—	—
31XX	5	5	4 ¾	4 ¼	4	—	—	—
32XX	4	3 ½	3	2 ½	[a]	—	—	—
33XX	3	—	[a]	[a]	[a]	—	—	—
34XX	4 ½	—	—	3	—	—	—	—
40XX	5	5	4 ¾	4 ½	4 ½	4 ¼	[a]	—
41XX	5	5	4 ¾	4 ¼	4	3	—	—
43XX	4 ¾	4 ¾	—	4	—	—	—	—
44XX	—	5	4 ¾	—	—	—	—	—
46XX	5	5	4 ¾	4 ¼	—	—	—	—
47XX	—	5	—	—	—	—	—	—
48XX	5	4 ¾	—	—	—	—	—	—
50XX	5	—	—	—	4 ¼	—	—	—
50BXX	—	—	—	4 ½	4 ¼	3 ½	[a]	—
51XX	5	5	4 ¾	4 ½	4	3 ¼	—	—

RECOMMENDED COLD SHEARING LIMITATIONS FOR COLD SHEARING QUALITY HOT ROLLED ALLOY AND CARBON STEEL BILLETS AND BARS (Standard AISI & SAE Grades and Formerly Standard SAE Grades) - *CONTINUED*

Maximum Square or Equivalent Cross-Sectional Area[a] After Cold Shear Annealing								
	When Maximum of Specified Carbon Range is, Percent							
Grade Series Designation	To 0.20 Incl.	Over 0.20 To 0.25 Incl.	Over 0.25 To 0.33 Incl.	Over 0.33 To 0.44 Incl.	Over 0.44 To 0.49 Incl.	Over 0.49 To 0.55 Incl.	Over 0.55 To 0.76 Incl.	Over 0.76 To 1.05 Incl.
51BXX	—	—	—	—	4	3 1/4	a	—
61XX	5	5	4 3/4	4 1/4	4	3	—	a
81XX	5	—	—	—	—	—	—	—
81BXX	—	—	—	—	4	—	—	—
86XX	5	5	4 3/4	4 1/2	4	3 1/4	a	—
86BXX	—	—	4 3/4	—	4	—	—	—
87XX	—	—	—	4 1/2	4	3 1/4	—	—
88XX	—	4 3/4	—	—	—	—	—	—
92XX	—	—	—	—	—	1	a	—
93XX	3	—	—	—	—	—	—	—
94XX	—	—	—	4 1/2	4	3 1/4	—	—
94BXX	5	—	4 3/4	4 1/2	—	—	—	—
97XX	—	—	—	—	—	3 1/4	a	—
98XX	—	—	—	3 3/4	3	a	—	—
43BVXX	4 3/4	—	—	—	—	—	—	—

NOTE: *For standard H grades, the maximum carbon content of the comparable standard steel is used when considering cold shearing limitations.*

a *All sizes in this carbon range should be thermally treated before cold shearing.*

b *Refer to Table 1-4 for cross-sectional area and metric equivalents.*

ESTIMATED MECHANICAL PROPERTIES AND MACHINABILITY OF HOT ROLLED AND COLD DRAWN CARBON STEEL BARS

Mechanical Properties

The mechanical properties listed in the following tables are given as a matter of general information. They do not form a part or requirement of any specification unless each instance is approved by the source of supply. The properties in these tables can generally be expected from bars in sizes ranging from ¾ to 1¼ inches based on the standard round tensile test specimen with 2-inch gage length.

Sizes under ¾ inches will show slightly higher strength than those shown in the tables. The mass effect of larger sections has a direct influence on mechanical properties and results in slightly lower values as the section increases.

Properties of turned and polished or turned and ground types of cold finished material will correspond to the hot rolled values.

The cold drawn properties are based on conventional production from hot rolled bars. When required, these properties may be varied by modifled cold drawing practices or a combination of cold drawing practice plus thermal treatment for grades SAE 1050 and lower in carbon. Grades higher in carbon than SAE 1050 are commonly annealed before cold drawing.

Machinability Ratings

The machinability ratings listed are based on a value of 100% for SAE 1212 cold drawn. This value involves turning at a cutting speed of 180 surface feet per minute for feeds up to .007 inches per revolution and depths of cut up to .250 inches, using appropriate cutting fluids with high speed steel tools, SAE Grade T-1(18-4-1) hardened to 63/65 RC.

Relative machinability data shown in the tables represent results obtained from various experimental data and actual shop production information obtained from results of machining cold drawn bars on single and multiple spindle automatic machines. Various factors influence machinability and, therefore, results shown in the tables are average and may be affected to some degree by amount of cold reduction, mechanical properties, grain size, and microstructure.

NOTE: *References: J414 and J770C SAE Handbook.*

ESTIMATED MECHANICAL PROPERTIES AND MACHINABILITY OF AISI AND SAE CARBON STEEL BARS

		Estimated Minimum Values					
AISI & SAE No.	Type of Processing	Tensile Strength (psi)	Yeild Strength (psi)	Elongation in 2 Inches, (%)	Reduction in Area, (%)	Brinell Hardness	Average Machinability Rating (Cold Drawn 1212 = 100%)
1006	hot rolled	43,000	24,000	30	55	86	—
	cold drawn	48,000	41,000	20	45	95	50
1008	hot rolled	44,000	24,500	30	55	86	—
	cold drawn	49,000	41,500	20	45	95	55
1010	hot rolled	47,000	26,000	28	50	95	—
	cold drawn	53,000	44,000	20	40	105	55
1012	hot rolled	48,000	26,500	28	50	95	—
	cold drawn	54,000	45,000	19	40	105	55
1015	hot rolled	50,000	27,500	28	50	101	—
	cold drawn	56,000	47,000	18	40	111	60
1016	hot rolled	55,000	30,000	25	50	111	—
	cold drawn	61,000	51,000	18	40	121	70
1017	hot rolled	53,000	29,000	26	50	105	—
	cold drawn	59,000	49,000	18	40	116	65
1018	hot rolled	58,000	32,000	25	50	116	—
	cold drawn	64,000	54,000	15	40	126	70
1019	hot rolled	59,000	32,500	25	50	116	—
	cold drawn	66,000	55,000	15	40	131	70
1020	hot rolled	55,000	30,000	25	50	111	—
	cold drawn	61,000	51,000	15	40	121	65
1021	hot rolled	61,000	33,000	24	48	116	—
	cold drawn	68,000	57,000	15	40	131	70

continued on next page...

ESTIMATED MECHANICAL PROPERTIES AND MACHINABILITY OF AISI AND SAE CARBON STEEL BARS - *CONTINUED*

		Estimated Minimum Values					
AISI & SAE No.	**Type of Processing**	**Tensile Strength (psi)**	**Yeild Strength (psi)**	**Elongation in 2 Inches, (%)**	**Reduction in Area, (%)**	**Brinell Hardness**	**Average Machinability Rating (Cold Drawn 1212 = 100%)**
1022	hot rolled	62,000	34,000	23	47	121	—
	cold drawn	69,000	58,000	15	40	137	70
1023	hot rolled	56,000	31,000	25	50	111	—
	cold drawn	62,000	52,500	15	40	121	65
1024*	hot rolled	74,000	41,000	20	42	149	—
	cold drawn	82,000	69,000	12	35	163	60
1025	hot rolled	58,000	32,000	25	50	116	—
	cold drawn	64,000	54,000	15	40	126	65
1026	hot rolled	64,000	35,000	24	49	126	—
	cold drawn	71,000	60,000	15	40	143	75
1027*	hot rolled	75,000	41,000	18	40	149	—
	cold drawn	83,000	70,000	12	35	163	65
1030	hot rolled	68,000	37,500	20	42	137	—
	cold drawn	76,000	64,000	12	35	149	70
1035	hot rolled	72,000	39,500	18	40	143	—
	cold drawn	80,000	67,000	12	35	163	65
1036*	hot rolled	83,000	45,500	16	40	163	—
	cold drawn	92,000	77,500	12	35	187	55
1037	hot rolled	74,000	40,500	18	40	143	—
	cold drawn	82,000	69,000	12	35	167	65
1038	hot rolled	75,000	41,000	18	40	149	—
	cold drawn	83,000	70,000	12	35	163	65

ESTIMATED MECHANICAL PROPERTIES AND MACHINABILITY OF AISI AND SAE CARBON STEEL BARS - *CONTINUED*

		Estimated Minimum Values					
AISI & SAE No.	**Type of Processing**	**Tensile Strength (psi)**	**Yeild Strength (psi)**	**Elongation in 2 Inches, (%)**	**Reduction in Area, (%)**	**Brinell Hardness**	**Average Machinability Rating (Cold Drawn 1212 = 100%)**
1039	hot rolled	79,000	43,500	16	40	156	—
	cold drawn	88,000	74,000	12	35	179	60
1040	hot rolled	76,000	42,000	18	40	149	—
	cold drawn	85,000	71,000	12	35	170	60
1041*	hot rolled	92,000	51,000	15	40	187	—
	cold drawn	102,500	87,000	10	30	207	45
	ACD[a]	94,000	80,000	10	45	184	60
1042	hot rolled	80,000	44,000	16	40	163	—
	cold drawn	89,000	75,000	12	35	179	60
	NCD[b]	85,000	73,000	12	45	179	70
1043	hot rolled	82,000	45,000	16	40	163	—
	cold drawn	91,000	77,000	12	35	179	60
	NCD[b]	87,000	75,000	12	45	179	70
1044	hot rolled	80,000	44,000	16	40	163	—
1045	hot rolled	82,000	45,000	16	40	163	—
	cold drawn	91,000	77,000	12	35	179	55
	ACD[a]	85,000	73,000	12	45	170	65
1046	hot rolled	85,000	47,000	15	40	170	—
	cold drawn	94,000	79,000	12	35	187	55
	ACD[a]	90,000	75,000	12	45	179	65
1047*	hot rolled	94,000	52,000	15	30	192	—
	cold drawn	103,000	88,000	10	28	207	40

continued on next page...

ESTIMATED MECHANICAL PROPERTIES AND MACHINABILITY OF AISI AND SAE CARBON STEEL BARS - *CONTINUED*

		Estimated Minimum Values					
AISI & SAE No.	Type of Processing	Tensile Strength (psi)	Yeild Strength (psi)	Elongation in 2 Inches, (%)	Reduction in Area, (%)	Brinell Hardness	Average Machinability Rating (Cold Drawn 1212 = 100%)
1047*	ACD[a]	95,000	85,000	10	35	187	45
1048*	hot rolled	96,000	53,000	14	33	197	—
	cold drawn	106,500	89,500	10	28	217	45
	ACD[a]	93,500	78,500	10	35	192	50
1049	hot rolled	87,000	48,000	15	35	179	—
	cold drawn	97,000	81,500	10	30	197	45
	ACD[a]	92,000	77,000	10	40	187	55
1050	hot rolled	90,000	49,500	15	35	179	—
	cold drawn	100,000	84,000	10	30	197	45
	ACD[a]	95,000	80,000	10	40	189	55
1052*	hot rolled	108,000	59,500	12	30	217	—
	ACD[a]	98,000	83,000	10	40	193	50
1055	hot rolled	94,000	51,500	12	30	192	—
	ACD[a]	96,000	81,000	10	40	197	55
1060	hot rolled	98,000	54,000	12	30	201	—
	SACD[c]	90,000	70,000	10	45	183	60
1064	hot rolled	97,000	53,500	12	30	201	—
	SACD[c]	89,000	69,000	10	45	183	60
1065	hot rolled	100,000	55,000	12	30	207	—
	SACD[c]	92,000	71,000	10	45	187	60
1070	hot rolled	102,000	56,000	12	30	212	—
	SACD[c]	93,000	72,000	10	45	192	55

ESTIMATED MECHANICAL PROPERTIES AND MACHINABILITY OF AISI AND SAE CARBON STEEL BARS - *CONTINUED*

		Estimated Minimum Values					
AISI & SAE No.	**Type of Processing**	**Tensile Strength (psi)**	**Yeild Strength (psi)**	**Elongation in 2 Inches, (%)**	**Reduction in Area, (%)**	**Brinell Hardness**	**Average Machinability Rating (Cold Drawn 1212 = 100%)**
1074	hot rolled	105,000	58,000	12	30	217	—
	SACD[c]	94,500	73,000	10	40	192	55
1078	hot rolled	100,000	55,000	12	30	207	—
	SACD[c]	94,000	72,500	10	40	192	55
1080	hot rolled	112,000	61,500	10	25	229	—
	SACD[c]	98,000	75,000	10	40	192	45
1084	hot rolled	119,000	65,500	10	25	241	—
	SACD[c]	100,000	77,000	10	40	192	45
1085	hot rolled	121,000	66,500	10	25	248	—
	SACD[c]	100,500	78,000	10	40	192	45
1086	hot rolled	112,000	61,500	10	25	229	—
	SACD[c]	97,000	74,000	10	40	192	45
1090	hot rolled	122,000	67,000	10	25	248	—
	SACD[c]	101,000	78,000	10	40	197	45
1095	hot rolled	120,000	66,000	10	25	248	—
	SACD[c]	99,000	76,000	10	40	197	45

a *ACD represents annealed cold drawn.*

b *NCD represents normalized cold drawn.*

c *SACD represents spheroidized cold drawn.*

* *These grades with maximum Mn in excess of 1% have been renumbered 1500 series. See table 3, SAE J403.*

ESTIMATED MECHANICAL PROPERTIES AND MACHINABILITY RATINGS OF RESULFURIZED CARBON STEEL BARS[a]

		Estimated Minimum Values					
AISI & SAE No.	Type of Processing	Tensile Strength (psi)	Yeild Strength (psi)	Elongation in 2 Inches, (%)	Reduction in Area, (%)	Brinell Hardness	Average Machinability Rating (Cold Drawn 1212 = 100%)
1111	hot rolled	55,000	33,000	25	45	121	—
	cold drawn	75,000	58,000	10	35	163	95
1112	hot rolled	56,000	33,500	25	45	121	—
	cold drawn	78,000	60,000	10	35	167	100
1113	hot rolled	56,000	33,500	25	45	121	—
	cold drawn	78,000	60,000	10	35	167	135
12L14	hot rolled	57,000	34,000	22	45	121	—
	cold drawn	78,000	60,000	10	35	163	160
1108	hot rolled	50,000	27,500	30	50	101	—
	cold drawn	56,000	47,000	20	40	121	80
1109	hot rolled	50,000	27,500	30	50	101	—
	cold drawn	56,000	47,000	20	40	121	80
1117	hot rolled	62,000	34,000	23	47	121	—
	cold drawn	69,000	58,000	15	40	137	90
1118	hot rolled	65,000	36,000	23	47	131	—
	cold drawn	72,000	61,000	15	40	143	85
1119	hot rolled	62,000	34,000	23	47	121	—
	cold drawn	69,000	58,000	15	40	137	100
1132	hot rolled	83,000	45,500	16	40	167	—
	cold drawn	92,000	77,000	12	35	183	75
1137	hot rolled	88,000	48,000	15	35	179	—
	cold drawn	98,000	82,000	10	30	197	70

ESTIMATED MECHANICAL PROPERTIES AND MACHINABILITY RATINGS OF RESULFURIZED CARBON STEEL BARS[a] - *CONTINUED*

		Estimated Minimum Values					
AISI & SAE No.	**Type of Processing**	**Tensile Strength (psi)**	**Yeild Strength (psi)**	**Elongation in 2 Inches, (%)**	**Reduction in Area, (%)**	**Brinell Hardness**	**Average Machinability Rating (Cold Drawn 1212 = 100%)**
1140	hot rolled	79,000	43,500	16	40	156	—
	cold drawn	88,000	74,000	12	35	170	70
1141	hot rolled	94,000	51,500	15	35	187	—
	cold drawn	105,100	88,000	10	30	212	70
1144	hot rolled	97,000	53,000	15	35	197	—
	cold drawn	108,000	90,000	10	30	217	80
1145	hot rolled	85,000	47,000	15	40	170	—
	cold drawn	94,000	80,000	12	35	187	65
1146	hot rolled	85,000	47,000	15	40	170	—
	cold drawn	94,000	80,000	12	35	187	70
1151	hot rolled	92,000	50,500	15	35	187	—
	cold drawn	102,000	86,000	10	30	207	65

a *All SAE 1100 series steels are rated on the basis of .10 max silicon or coarse grain melting practice.*

ESTIMATED MECHANICAL PROPERTIES AND MACHINABILITY RATINGS OF SELECTED COLD DRAWN ALLOY STEELS

AISI SAE No.	Treatment	Tensile Strength (psi)	Yield Strength (psi)	Elong. (%) in 2”	Reduction of Area (%)	Brinell Hardness	Relative Machinability Rating, (%), Based on SAE 1212 as 100%
1340	As-Rolled						
	Normalized	121,360	81,000	22.0	62.9	248	
	Annealed	102,000	63,300	25.5	57.3	207	
	Cold Drawn						50
4130	As-Rolled						
	Normalized	97,000	63,300	25.5	59.5	197	
	Annealed	81,300	52,300	28.2	55.6	156	
	Cold Drawn						70
4140	As-Rolled						
	Normalized	148,000	95,000	17.7	46.8	302	
	Annealed	95,000	60,500	25.7	56.9	197	
	Cold Drawn						65
4150	As-Rolled						
	Normalized	167,500	106,500	11.7	30.8	321	
	Annealed	105,800	55,000	20.2	40.2	197	
	Cold Drawn						55
4320	As-Rolled						
	Normalized	115,000	67,300	20.8	50.7	235	
	Annealed	84,000	61,600	29.0	58.4	163	
	Cold Drawn						60
4340	As-Rolled						
	Normalized	185,500	125,000	12.2	36.3	363	
	Annealed	108,000	68,500	22.0	49.9	217	
	Cold Drawn						50

ESTIMATED MECHANICAL PROPERTIES AND MACHINABILITY RATINGS OF SELECTED COLD DRAWN ALLOY STEELS - *CONTINUED*

AISI SAE No.	Treatment	Tensile Strength (psi)	Yield Strength (psi)	Elong. (%) in 2”	Reduction of Area (%)	Brinell Hardness	Relative Machinability Rating, (%), Based on SAE 1212 as 100%
4620	As-Rolled						
	Normalized	83,300	53,100	29.0	66.7	174	
	Annealed	74,300	54,000	31.3	60.3	149	
	Cold Drawn						65
5140	As-Rolled						
	Normalized	115,000	68,500	22.7	59.2	229	
	Annealed	83,000	42,500	28.6	57.3	167	
	Cold Drawn						65
5160	As-Rolled						
	Normalized	138,800	77,000	17.5	44.8	269	
	Annealed	104,800	40,000	17.2	30.6	197	
	Cold Drawn						55
8620	As-Rolled						
	Normalized	91,800	51,800	26.3	59.7	183	
	Annealed	77,800	55,900	31.3	62.1	149	
	Cold Drawn						65
8630	As-Rolled						
	Normalized	94,300	62,300	23.5	53.5	187	
	Annealed	81,800	54,000	29.0	58.9	156	
	Cold Drawn						70
8740	As-Rolled						
	Normalized	134,800	88,000	16.0	47.9	269	
	Annealed	100,800	60,300	22.2	46.4	201	
	Cold Drawn						65

BAR TOLERANCE FOR HOT ROLLED ALLOY BARS

Specified Sizes (Rounds or Squares)	Variation from Size		Out-of-Round or Square	Machining Allowance - Minimum Stock Removal*
	Over	Under		
To 5/16" included	.005"	.005"	.008"	.016"
Over 5/16" to 7/16" included	.006"	.006"	.009"	.016"
Over 7/16" to 5/8" included	.007"	.007"	.010"	.016"
Over 5/8" to 7/8" included	.008"	.008"	.012"	.021"
Over 7/8" to 1" included	.009"	.009"	.013"	.023"
Over 1" to 1-1/8" included	.010"	.010"	.015"	.025"
Over 1-1/8" to 1-1/4" included	.011"	.011"	.016"	.028"
Over 1-1/4" to 1-3/8" included	.012"	.012"	.018"	.030"
Over 1-3/8" to 1-1/2" included	.014"	.014"	.021"	.033"
Over 1-1/2" to 2" included	1/64"	1/64"	.023"	.042"
Over 2" to 2-1/2" included	1/32"	0"	.023"	.052"
Over 2-1/2" to 3-1/2" included	3/64"	0"	.035"	.072"
Over 3-1/2" to 4-1/2" included	1/16"	0"	.046"	.090"
Over 4-1/2" to 5-1/2" included	5/64"	0"	.058"	.110"
Over 5-1/2" to 6-1/2" included	1/8"	0"	.070"	.125"
Over 6-1/2" to 8-1/4" included	5/32"	0"	.085"	.155"
Over 8-1/4" to 9-1/2" included	3/16"	0"	.100"	.203"
Over 9-1/2" to 10" included	1/4"	0"	.120"	.250"

**Double the amount shown for proper stock removal on diameter or cross section.*

STRAIGHTNESS TOLERANCE FOR HOT ROLLED STEEL BARS

Rounds, Squares, Hexagons, Octagons, Flats, and SpringFlats

Measurement is taken on the concave side of the bar with a straight edge.

Normal Straightness	Special Straightness
1/4" in any 5 feet	1/8" in any 5 feet
or	*or*
$1/4" \times \frac{\text{length in feet}}{5}$	$1/8" \times \frac{\text{length in feet}}{5}$

NOTE: *Because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation or controlled cooling has been performed.*

NOTE: *Tolerances shown are based upon ASTMA29.*

DIMENSIONAL TOLERANCES-SI UNITS

Permissible variations in dimensions expressed in SI units of measurement.

Tolerances in Sectional Dimensions for Round and Square Bars and Round-Cornered Square Bars

Size, mm	Tolerance from Specified Size, Over and Under, mm or %[A]	Out-of-Round, or Out-of-Square Section,[B] mm or %[A]
To 7, incl	0.13 mm	0.20 mm
Over 7 to 11, incl	0.15 mm	0.22 mm
Over 11 to 15, incl	0.18 mm	0.27 mm
Over 15 to 19, incl	0.20 mm	0.30 mm
Over 19 to 250, incl	1%	1.5%

[A] *The tolerance shall be rounded to the nearest tenth of a millimetre after calculation.*

[B] *Out-of-round is the difference between the maximum and the minimum diameters of the bar, measured at the same cross section, Out-of-square is the difference in the two dimensions at the same cross section of a square bar between opposite faces.*

PERMISSIBLE VARIATIONS IN LENGTH FOR HOT-WROUGHT ROUNDS, SQUARES, HEXAGONS, AND BAR SIZE SECTIONS OF STEEL

Specified Size of Rounds, Squares, and Hexagons, in.	Permissible Variations Over Specified Length, in.[A]		
	5 to 10 ft, excl	10 to 20 ft, excl	20 to 30 ft, excl
Mill Shearing			
To 1, incl	1/2	3/4	1-1/4
Over 1 to 2, incl	5/8	1	1-1/2
Over 2 to 5, incl	1	1-1/2	1-3/4
Over 5 to 10, incl	2	2-1/2	2-3/4
Bar Size Sections	5/8	1	1-1/2
Hot Sawing			
2 to 5, incl	[B]	1-1/2	1-3/4
Over 5 to 10, incl	[B]	2-1/2	2-3/4

	30 to 40 ft, excl	40 to 60 ft, excl
Mill Shearing		
To 1, incl	1-3/4	2-1/4
Over 1 to 2, incl	2	2-1/2
Over 2 to 5, incl	2-1/4	2-3/4
Over 5 to 10, incl	3	3-1/4
Bar Size Sections	2	2-1/2
Hot Sawing		
2 to 5, incl	2-1/4	2-3/4
Over 5 to 10, incl	3	3-1/4

[A] *No permissible variations under.*

[B] *Smaller sizes and shorter lengths are not hot sawed.*

WEIGHTS AND AREAS OF SQUARE AND ROUND STEEL BARS

Size or Diam. in.	Weight lb. per ft.		Area, sq. in.	
	Square ■	Round ●	Square □	Round ❍
1/16	.013	.010	.0039	.0031
5/64	.021	.016	.0061	.0048
3/32	.030	.023	.0088	.0069
7/64	.041	.032	.0120	.0094
1/8	.053	.042	.0156	.0123
9/64	.067	.053	.0198	.0155
5/32	.083	.065	.0244	.0192
11/64	1.00	.079	.0295	.0232
3/16	.120	.094	.0352	.0276
13/64	.140	.110	.0413	.0324
7/32	.163	.128	.0479	.0376
15/64	.187	.147	.0549	.0431
1/4	.212	.167	.0625	.0491
17/64	.240	.188	.0706	.0554
9/32	.269	.211	.0791	.0621
19/64	.300	.235	.0881	.0692
5/16	.332	.261	.0977	.0767
21/64	.366	.288	.1077	.0846
11/32	.402	.316	.1182	.0928
23/64	.439	.345	.1292	.1014
3/8	.478	.376	.1406	.1104
25/64	.519	.407	.1526	.1198
13/32	.561	.441	.1650	.1296
27/64	.605	.475	.1780	.1398
7/16	.651	.511	.1914	.1503
29/64	.698	.548	.2053	.1613
15/32	.747	.587	.2197	.1726
31/64	.798	.627	.2346	.1843
1/2	.850	.668	.2500	.1963
33/64	.904	.710	.2659	.2088
17/32	.960	.754	.2822	.2217
35/64	1.017	.799	.2991	.2349
9/16	1.076	.845	.3164	.2485
37/64	1.136	.893	.3342	.2625
19/32	1.199	.941	.3525	.2769
39/64	1.263	.992	.3713	.2916
5/8	1.328	1.043	.3906	.3068
41/64	1.395	1.096	.4104	.3223
21/32	1.464	1.150	.4307	.3382
43/64	1.535	1.205	.4514	.3545
11/16	1.607	1.262	.4727	.3712
45/64	1.681	1.320	.4944	.3883
23/32	1.756	1.379	.5166	.4057

WEIGHTS AND AREAS OF SQUARE AND ROUND STEEL BARS - *CONTINUED*

Size or Diam. in.	Weight lb. per ft.		Area, sq. in.	
	Square ■	Round ●	Square □	Round ❍
47/64	1.834	1.440	.5393	.4236
3/4	1.913	1.502	.5625	.4418
49/64	1.993	1.565	.5862	.4604
25/32	2.075	1.630	.6103	.4794
51/64	2.159	1.696	.6350	.4987
13/16	2.245	1.763	.6602	.5185
53/64	2.332	1.831	.6858	.5386
27/32	2.420	1.901	.7119	.5591
55/64	2.511	1.972	.7385	.5800
7/8	2.603	2.044	.7656	.6013
57/64	2.697	2.118	.7932	.6230
29/32	2.792	2.193	.8213	.6450
59/64	2.889	2.270	.8498	.6675
15/16	2.988	2.347	.8789	.6903
61/64	3.089	2.426	.9084	.7135
31/32	3.191	2.506	.9385	.7371
63/64	3.294	2.587	.9689	.7610
1	3.400	2.670	1.0000	.7854
1/32	3.616	2.840	1.0635	.8353
1/16	3.838	3.014	1.1289	.8866
3/32	4.067	3.194	1.1963	.9396
1/8	4.303	3.379	1.2656	.9940
5/32	4.545	3.570	1.3369	1.0500
3/16	4.795	3.766	1.4102	1.1075
7/32	5.050	3.966	1.4853	1.1666
1/4	5.312	4.173	1.5625	1.2272
9/32	5.581	4.384	1.6416	1.2893
5/16	5.857	4.600	1.7227	1.3530
11/32	6.139	4.822	1.8056	1.4182
3/8	6.428	5.049	1.8906	1.4849
13/32	6.724	5.281	1.9775	1.5532
7/16	7.026	5.518	2.0664	1.6230
15/32	7.334	5.761	2.1572	1.6943
1/2	7.650	6.008	2.2500	1.7671
17/32	7.972	6.261	2.3447	1.8415
9/16	8.301	6.520	2.4414	1.9175
19/32	8.636	6.783	2.5400	1.9949
5/8	8.978	7.051	2.6406	2.0739
21/32	9.327	7.325	2.7431	2.1545
11/16	9.682	7.604	2.8477	2.2365
23/32	10.044	7.889	2.9541	2.3202
3/4	10.413	8.178	3.0625	2.4053
25/32	10.788	8.473	3.1728	2.4920

WEIGHTS AND AREAS OF SQUARE AND ROUND STEEL BARS - *CONTINUED*

Size or Diam. in.	Weight lb. per ft.		Area, sq. in.	
	Square ■	Round ●	Square □	Round ❍
13/16	11.170	8.773	3.2852	2.5802
27/32	11.558	9.078	3.3994	2.6699
7/8	11.953	9.388	3.5156	2.7612
29/32	12.355	9.704	3.6337	2.8540
15/16	12.763	10.024	3.7539	2.9483
31/32	13.178	10.350	3.8760	3.0442
2	13.600	10.681	4.0000	3.1416
1/16	14.463	11.359	4.2539	3.3410
1/8	15.353	12.058	4.5156	3.5466
3/16	16.270	12.778	4.7852	3.7583
1/4	17.213	13.519	5.0625	3.9761
5/16	18.182	14.280	5.3477	4.2000
3/8	19.178	15.062	5.6406	4.4301
7/16	20.201	15.866	5.9414	4.6664
1/2	21.250	16.690	6.2500	4.9087
9/16	22.326	17.535	6.5664	5.1572
5/8	23.428	18.400	6.8906	5.4119
11/16	24.557	19.287	7.2227	5.6727
3/4	25.713	20.195	7.5625	5.9396
13/16	26.895	21.123	7.9102	6.2126
7/8	28.103	22.072	8.2656	6.4918
15/16	29.338	23.042	8.6289	6.7771
3	30.600	24.033	9.0000	7.0686
1/16	31.888	25.045	9.3789	7.3662
1/8	33.203	26.078	9.7656	7.6699
3/16	34.545	27.131	10.160	7.9798
1/4	35.913	28.206	10.563	8.2958
5/16	37.307	29.301	10.973	8.6179
3/8	38.728	30.417	11.391	8.9462
7/16	40.176	31.554	11.816	9.2806
1/2	41.650	32.712	12.250	9.6211
9/16	43.151	33.891	12.691	9.9678
5/8	44.678	35.090	13.141	10.321
11/16	46.232	36.311	13.598	10.680
3/4	47.813	37.552	14.063	11.045
13/16	49.420	38.814	14.535	11.416
7/8	51.053	40.097	15.016	11.793
15/16	52.713	41.401	15.504	12.177
4	54.400	42.726	16.000	12.566
1/16	56.113	44.071	16.504	12.962
1/8	57.853	45.438	17.016	13.364
3/16	59.620	46.825	17.535	13.772
1/4	61.413	48.233	18.063	14.186

WEIGHTS AND AREAS OF SQUARE AND ROUND STEEL BARS - *CONTINUED*

Size or Diam. in.	Weight lb. per ft.		Area, sq. in.	
	Square ■	Round ●	Square □	Round ❍
5/16	63.232	`49.662	18.598	14.607
3/8	65.078	51.112	19.141	15.033
7/16	66.951	52.583	19.691	15.466
1/2	68.850	54.075	20.250	15.904
9/16	70.776	55.587	20.816	16.349
5/8	72.728	57.121	21.391	16.800
11/16	74.707	58.675	21.973	17.257
3/4	76.713	60.250	22.563	17.721
13/16	78.745	61.846	23.160	18.190
7/8	80.803	63.463	23.766	18.665
15/16	82.888	65.100	24.379	19.147
5	85.000	66.759	25.000	19.635
1/16	87.138	68.438	25.629	20.129
1/8	89.303	70.139	26.266	20.629
3/16	91.495	71.860	26.910	21.135
1/4	93.713	73.602	27.563	21.648
5/16	95.957	75.364	28.223	22.166
3/8	98.228	77.148	28.891	22.691
7/16	100.53	78.953	29.566	23.221
1/2	102.85	80.778	30.250	23.758
9/16	105.20	82.624	30.941	24.301
5/8	107.58	84.492	31.641	24.850
11/16	109.98	86.380	32.348	25.406
3/4	112.41	88.289	33.063	25.967
13/16	114.87	90.218	33.785	26.535
7/8	117.35	92.169	34.516	27.109
15/16	119.86	94.140	35.254	27.688
6	122.40	96.133	36.000	28.274
1/16	124.96	98.146	36.754	28.866
1/8	127.55	100.18	37.516	29.465
3/16	130.17	102.23	38.285	30.069
1/4	132.81	104.31	39.063	30.680
5/16	135.48	106.41	39.848	31.296
3/8	138.18	108.52	40.641	31.919
7/16	140.90	110.66	41.441	32.548
1/2	143.65	112.82	42.250	33.183
9/16	146.43	115.00	43.066	33.824
5/8	149.23	117.20	43.891	34.472
11/16	152.06	119.43	44.723	35.125
3/4	154.91	121.67	45.563	35.785
13/16	157.79	123.93	46.410	36.450
7/8	160.70	126.22	47.266	37.122
15/16	163.64	128.52	48.129	37.800

WEIGHTS AND AREAS OF SQUARE AND ROUND STEEL BARS - *CONTINUED*

Size or Diam. in.	Weight lb. per ft.		Area, sq. in.	
	Square ■	Round ●	Square □	Round ❍
7	166.60	130.85	49.000	38.485
1/16	169.59	133.19	49.879	39.175
1/8	172.60	135.56	50.766	39.871
3/16	175.64	137.95	51.660	40.574
1/4	178.71	140.36	52.563	41.282
5/16	181.81	142.79	53.473	41.997
3/8	184.93	145.24	54.391	42.718
7/16	188.08	147.71	55.316	43.445
1/2	191.25	150.21	56.250	44.179
9/16	194.45	152.72	57.191	44.918
5/8	197.68	155.26	58.141	45.664
11/16	200.93	157.81	59.098	46.415
3/4	204.21	160.39	60.063	47.173
13/16	207.52	162.99	61.035	47.937
7/8	210.85	165.60	62.016	48.707
15/16	214.21	168.24	63.004	49.483
8	217.60	170.90	64.000	50.265
1/16	221.01	173.58	65.004	51.054
1/8	224.45	176.29	66.016	51.849
3/16	227.92	179.01	67.035	52.649
1/4	231.41	181.75	68.063	53.456
5/16	234.93	184.52	69.098	54.269
3/8	238.48	187.30	70.141	55.088
7/16	242.05	190.11	71.191	55.914
1/2	245.65	192.93	72.250	56.745
9/16	249.28	195.78	73.316	57.583
5/8	252.93	198.65	74.391	58.426
11/16	256.61	201.54	75.473	59.276
3/4	260.31	204.45	76.563	60.132
13/16	264.04	207.38	77.660	60.994
7/8	267.80	210.33	78.766	61.862
15/16	271.59	213.31	79.879	62.737
9	275.40	216.30	81.000	63.617
1/16	279.20	219.30	82.129	64.504
1/8	283.10	224.40	83.266	65.397
3/16	287.00	225.40	84.410	66.296
1/4	290.90	228.50	85.563	67.201
5/16	294.90	231.60	86.723	68.112
3/8	298.80	234.70	87.891	69.029
7/16	302.80	237.80	89.066	69.953
1/2	306.80	241.00	90.250	70.882
9/16	310.90	244.20	91.441	71.818
5/8	315.00	247.40	92.641	72.760

WEIGHTS AND AREAS OF SQUARE AND ROUND STEEL BARS - *CONTINUED*

Size or Diam. in.	Weight lb. per ft.		Area, sq. in.	
	Square ■	Round ●	Square □	Round ❍
11/16	319.10	250.60	93.848	73.708
3/4	323.20	253.90	95.063	74.662
3/16	327.40	257.10	96.285	75.622
7/8	331.60	260.40	97.516	76.589
15/16	335.80	263.70	98.754	77.561
10	340.00	267.00	100.000	78.540

SPC TERMS

X - (Average) The individual measurement.

$\overline{X}$ - (X bar) Average of a subgroup.

$\overline{\overline{X}}$ - (X double bar) Average of the $\overline{X}$'s. Also referred to as the Process Average.

R - (Range) Amount of the difference between the largest and the smallest measurement in each subgroup.

MR - (Moving Range) The difference between X of the present subgroup and the X of the preceding subgroup. Used with a subgroup size of 1.

$\overline{R}$ - (R bar) The average of the ranges.

n - The number of measurements in each subgroup.

k - The number of subgroups on the control chart.

σ - (Greek letter Sigma) The measure of dispersion around a central point. Also referred to as the Standard Deviation.

$\hat{\sigma}$ - (Estimated σ) Uses variation within subgroups to estimate the population standard deviation.

UCL - Upper Control Limit. (usually $+3\sigma$)

LCL - Lower Control Limit. (usually -3σ)

USL - Upper Specification Limit. (usually $+4\sigma$)

LSL - Lower Specification Limit. (usually -4σ)

Cp - Indicates the potential capability of the process if it is stable and centered between the upper and lower specification limits.

Cpk - Indicates the capability of the process if it is stable and locates the process with respect to the specification limits.*

Cr - (Capability Ratio, = 1/Cp) Sometimes expressed as the percent of tolerance used in (%).

*When $\pm 4\sigma/\pm 3\sigma = 1.33$ the process is capable.

CALCULATIONS FOR X AND R CHARTS AND CAPABILITY

Control Charts for Variables

Calculate the Average ($\overline{X}$) and Range (R) of each subgroup

$$\overline{X} = \frac{X_1 + X_2 + ... X_n}{n}$$

$$R = X_{max} - X_{min}$$

Calculate the Average Range ($\overline{R}$) and the Process Average ($\overline{\overline{X}}$)

$$\overline{\overline{X}} = \frac{X_1 + X_2 + ... + X_k}{k}$$

$$\overline{R} = \frac{R_1 + R_2 + ... + R_k}{k}$$

Calculate the Control Limits

$$UCL_{\overline{X}} = \overline{\overline{X}} + A_2\overline{R} \qquad UCL_R = D_4\overline{R}$$

$$LCL_{\overline{X}} = \overline{\overline{X}} - A_2\overline{R} \qquad LCL_R = D_3\overline{R}$$

Process Capability

Estimated σ ($\hat{\sigma}$)

$$\hat{\sigma} = \overline{R}/d_2$$

Estimated Process capability (Cp)

$$Cp = \frac{USL - LSL}{6\hat{\sigma}}$$

Estimated Capability Ratio (Cr)

$$Cr = 1/Cp \times 100\ (\%)$$

Estimated Process Capability (Cpk)

$$C_{PU} = \frac{USL - \overline{\overline{X}}}{3\hat{\sigma}} \qquad C_{PL} = \frac{\overline{\overline{X}} - LSL}{3\hat{\sigma}}$$

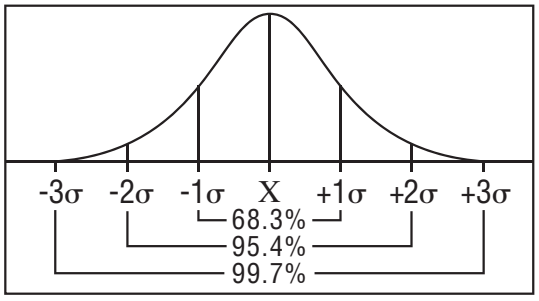
$$C_{PK} = \text{Minimum of } C_{PU} \text{ or } C_{PL}$$

Factor Values

N =	2	3	4	5	6	12
D_4	3.27	2.57	2.28	2.11	2.00	1.72
D_3	*	*	*	*	*	0.26
A_2	1.86	1.02	0.73	0.58	0.48	0.27
d_2	1.13	1.69	2.06	2.33	2.53	3.26

* *No constant for subgroup sizes below 7.*

Normal Distribution



NOTE: *A_2, D_3, D_4, d_2 factors are dependent on subgroup size (n). See factor values table.*

NOTE: *Calculations of Process capability (Cp, Cpk, Cr) are only valid for stable processes.*

CONTROL CHARTS FOR ATTRIBUTES

The p Chart

$$\bar{p} = \frac{\text{number of rejects in subgroup}}{\text{number inspected in subgroups}}$$

$$UCL_P = P + \frac{3\sqrt{p\,(1 - \bar{p})}}{\sqrt{n}}$$

$$LCL_P = \bar{P} - \frac{3\sqrt{p\,(1 - \bar{p})}}{\sqrt{n}}$$

The u Chart

$$\bar{u} = \frac{\text{total non-comformities}}{\text{total units inspected}}$$

$$UCL_u = u + \frac{3\sqrt{\bar{u}}}{\sqrt{n}}$$

$$LCL_u = \bar{u} - \frac{3\sqrt{\bar{u}}}{\sqrt{n}}$$

The np Chart

np = Number of non-conforming units within a sample.

$n\bar{p}$ = Average number of non-conforming units per sample.

$$UCL_{np} = n\bar{p} + 3\sqrt{n\bar{p}\,(1 - \bar{p})}$$

$$LCL_{np} = n\bar{p} - 3\sqrt{n\bar{p}\,(1 - \bar{p})}$$

The c Chart

c = The count (number) of non-conformities within a sample.

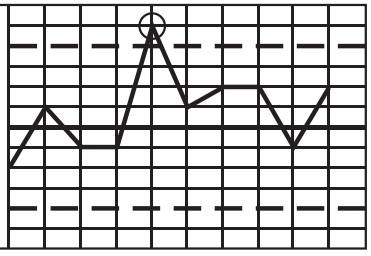
$\bar{c}$ = Average number of non-conformities per sample.

$$UCL_c = c + 3\sqrt{c}$$

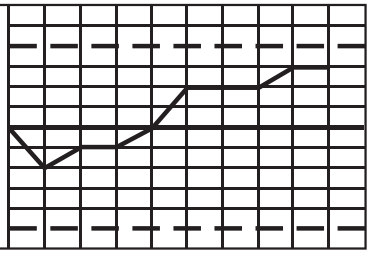
$$LCL_c = c - 3\sqrt{c}$$

Identification of Out-of-Control Conditions (Each Point is a Subgroup)

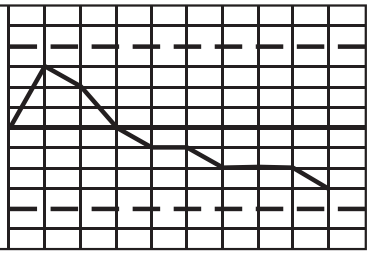
One or More Points Outside Control Limits



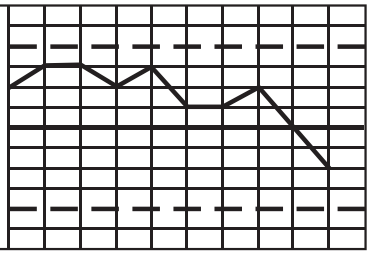
A Run of 7 or More Points Increasing



A Run of 7 or More Points Decreasing



A Run of 7 or More Points on Either Side of Aim Side



GLOSSARY OF METALLURGICAL TERMS

ALLOYING ELEMENTS

Aluminum

Aluminum is used to deoxidize steel and control grain size. Grain size control is effected by forming a fine dispersion with nitrogen and oxygen which restricts austenite grain growth. Aluminum is also an extremely effective nitride former in nitriding steels.

Boron

Boron is usually added between .0005-.003% to significantly increase the hardenability, especially for low carbon alloys. It does not affect the strength of ferrite, therefore not sacrificing ductility, formability or machinability in the annealed state.

Calcium

Calcium is used in certain steels to control the shape, size and distribution of oxide and/or sulfide inclusions. Benefits may include improved ductility, impact strength and machinability.

Carbon

Carbon is the most important alloying element which is essential for the formation of cementite, pearlite, spheriodite, bainite, and iron-carbon martensite. Compared to steels with similar microstructures, strength, hardness, hardenability, and ductile-to-brittle transition temperature are increased with increasing carbon content up to approximately .60%. Toughness and ductility of pearlitic steels are decreased with increasing carbon content.

Chromium

Chromium is used in low alloy steels to increase 1) resistance to corrosion and oxidation, 2) high temperature strength, 3) hardenability, and 4) abrasion resistance in high carbon alloys. Straight chromium steels are susceptible to temper embrittlement and can be brittle.

Copper

Copper is detrimental to hot workability and subsequent surface quality. It is used in certain steels to improve resistance to atmospheric corrosion.

Lead

Lead improves machinability. It does not dissolve in steel but stays as globules. Environmental concerns are resulting in a decreased usage of lead in the steel industry.

Manganese

Manganese is important because it deoxidizes the melt and facilitates hot working of the steel by reducing the susceptibility to hot shortness. It combines with sulfur to form MnS stringers which increases machinability. Manganese contributes to the effectiveness of normalizing for strengthening, to the formation of fine pearlite, and lowers the Ms temperature, therefore increasing the probability of retained austenite.

Molybdenum

Molybdenum increases hardenability of steels and helps maintain a specified hardenability. It increases high temperature tensile and creep strengths. Molybdenum hardened steels require higher tempering temperatures for softening purposes.

ALLOYING ELEMENTS

Nickel

Nickel is used in low alloy steels to reduce the sensitivity of the steel to variations in heat treatment and distortion and cracking on quenching. It also improves low temperature toughness and hardenability.

Niobium (Columbium)

Niobium lowers transition temperature and raises the strength of low carbon steel. Niobium increases strength at elevated temperatures, results in finer grain size and forms stable carbides, lowering the hardenability of the steel.

Nitrogen

Nitrogen increases the strength, hardness and machinability of steel, but it decreases the ductility and toughness. In aluminum killed steels, nitrogen combines with the aluminum to provide grain size control. Nitrogen can reduce the effect of boron on the hardenability of steels.

Phosphorous

Phosphorous is generally restricted to below 0.04 weight percent to minimize its detrimental effect on ductility and toughness. Certain steels may contain higher levels to enhance machinability, strength and/or atmospheric corrosion resistance.

Silicon

Silicon is one of the principal deoxidizers with the amount used dependent on the deoxidization practice. It slightly increases the strength of ferrite without a serious loss of ductility. In larger quantities, it aids the resistance to scaling up to 500°F in air and decreases magnetic hysteresis loss.

Sulfur

Sulfur is detrimental to transverse strength and impact resistance. It affects longitudinal properties to a lesser degree. Existing primarily in the form of manganese sulfide stringers, sulfur is typically added to improve machinability.

Titanium

Titanium is added to boron steels because it combines with oxygen and nitrogen, thus increasing the effectiveness of boron. Titanium, as titanium nitride, also provides grain size control at elevated temperatures in microalloy steels. In excess, titanium is detrimental to machinability and internal cleanness.

Tellurium

Tellurium is added to steel to modify sulfide type inclusion size, morphology and distribution. The resulting sulfide type inclusions are finer and remain ellipsoidal in shape following hot working, thereby improving transverse properties.

continued on next page...

ALLOYING ELEMENTS

Vanadium

Vanadium inhibits grain growth during heat treating while improving strength and toughness of hardened and tempered steels. Additions up to .05% increase hardenability whereas larger amounts tend to reduce hardenability because of carbide formation. Vanadium is also utilized in ferrite/pearlite microalloy steels to increase hardness through carbonitride precipitation strengthening of the matrix.

STANDARD MILL TERMINOLOGY

Annealing

A treatment consisting of heating uniformly to a temperature, within or above the critical range, and cooling at a controlled rate to a temperature under the critical range. This treatment is used to produce a definite microstructure, usually one designed for best machinability, and/or to remove stresses, induce softness, and alter ductility, toughness or other mechanical properties.

Billet

A solid semifinished round or square with an area less than 36 sq. inches that has been hot worked usually smaller than a bloom. Also a general term for wrought starting stock for forgings or extrusions.

Bloom

A semifinished hot rolled rectangular product. The width of the bloom is no more than twice the thickness and the cross-sectional area is usually not less than 36 square inches.

DI (Ideal Diameter)

The diameter of a round steel bar that will harden at the center to a given percent of martensite when subjected to an ideal quench (i.e., Grossman quench severity H=infinity).

Elongation

In tensile testing, the increase in gage length, measured after the fracture of a specimen within the gage length, usually expressed as a percentage of the original gage length.

End-Quench Hardenability Test (Jominy Test)

A laboratory procedure for determining the hardenability of a steel or other ferrous alloy. Hardenability is determined by heating a standard specimen above the upper critical temperature, placing the hot specimen in a fixture so that a stream of cold water impinges on one end, and, after cooling to room temperature is completed, measuring the hardness near the surface of the specimen at regularly spaced intervals along its length. The data are normally plotted as hardness versus distance from the quenched end.

STANDARD MILL TERMINOLOGY

Hardness

Resistance of a metal to plastic deformation, usually by indentation. However, this may also refer to stiffness or temper, or to resistance to scratching, abrasion, or cutting.

Impact Test

A test to determine the behavior of materials when subjected to high rates of loading, usually in bending, tension or torsion. The quantity measured is the energy absorbed in breaking the specimen by a single blow, as in the Charpy or Izod tests.

Ingot

A casting of a simple shape which can be used for hot working or rerolling into blooms or billets.

Killed Steel

Steel treated with a strong deoxidizer to reduce oxygen to a level where no reaction occurs between carbon and oxygen during solidification.

Lap

A surface imperfection caused by the folding over of hot metal, fins, or sharp corners and then rolling or forging them into the surface but not welding them.

Machinability

This is a generic term for describing the ability of a material to be machined. To be meaningful, machinability must be qualified in terms of tool wear, tool life, chip control, and/or surface finish and integrity. Overall machining performance is affected by variables relating to the machining operation and the workpiece. An overall review is provided in the ASM Metals Handbook: Machinability, Volume 16.

Normalizing

A treatment consisting of heating uniformly to temperature at least 100°F above the critical range (A_3) and cooling in still air at room temperature. The treatment produces a recrystallization and refinement of the grain structure and gives uniformity in hardness and structure to the product.

Pickling

An operation by which surface oxide (scale) is removed by chemical action. Sulfuric acid is typically used for carbon and low-alloy steels. After the acid bath, the steel is rinsed in water.

Quenching

A treatment consisting of heating uniformly to a predetermined temperature and cooling rapidly in air or liquid medium to produce a desired crystalline structure.

continued on next page...

STANDARD MILL TERMINOLOGY

Reduction of Area

The difference, expressed as a percentage of original area, between the original cross-sectional area of a tensile test specimen and the minimum cross-sectional area measured after complete separation.

Reduction Ratio

The final cross-sectional area divided by the initial cross-sectional area. Rolling a 6x6 bloom to a 2 in. round. 36 in. sq. ÷ 3.14 = 11.46

Rimmed Steel

A low carbon steel having enough iron oxide to give a continuous evolution of carbon monoxide during solidification giving a rim of material virtually free of voids.

Scab

An imperfection which is a flat piece of metal rolled into the steel surface.

Seam

A defect on the surface of a metal which appears as a crack. Experience indicates that most seams are created during the cooling or reheating of cast structures.

Semi-Killed Steel

Incompletely deoxidized steel which contains enough dissolved oxygen to react with the carbon to form carbon monoxide to offset solidification shrinkage.

Spheroidize Anneal

A special type of annealing that requires an extremely long cycle. This treatment is used to produce globular carbides and maximum softness for best machinability in some grades, or to improve cold formability.

Strand Casting (Continuous Casting)

Operation in which a cast shape is continuously drawn through the bottom of the mold as it solidifies. The length is not determined by mold dimensions.

Stress Relieve Temper

A thermal treatment to restore elastic properties and to minimize distortion on subsequent machining or hardening operations. This treatment is usually applied to material that has been heat treated (quenched and tempered). Normal practice would be to heat to a temperature 100°F lower than the tempering temperatures used to establish mechanical properties and hardness. Ordinarily, no straightening is performed after the stress relieve temper.

STANDARD MILL TERMINOLOGY

Tempering

A critical treatment of heating uniformly to some predetermined temperature under the critical range (A_1), holding at that temperature a designated period of time and cooling in air or liquid. This treatment is used to produce one or more of the following end results: A) to relieve the stresses of as-quenched martensite, B) to soften material for subsequent machining or cold working, C) to improve ductility and relieve stresses resulting from prior treatment or cold working, and D) to produce the desired mechanical properties or structure in the second step of a double treatment.

Tensile Strength

In tensile testing, the ratio of maximum load to original cross-sectional area.

Yield Point

The first stress in a material, usually less than the maximum attainable stress, at which an increase in strain occurs without an increase in stress. If there is a decrease in stress after yielding, a distinction may be made between upper and lower yield points.

Yield Strength

The stress at which a material exhibits a specified deviation from proportionality of stress and strain. An offset of .2% is commonly used.

NOTE: *Information adapted from ASM and/or SAE publications.*

EQUATIONS FOR HARDENABLE ALLOY STEELS

Ae_1 (°F) ~ 1333 - 25 x Mn + 40 x Si + 42 x Cr - 26 x Ni *1

Ae_3 (°F) ~ 1570 - 323 x C - 25 x Mn + 80 x Si - 3 x Cr - 32 x Ni *2

Ac_1 (°C) ~ 723 - 10.7 x Mn + 29.1 x Si + 16.9 x Cr - 16.9 x Ni + 290 x As + 6.38 x W . . *3

Ac_3 (°C) ~ 910 - 203 x $\sqrt{C}$ + 44.7 x Si - 15.2 x Ni + 31.5 x Mo + 104 x V + 13.1 x W . . . *4

Ms (°F) ~ 930 - 600 x C - 60 x Mn - 20 x Si - 50 x Cr - 30 x Ni - 20 x Mo - 20 x W *5

M_{10} (°F) ~ Ms - 18 . . . . . *6

M_{50} (°F) ~ Ms - 85 . . . . . *7

M_{90} (°F) ~ Ms - 185 . . . . . *8

Mf (°F) ~ Ms - 385 . . . . . *9

Bs (°F) ~ 1526 - 486 x C - 162 x Mn - 126 x Cr - 67 x Ni - 150 x Mo *10

B_{50} (°F) ~ Bs - 108 . . . . . *11

Bf (°F) ~ Bs - 216 . . . . . *12

Carburized Case Depth (in.) ~ .025$\sqrt{t}$, for 1700°F *13

Carburized Case Depth (in.) ~ .021$\sqrt{t}$, for 1650°F *14

Carburized Case Depth (in.) ~ .018$\sqrt{t}$, for 1600°F *15

NOTE: *t = Time in hours.*

**Each equation above is subject to the chemistry limitations under which it was developed;*

1 & 2: R. A. Grange, Metal Progress, 79, April 1961, p. 73.
3 & 4: K. W. Andrews, JISI, 203, 1965, p. 721.
5: E. S. Rowland and S. R. Lyle, Trans. ASM, 37, 1946, p. 27.
6 - 12: W. Steven and A. G. Haynes, JISI, 183, 1956, p. 349.
13 - 15: F. E. Harris, Metal Progress, 44, August 1943, p. 265.

PHYSICAL CONSTANTS

Acceleration of Gravity, g	32.17 ft/s^2 = 9.807 m/s^2
Density of Water	62.4 lb_m/ft^3 = 1 g/cm^3 1 gal H_2O = 8.345 lb_m
Gas Constant, R	1545 ft-lb_t/pmole-R = 8.314 J/gmole-K
Gas Volume (STP: 68°F, 1 atm)	359 ft^3/pmole = .02241 m^3/gmole
Joule's Constant, J	778 ft-lb_t/BTU
Poisson's Ratio, μ	.0.3 (for Steel)
Fe-Fe_3C Eutectoid Composition	0.77 w/o Carbon
Fe-Fe_3C Eutectoid Temperature	1340°F (727°C)
Modulus of Elasticity (Steel)	30 x 10^6 psi
Steel Densities:	
Carbon & Low-Alloy Steels	0.283 lb_m/in^3 = 7.84 g/cm^3
304 SS	0.29 lb_m/in^3 = 7.88 g/cm^3
Tool Steels	Carbon Steels x 1.000
Moly High Speed	Carbon Steels x 1.035
Multiphase Alloys	Carbon Steels x 1.074
Steel Tensile Strength (psi)	~ 500 x Brinell Number

SI PREFIXES

giga	G	10^9
mega	M	10^6
kilo	k	10^3
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

METRIC CONVERSION FACTORS

To Convert	into	Multiply by
Celsius (˚C)	Fahrenheit (˚F)	1.8 + 32
centimetres (cm)	feet (ft)	0.03280840
centimetres (cm)	inches (in.)	0.3937
centimetres (cm)	millimetres (mm)	10
cubic centimetres (cm^3)	cubic inches ($in.^3$)	0.061023
cubic feet (ft^3)	cubic metres (m^3)	0.02832
cubic inches ($in.^3$)	cubic centimetres (cm^3)	16.38706
cubic metres (m^3)	cubic feet (ft^3)	35.3147
Fahrenheit (˚F)	Celsius (˚C)	˚F-32/1.8
feet (ft)	centimetres (cm)	30.48
feet (ft)	metres (m)	0.3048
foot-pounds (ft-lb)	newton-metres (N-m)	1.355818
foot-pounds (ft-lb)	kilogram-metres	1.48817
foot-pounds-force (ft-lbf)	joules (J)	1.356
foot-pounds-force (ft-lbf)	kilogram-metres (kg-m)	1.383
gallons, U.S. liquid (gal)	litres (l)	3.785412
inches (in.)	millimetres (mm)	25.4
inches (in.)	centimetres (cm)	2.540
inches (in.)	metres (m)	0.0254
joules (J)	foot-pounds-force (ft-lbf)	0.7375621
kilograms (kg)	tons (short)	0.001102311
kilograms (kg)	pounds (Av) (lb)	2.20462
kilograms force per mm^2	megapascals (MPa) or (MN/m^2)	9.806650
kilograms-metres (kg-m)	foot-pounds-force (ft-lbf)	7.233
litres (l)	gallons, U.S. liquid (gal)	0.2641720
megapascals (MPa)	pounds per square inch (psi)	145.0377
metres (m)	inches (in.)	39.37008
metres (m)	feet (ft)	3.280840
metric tonnes	tons (short)	1.102
millimetres (mm)	inches (in.)	0.03937008
millimetres (mm)	feet (ft)	0.003280840
newtons (N)	pounds-force (lbf)	0.2248089

METRIC CONVERSION FACTORS

To Convert	into	Multiply by
pounds (AV) (lb)	kilogram (kg)	0.453592
pounds-force (lbf)	newtons (N)	0.448222
pounds per square inch (psi)	pascals (P)	6894.757
square centimetres (cm^2)	square feet (ft^2)	0.001076391
square centimetres (cm^2)	square inches ($in.^2$)	0.1550003
square feet (ft^2)	square centimetres (cm^2)	929.9304
square feet (ft^2)	square metres (m^2)	0.09290304
square inches ($in.^2$)	square centimetres (cm^2)	6.4516
square inches ($in.^2$)	square metres (m^2)	0.00064516
square inches ($in.^2$)	square millimetres (mm^2)	645.16
square millimetres (mm^2)	square inches ($in.^2$)	0.001550003
tons (short)	kilograms (kg)	907.1847

ENGINEERING CONVERSION FACTORS

Explanation of Dimensional Units

All table entries are categorized according to their specific combination of basic dimensions of Length [L], Mass [M] and Time [t]. For example, all units of force have the dimensions [M][L][t]-2. The following better illustrates this convention:

$$\text{Force} = [M][L][t]^{-2}$$
$$= (\text{Mass}) \times (\text{Acceleration})$$
$$1\ kg_f = (1\ kg) \times (9.80665\ m/s^2)$$

Example Conversion

Meters to Yards: (50 m) x (3.28084 ft/m) x (1/3 yd/ft) = 54.68066 yd

Significant Digits

The convention is to retain the number of digits which correctly infers the known accuracy of the numbers involved. Normally, this means using the same number of significant digits as occur in the original number. For the above example, the answer would therefore be rounded to 55 yards.

When the accuracy of the measurement is known, additional digits may become significant. For example, if the measurement of 50 meters is known to be accurate to .01 meters (.0109 yards), then the conversion result may be rounded to 54.58 yards.

Multiplier			
	to Convert →	to Convert ←	
Area $[L]^2$			
ft^2	0.0929031	10.7639	m^2
in^2	645.16	0.001550	mm^2
in^2	6.451601	0.155000	cm^2
Energy, Work or Heat $[M]\ [L]^2\ [t]^{-2}$			
Btu	1.05435	0.948451	kJ
Btu	0.251996	3.96832	kcal
Calories (cal)	4.184*	0.239006	Joules (J)
ft-lb_f	1.355818	0.737562	J
ft-lb_f	0.138255	7.23301	kg_f-m
hp-hr	2.6845	0.372506	MJ
KWH	3.600	0.27777	MJ
m-kg_f	9.80665*	0.101972	J
N-m	1.0	1.0	J
Flow Rate $[L]^3\ [t]^{-1}$			
ft^3/min	7.4805	0.133681	gal/min
ft^3/min	0.471934	2.118940	l/s
gal/min	15.85034	0.063090	l/s
Force or Weight $[M]\ [L]\ [t]^{-2}$			
kg_f	9.80665*	0.101971	Newton (N)
lb_f	4.44822	0.224809	N
lb_f	0.453592	2.204623	kg_f

ENGINEERING CONVERSION FACTORS - *CONTINUED*

	Multiplier		
	to Convert →	← to Convert	
Fracture Toughness			
$ksi\sqrt{in}$	1.098800	0.910084	$MPa\sqrt{m}$
Heat Content			
Btu/lb_m	0.555556	1.8*	cal/g
Btu/lb_m	2.324444	0.430210	J/g
Btu/ft^3	0.037234	26.857	MJ/m^3
Heat Flux			
$Btu/hr\text{-}ft^2$	7.5346 E-5	13272.1	$cal/s\text{-}cm^2$
$Btu/hr\text{-}ft^2$	3.1525	0.31721	W/m^2
$cal/s\text{-}cm^2$	4.184*	0.239006	W/cm^2
Length [L]			
Foot (ft)	0.304800	3.280840	Meter (m)
Inch (in)	25.4000	0.039370	Millimeter (mm)
Mile (mi)	1.609344	0.621371	Kilometer (km)
Mass Density [M] $[L]^{-3}$			
lb_m/in^3	27.68	0.03613	g/cm^3
lb_m/ft^3	16.0184	0.062428	kg/m^3
Power [M] $[L]^2$ $[t]^{-3}$			
Btu/hr	0.292875	3.41443	Watt (W)
$ft\text{-}lb_f/s$	1.355818	0.737562	W
Horsepower (hp)	745.6999	1.341022 E-3	W
Horsepower	550.*	0.001818	$ft\text{-}lb_f/s$
Pressure (fluid) [M] $[L]^{-1}$ $[t]^{-2}$			
Atmosphere (atm)	14.696	0.068046	lb_f/in^2
atm	1.01325 E5*	9.869233 E-6	Pascal (Pa)
lb_f/ft^2	47.88026	2.088543 E-2	Pa
lb_f/in^2	27.6807	0.036126	in. H_2O at 39.2°F
Stress [M] $[L]^{-1}$ $[t]^{-2}$			
kg_f/cm^2	9.80665 E4*	0.101972 E-5	MPa
ksi	6.89476	0.145038	MPa
N/mm^2	1.0	1.0	MPa
Volume $[L]^3$ & Capacity			
in^3	16.3871	0.061024	cm^3
ft^3	0.028317	35.3147	m^3
ft^3	7.4805	0.133681	Gallon
ft^3	28.3168	0.035315	Liter (l)
Gallon	3.785412	0.264172	Liter
Specific Heat			
$Btu/lb_m\text{-}°F$	1.0	1.0	$cal/g\text{-}°C$
Temperature*			
Fahrenheit	(°F-32)/1.8	1.8(°C)+32	Celsius
Fahrenheit	°F+459.67	R-459.67	Rankine
Celsius	°C+273.16	K-273.16	Kelvin
Rankine	R/1.8	1.8(K)	Kelvin
Thermal Conductivity			
$Btu\text{-}ft/hr\text{-}ft^2\text{-}°F$	14.8816	.067197	$cal\text{-}cm/hr\text{-}cm^2\text{-}°C$

** Indicates exact conversion(s).*

METRIC - ENGLISH
STRESS CONVERSION TABLES

Kg Per Sq Mm to Psi to M Pa

Kg per Sq. mm	Psi	M Pa	Kg per Sq. mm	Psi	M Pa
10	14,223	98.1	**56**	79,651	549.2
11	15,646	107.9	**57**	81,073	559.0
12	17,068	117.7	**58**	82,496	568.8
13	18,490	127.5	**59**	83,918	578.6
14	19,913	137.3	**60**	85,340	588.4
15	21,335	147.1	**61**	86,763	598.2
16	22,757	156.9	**62**	88,185	608.0
17	24,180	166.7	**63**	89,607	617.8
18	25,602	176.5	**64**	91,030	622.6
19	27,024	186.3	**65**	92,452	637.4
20	28,447	196.1	**66**	93,874	647.2
21	29,869	205.9	**67**	95,297	657.0
22	31,291	215.7	**68**	96,719	666.9
23	32,714	225.6	**69**	98,141	676.7
24	34,136	235.4	**70**	99,564	686.5
25	35,558	245.2	**71**	100,986	696.3
26	36,981	255.0	**72**	102,408	706.1
27	38,403	264.8	**73**	103,831	715.9
28	39,826	274.6	**74**	105,253	725.7
29	41,248	284.4	**75**	106,675	735.5
30	42,670	294.2	**76**	108,098	745.3
31	44,093	304.0	**77**	109,520	755.1
32	45,515	313.8	**78**	110,943	764.9
33	46,937	323.6	**79**	112,365	774.7
34	48,360	333.4	**80**	113,787	784.5
35	49,782	343.2	**81**	115,210	794.3
36	51,204	353.0	**82**	116,632	804.1
37	52,627	362.9	**83**	118,054	814.0
38	54,049	372.7	**84**	119,477	823.8
39	55,471	382.5	**85**	120,899	833.6
40	56,894	393.3	**86**	122,321	843.4
41	58,316	402.1	**87**	123,744	853.2
42	59,738	411.9	**88**	125,166	863.0
43	61,161	421.7	**89**	126,588	872.8
44	62,583	431.5	**90**	128,011	882.6
45	64,005	441.3	**91**	129,433	892.4
46	65,428	451.1	**92**	130,855	902.2
47	66,850	460.9	**93**	132,278	912.0
48	68,272	470.7	**94**	133,700	921.8
49	69,695	480.5	**95**	135,122	931.6
50	71,117	490.3	**96**	136,545	941.4
51	72,539	500.1	**97**	137,967	951.2
52	73,962	510.0	**98**	139,389	961.0
53	75,384	519.8	**99**	140,812	970.9
54	76,806	529.6	**100**	142,234	980.7
55	78,229	539.4	**101**	143,656	990.5

METRIC - ENGLISH
STRESS CONVERSION TABLES - *CONTINUED*

Kg Per Sq Mm to Psi to M Pa

Kg per Sq. mm	Psi	M Pa	Kg per Sq. mm	Psi	M Pa
102	145,079	1000.3	**131**	186,327	1284.7
103	146,501	1010.1	**132**	187,749	1294.5
104	147,923	1020.0	**133**	189,171	1304.3
105	149,346	1029.7	**134**	190,594	1314.1
106	150,768	1039.5	**135**	192,016	1323.9
107	152,190	1049.3	**136**	193,438	1333.7
108	153,613	1059.1	**137**	194,861	1343.5
109	155,035	1068.9	**138**	196,283	1353.3
110	156,457	1078.7	**139**	197,705	1363.1
111	157,880	1088.5	**140**	199,128	1372.9
112	159,302	1098.3	**141**	200,550	1382.7
113	160,724	1108.2	**142**	201,972	1392.5
114	162,147	1118.0	**143**	203,395	1402.4
115	163,569	1127.8	**144**	204,817	1412.2
116	164,991	1137.6	**145**	206,239	1422.0
117	166,414	1147.4	**146**	207,662	1431.8
118	167,836	1157.2	**147**	209,084	1441.6
119	169,258	1167.0	**148**	210,506	1451.4
120	170,681	1176.8	**149**	211,929	1461.2
121	172,103	1186.6	**150**	213,351	1471.0
122	173,525	1196.4	**151**	214,773	1480.8
123	174,948	1206.2	**152**	216,196	1490.6
124	176,370	1216.0	**153**	217,618	1500.4
125	177,792	1225.8	**154**	219,040	1510.2
126	179,215	1235.6	**155**	220,463	1520.0
127	180,637	1245.4	**156**	221,885	1529.8
128	182,059	1255.3	**157**	223,307	1539.6
129	183,482	1265.1	**158**	224,730	1549.5
130	184,904	1274.9	**159**	226,152	1559.3

WORK - ENERGY CONVERSION TABLES

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

WORK - ENERGY CONVERSION TABLES - *CONTINUED*

ft-lbf	Reading	joules	ft-lbf	Reading	joules
71.5435	**97**	131.514	73.0186	**99**	134.226
72.2811	**98**	132.870	73.7562	**100**	135.582

NOTE: *Look up reading in the middle column. If in ft-lbf , read joules equivalent in right hand column; if in joules, read ft-lbf equivalent in left hand column.*

EXAMPLES: *1 ft-lbf = 1.356 joules, 1 joules = 0.7376 ft-lbf.*

INCHES INTO MILLIMETERS CONVERSION TABLE

Fractions	Inches	Millimeters	Fractions	Inches	Millimeters
1/64"	.015625	.369875	**33/64"**	.515625	13.096875
1/32"	.031250	.793750	**17/32"**	.531250	13.493750
3/64"	.046875	1.190625	**35/64"**	.546875	13.890625
1/16"	**.062500**	**1.587500**	**9/16"**	**.562500**	**14.287500**
5/64"	.078125	1.984375	**37/64"**	.578125	14.684375
3/32"	.093750	2.381250	**19/32"**	.593750	15.081250
7/64"	.109375	2.778125	**39/64"**	.609375	15.478125
1/8"	**.125000**	**3.175000**	**5/8"**	**.625000**	**15.875000**
9/64"	.140625	3.571875	**41/64"**	.640625	16.271875
5/32"	.156250	3.968750	**21/32"**	.656250	16.668750
11/64"	.171875	4.365625	**43/64"**	.671875	17.065625
3/16"	**.187500**	**4.762500**	**11/16"**	**.687500**	**17.462500**
13/64"	.203125	5.159375	**45/64"**	.703125	17.859375
7/32"	.218750	5.556250	**23/32"**	.718750	18.256250
15/64"	.234375	5.953125	**47/64"**	.734375	18.653125
1/4"	**.250000**	**6.350000**	**3/4"**	**.750000**	**19.050000**
17/64"	.265625	6.746875	**49/64"**	.765625	19.446875
9/32"	.281250	7.143750	**25/32"**	.781250	19.843750
19/64"	.296875	7.540625	**51/64"**	.796875	20.240625
5/16"	**.312500**	**7.937500**	**13/16"**	**.812500**	**20.637500**
21/64"	.328125	8.334375	**53/64"**	.828125	21.034375
11/32"	.343750	8.731250	**27/32"**	.843750	21.431250
23/64"	.359375	9.128125	**55/64"**	.859375	21.828125
3/8"	**.375000**	**9.525000**	**7/8"**	**.875000**	**22.225000**
25/64"	.390625	9.921875	**57/64"**	.890625	22.621875
13/32"	.406250	10.318750	**29/32"**	.906250	23.018750
27/64"	.421875	10.715625	**59/64"**	.921875	23.415625
7/16"	**.437500**	**11.112500**	**15/16"**	**.937500**	**23.812500**
29/64"	.453125	11.509375	**61/64"**	.953125	24.209375
15/32"	.468750	11.906250	**31/32"**	.968750	24.606250
31/64"	.484375	12.303125	**63/64"**	.984375	25.003125
1/2"	**.500000**	**12.700000**	**1"**	**1.000000**	**25.400000**

NOTE: *On the basis of the conversion factor 1 inch = 25.4 millimeters.*

NOTE: *All values in these tables are exact.*

TEMPERATURE CONVERSION TABLES

˚C	Degrees	˚F	˚C	Degrees	˚F
-273	**-459.4**	—	-17.2	**1**	33.8
-268	**-450**	—	-16.7	**2**	35.6
-262	**-440**	—	-16.1	**3**	37.4
-257	**-430**	—	-15.6	**4**	39.2
-251	**-420**	—	-15.0	**5**	41.0
-246	**-410**	—	-14.4	**6**	42.8
-240	**-400**	—	-13.9	**7**	44.6
-234	**-390**	—	-13.3	**8**	46.4
-229	**-380**	—	-12.8	**9**	48.2
-223	**-370**	—	-12.2	**10**	50.0
-218	**-360**	—	-11.7	**11**	51.8
-212	**-350**	—	-11.1	**12**	53.6
-207	**-340**	—	-10.6	**13**	55.4
-201	**-330**	—	-10.0	**14**	57.2
-196	**-320**	—	-9.4	**15**	59.0
-190	**-310**	—	-8.9	**16**	60.8
-184	**-300**	—	-8.3	**17**	62.6
-179	**-290**	—	-7.8	**18**	64.4
-173	**-280**	—	-7.2	**19**	66.2
-169	**-273**	-459.4	-6.7	**20**	68.0
-168	**-270**	-454	-6.1	**21**	69.8
-162	**-260**	-436	-5.6	**22**	71.6
-157	**-250**	-418	-5.0	**23**	73.4
-151	**-240**	-400	-4.4	**24**	75.2
-146	**-230**	-382	-3.9	**25**	77.0
-140	**-220**	-364	-3.3	**26**	78.8
-134	**-210**	-346	-2.8	**27**	80.6
-129	**-200**	-328	-2.2	**28**	82.4
-123	**-190**	-310	-1.7	**29**	84.2
-118	**-180**	-292	-1.1	**30**	86.0
-112	**-170**	-274	-0.6	**31**	87.8
-107	**-160**	-256	0	**32**	89.6
-101	**-150**	-238	0.6	**33**	91.4
-96	**-140**	-220	1.1	**34**	93.2
-90	**-130**	-202	1.7	**35**	95.0
-84	**-120**	-184	2.2	**36**	96.8
-79	**-110**	-166	2.8	**37**	98.6
-73	**-100**	-148	3.3	**38**	100.4
-68	**-90**	-130	3.9	**39**	102.2
-62	**-80**	-112	4.4	**40**	104.0
-57	**-70**	-94	5.0	**41**	105.8
-51	**-60**	-76	5.6	**42**	107.6
-46	**-50**	-58	6.1	**43**	109.4
-40	**-40**	-40	6.7	**44**	111.2
-34	**-30**	-22	7.2	**45**	113.0
-29	**-20**	-4	7.8	**46**	114.8
-23	**-10**	14	8.3	**47**	116.6
-17.8	**0**	32	8.9	**48**	118.4

TEMPERATURE CONVERSION TABLES - *CONTINUED*

˚C	Degrees	˚F	˚C	Degrees	˚F
9.4	**49**	120.2	36.1	**97**	206.6
10.0	**50**	122.0	36.7	**98**	208.4
10.6	**51**	123.8	37.2	**99**	210.2
11.1	**52**	125.6	37.8	**100**	212.0
11.7	**53**	127.4	43	**110**	230
12.2	**54**	129.2	49	**120**	248
12.8	**55**	131.0	54	**130**	266
13.3	**56**	132.8	60	**140**	284
13.9	**57**	134.6	66	**150**	302
14.4	**58**	136.4	71	**160**	320
15.0	**59**	138.2	77	**170**	338
15.6	**60**	140.0	82	**180**	356
16.1	**61**	141.8	88	**190**	374
16.7	**62**	143.6	93	**200**	392
17.2	**63**	145.4	99	**210**	410
17.8	**64**	147.2	100	**212**	413.6
18.3	**65**	149.0	104	**220**	428
18.9	**66**	150.8	110	**230**	446
19.4	**67**	152.6	116	**240**	464
20.0	**68**	154.4	121	**250**	482
20.6	**69**	156.2	127	**260**	500
21.1	**70**	158.0	132	**270**	518
21.7	**71**	159.8	138	**280**	536
22.2	**72**	161.6	143	**290**	554
22.8	**73**	163.4	149	**300**	572
23.3	**74**	165.2	154	**310**	590
23.9	**75**	167.0	160	**320**	608
24.4	**76**	168.8	166	**330**	626
25.0	**77**	170.6	171	**340**	644
25.6	**78**	172.4	177	**350**	662
26.1	**79**	174.2	182	**360**	680
26.7	**80**	176.0	188	**370**	698
27.2	**81**	177.8	193	**380**	716
27.8	**82**	179.6	199	**390**	734
28.3	**83**	181.4	204	**400**	752
28.9	**84**	183.2	210	**410**	770
29.4	**85**	185.0	216	**420**	788
30.0	**86**	186.8	221	**430**	806
30.6	**87**	188.6	227	**440**	824
31.1	**88**	190.4	232	**450**	842
31.7	**89**	192.2	238	**460**	860
32.2	**90**	194.0	243	**470**	878
32.8	**91**	195.8	249	**480**	896
33.3	**92**	197.6	254	**490**	914
33.9	**93**	199.4	260	**500**	932
34.4	**94**	201.2	266	**510**	950
35.0	**95**	203.0	271	**520**	968
35.6	**96**	204.8	277	**530**	986

continued on next page...

TEMPERATURE CONVERSION TABLES - *CONTINUED*

˚C	Degrees	˚F	˚C	Degrees	˚F
282	**540**	1004	549	**1020**	1868
288	**550**	1022	554	**1030**	1886
293	**560**	1040	560	**1040**	1904
299	**570**	1058	566	**1050**	1922
304	**580**	1076	571	**1060**	1940
310	**590**	1094	577	**1070**	1958
316	**600**	1112	582	**1080**	1976
321	**610**	1130	588	**1090**	1994
327	**620**	1148	593	**1100**	2012
332	**630**	1166	599	**1110**	2030
338	**640**	1184	604	**1120**	2048
343	**650**	1202	610	**1130**	2066
349	**660**	1220	616	**1140**	2084
354	**670**	1238	621	**1150**	2102
360	**680**	1256	627	**1160**	2120
366	**690**	1274	632	**1170**	2138
371	**700**	1292	638	**1180**	2156
377	**710**	1310	643	**1190**	2174
382	**720**	1328	649	**1200**	2192
388	**730**	1346	654	**1210**	2210
393	**740**	1364	660	**1220**	2228
399	**750**	1382	666	**1230**	2246
404	**760**	1400	671	**1240**	2264
410	**770**	1418	677	**1250**	2282
416	**780**	1436	682	**1260**	2300
421	**790**	1454	688	**1270**	2318
427	**800**	1472	693	**1280**	2336
432	**810**	1490	699	**1290**	2354
438	**820**	1508	704	**1300**	2372
443	**830**	1526	710	**1310**	2390
449	**840**	1544	716	**1320**	2408
454	**850**	1562	721	**1330**	2426
460	**860**	1580	727	**1340**	2444
466	**870**	1598	732	**1350**	2462
471	**880**	1616	738	**1360**	2480
477	**890**	1634	743	**1370**	2498
482	**900**	1652	749	**1380**	2516
488	**910**	1670	754	**1390**	2534
493	**920**	1688	760	**1400**	2552
499	**930**	1706	766	**1410**	2570
504	**940**	1724	771	**1420**	2588
510	**950**	1742	777	**1430**	2606
516	**960**	1760	782	**1440**	2624
521	**970**	1778	788	**1450**	2642
527	**980**	1796	793	**1460**	2660
532	**990**	1814	799	**1470**	2678
538	**1000**	1832	804	**1480**	2696
543	**1010**	1850	810	**1490**	2714

TEMPERATURE CONVERSION TABLES - *CONTINUED*

˚C	Degrees	˚F	˚C	Degrees	˚F
816	**1500**	2732	1082	**1980**	3596
821	**1510**	2750	1088	**1990**	3614
827	**1520**	2768	1093	**2000**	3632
832	**1530**	2786	1099	**2010**	3650
838	**1540**	2804	1104	**2020**	3668
843	**1550**	2822	1110	**2030**	3686
849	**1560**	2840	1116	**2040**	3704
854	**1570**	2858	1121	**2050**	3722
860	**1580**	2876	1127	**2060**	3740
866	**1590**	2894	1132	**2070**	3758
871	**1600**	2912	1138	**2080**	3776
877	**1610**	2930	1143	**2090**	3794
882	**1620**	2948	1149	**2100**	3812
888	**1630**	2966	1154	**2110**	3830
893	**1640**	2984	1160	**2120**	3848
899	**1650**	3002	1166	**2130**	3866
904	**1660**	3020	1171	**2140**	3884
910	**1670**	3038	1177	**2150**	3902
916	**1680**	3056	1182	**2160**	3920
921	**1690**	3074	1188	**2170**	3938
927	**1700**	3092	1193	**2180**	3956
932	**1710**	3110	1199	**2190**	3974
938	**1720**	3128	1204	**2200**	3992
943	**1730**	3146	1210	**2210**	4010
949	**1740**	3164	1216	**2220**	4028
954	**1750**	3182	1221	**2230**	4046
960	**1760**	3200	1227	**2240**	4064
966	**1770**	3218	1232	**2250**	4082
971	**1780**	3236	1238	**2260**	4100
977	**1790**	3254	1243	**2270**	4118
982	**1800**	3272	1249	**2280**	4136
988	**1810**	3290	1254	**2290**	4154
993	**1820**	3308	1260	**2300**	4172
999	**1830**	3326	1266	**2310**	4190
1004	**1840**	3344	1271	**2320**	4208
1010	**1850**	3362	1277	**2330**	4226
1016	**1860**	3380	1282	**2340**	4244
1021	**1870**	3398	1288	**2350**	4262
1027	**1880**	3416	1293	**2360**	4280
1032	**1890**	3434	1299	**2370**	4298
1038	**1900**	3452	1304	**2380**	4316
1043	**1910**	3470	1310	**2390**	4334
1049	**1920**	3488	1316	**2400**	4352
1054	**1930**	3506	1321	**2410**	4370
1060	**1940**	3524	1327	**2420**	4388
1066	**1950**	3542	1332	**2430**	4406
1071	**1960**	3560	1338	**2440**	4424
1077	**1970**	3578	1343	**2450**	4442

continued on next page...

TEMPERATURE CONVERSION TABLES - *CONTINUED*

˚C	Degrees	˚F	˚C	Degrees	˚F
1349	**2460**	4460	1504	**2740**	4964
1354	**2470**	4478	1510	**2750**	4982
1360	**2480**	4496	1516	**2760**	5000
1366	**2490**	4514	1521	**2770**	5018
1371	**2500**	4532	1527	**2780**	5036
1377	**2510**	4550	1532	**2790**	5054
1382	**2520**	4568	1538	**2800**	5072
1388	**2530**	4586	1543	**2810**	5090
1393	**2540**	4604	1549	**2820**	5108
1399	**2550**	4622	1554	**2830**	5126
1404	**2560**	4640	1560	**2840**	5144
1410	**2570**	4658	1566	**2850**	5162
1416	**2580**	4676	1571	**2860**	5180
1421	**2590**	4694	1577	**2870**	5198
1427	**2600**	4712	1582	**2880**	5216
1432	**2610**	4730	1588	**2890**	5234
1438	**2620**	4748	1593	**2900**	5252
1443	**2630**	4766	1599	**2910**	5270
1449	**2640**	4784	1604	**2920**	5288
1454	**2650**	4802	1610	**2930**	5306
1460	**2660**	4820	1616	**2940**	5324
1466	**2670**	4838	1621	**2950**	5342
1471	**2680**	4856	1627	**2960**	5360
1477	**2690**	4874	1632	**2970**	5378
1482	**2700**	4892	1638	**2980**	5396
1488	**2710**	4910	1643	**2990**	5414
1493	**2720**	4928	1649	**3000**	5432
1499	**2730**	4946			

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

NOTE: *Albert Sauveur type of table. Values revised.*

NOTES

HARDNESS CONVERSION TABLES

Based on Brinell (Approximate)

BRINELL HARDNESS		ROCKWELL HARDNESS				Diamond Pyramid	Approx.
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	Super -ficial 30 N	Hardness Number (Vickers)	Tensile Strength 1000 psi
—	—	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	83.2	—	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
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

HARDNESS CONVERSION TABLES - *CONTINUED*

Based on Brinell (Approximate)

BRINELL HARDNESS		ROCKWELL HARDNESS				Diamond Pyramid	Approx.
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	Super -ficial 30 N	Hardness Number (Vickers)	Tensile Strength 1000 psi
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

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

NOTE: *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.*

FORGING TERMINOLOGY

Acid Embrittlement

A form of hydrogen embrittlement that may be induced in some metals by acid treatment.

Age Hardening (Aging)

An aging process that results in an increase in hardness and strength with, usually, some loss of ductility. It is generally induced by a low-temperature treatment following a relatively rapid cooling from some elevated temperature. Aging tends to restore equilibrium in the metal and eliminate any unstable condition induced by a prior operation. *See also Precipitation Hardening and Solution Heat Treatment.*

Air-Hardening Steel

An alloy steel that does not require a liquid quench to harden, but hardens simply by cooling in air from above its transformation temperature range.

Aircraft Quality

Denotes stock of sufficient quality to be forged into highly stressed parts for aircraft or other critical applications. Such materials are of extremely high quality, requiring closely controlled, restrictive practices in their manufacture in order that they may pass rigid requirements, such as magnetic particle inspection *(Ref: Aerospace Material Specification 2301).*

Air Quenching

A heat-treating process consisting of heating steel above the transformation temperature range and then cooling in agitated air. The process is a type of normalizing but with more rapid air circulation.

Alloy

A material that exhibits metallic properties and is composed of two or more chemical elements with at least one being metallic. In practice, the word is commonly used to denote relatively high-alloy grades of material—for example, “alloy” steels as differentiated from “carbon” steels. Materials are alloyed to enhance physical and mechanical properties such as strength, ductility, and hardenability.

Alloying Element

An element added to a metal that remains within the metal and changes its properties.

Alloy Steel

Steel that, in addition to carbon, contains one or more elements in sufficient amounts to appreciably alter the mechanical or physical properties when compared with those of carbon steel.

Aluminum-Treated Steel

Steel to which aluminum has been added to deoxidize it, or to control grain size, or to modify mechanical properties by subsequent precipitation hardening or nitriding.

Annealing

A heat-treating operation wherein metal is heated to a temperature above its critical range, held at that temperature long enough to allow full crystallization, then slowly cooled through the critical range. Annealing reduces hardness, improves machinability, increases ductility, facilitates cold working, or produces a desired microstructure.

Auxiliary Operations

Additional processing steps performed on forgings to obtain properties, such as surface conditions or shapes, not obtained in the regular processing operation.

Backward Extrusion

Forcing metal to flow in a direction opposite to the motion of a punch or die.

Bar

A section hot rolled from a billet to a form, such as round, hexagonal, octagonal, square, or rectangular, with sharp or rounded corners or edges, with a cross-sectional area of less than 16"; a solid section that is long in relation to its cross-sectional dimensions, having a completely symmetrical cross section and whose width or greatest distance between parallel faces is 3/8" or more.

Bend

Operation to preform (bend) stock to approximate shape of die impression for subsequent forging.

Bend or Twist (Defect)

Distortion similar to warpage, but resulting from different causes; generally caused in the forging or trimming operations. When the distortion is along the length of the part, it is called “bend”: when across the width, it is called “twist”.

Billet

1) A semi-finished section hot-rolled from a metal ingot, with a rectangular cross section ranging from 16" to 36", the width being less than twice the thickness. Where the cross section exceeds 36", the word “bloom” is properly but not universally used. Sizes smaller than 16" are usually termed “bars”. 2) A semi-finished, cogged, hot-rolled, or continuous-cast metal product of uniform section, usually rectangular with radiused corners. Billets are relatively larger than bars.

Blank

A piece of stock (also called a “slug” or “multiple”) from which a forging is to be made.

Blast Cleaning (Blasting)

A process for cleaning or finishing metal objects by use of an air jet or centrifugal wheel that propels abrasive particles (grit, sand, or shot) against the surfaces of the workpiece at high velocity.

continued on next page...

Block

The forging operation in which metal is progressively formed to general desired shape and contour via an impression die (used when only one block operation is scheduled).

Blow

The impact or force delivered by one work-stroke of the forging equipment.

Bore Sonic Testing

A method of examining bored forgings ultrasonically from the inner surface.

Boring

Machining a hole or enlarging an existing one.

Boss

A relatively short protrusion or projection on the surface of a forging, often cylindrical in shape.

Box Annealing

A heat-treating process whereby metal to be annealed is packed in a closed container to protect its surfaces from oxidation.

Brinell Hardness Testing

A test to determine the hardness of a metal made by forcing a hard steel, or carbide ball of specified diameter, at a known pressure (10-mm ball, 500-kg load for aluminum alloys). The result is expressed as the Brinell Hardness Number (BHN), which is the value obtained by dividing the applied load in kilograms by the surface area of the resulting impression in square millimeters.

Burning

Permanently damaging a metal or alloy by heating so as to cause either incipient melting or intergranular oxidation.

Burst

An internal discontinuity caused by improper forging.

Carbon Steel

Steel containing carbon up to about 2.0 percent, but usually under 1.0 percent, and only residual amounts of other alloying elements, except for those added for composition control (silicon usually limited to 0.60 and manganese to 1.65 percent, maximum).

Carbonitriding

A process of case hardening a ferrous material in a gaseous atmosphere containing both carbon and nitrogen.

Case

The surface layer of an alloy that has been made substantially harder than the interior by some form of hardening operation.

Case Hardening

A heat treatment or combination of processes in which the surface layer of a ferrous alloy is made substantially harder than the interior. Carburizing, cyaniding, nitriding, and heating and quenching techniques are commonly used. Case hardening can provide a hard, wear-resistant surface on a forging, while retaining a softer, tougher core.

Cast Steel

A product made by pouring molten steel into molds to obtain a desired shape.

Centerline Segregation

Chemical segregation occurring in a zone along the axis of an ingot.

Charpy Impact Test

An impact test in which a specially V-notched specimen is broken by the impact of a pendulum. The energy absorbed in fracture is a measure of the impact strength or notch toughness of the sample.

Check Analysis

A supplemental chemical analysis, sometimes called product analysis, obtained from the semi-finished or finished product.

Chipping

Removing seams or other defects from a surface with a chisel or gouge. Chipping may also by used to remove excess metal.

Chop

A die forging defect; metal sheared from a vertical surface and spread by the die over an adjoining horizontal surface.

Cleaning

The process of removing scale, oxides, or lubricant—acquired during heating for forging or heat treating—from the surface of the forging. *See also Blasting, Pickling, Tumbling.*

Closed Die Forging

See Impression Die Forging.

Closing In

The forging operation of locally reducing diameters in hollow forging.

Coarse Grain Size

An austenitic grain size generally less than ASTM 5.

continued on next page..

Cogging

The reducing operation in working the ingot into a billet by the use of a forging hammer or a forging press.

Coining

The process of applying necessary pressure to all or some portion of the surface of a forging to obtain closer tolerances or smoother surfaces or to eliminate draft.

Cold Inspection

A visual (usually final) inspection of the forgings for visible defects, dimensions, weight, and surface condition at room temperature.

Cold Shut

A defect characterized by a fissure or lap in the surface of a forging that has been closed without fusion during the forging operation.

Cold Working

Plastic deformation of a metal at a temperature low enough to induce strain hardening.

Columnar Structure

A structure of elongated parallel crystals formed during solidification of steel by growth taking place perpendicular to the mold surface.

Conventional Forging

A forging characterized by design complexity and tolerances that fall within the broad range of general forging practice.

Core

The softer interior portion of an alloy piece that has been surface (case) hardened; or that portion of a forging removed by trepanning or punching.

Critical (Temperature) Range

Temperatures at which changes in the phase of a metal take place. Changes are determined by absorption of heat when the metal is heated, and liberation of heat when it is cooled.

Decarburization

The loss of carbon from the surface of steel by heating above lower critical temperature or by chemical action. Decarburization is usually present to a slight extent in steel forgings. Excessive decarburization can result in defective products.

Descaling

The process of removing oxide scale from heated stock prior to or during forging operations, using such means as extra blows, wire brushes, scraping devices, or water spray.

Die

A forging die is a steel block with a flat or contoured working face which is used in a hammer or press for shaping metal.

Differential Heat Treatment

A heat treating process by which the temperature is varied within the object being treated so that after cooling different portions may have different properties.

Draft

1) Taper on the sides of a forging (and the forging die impression) that is necessary for removal of the workpiece from the dies. 2) As applied to open-die forging, draft is the amount of relative movement of the dies toward each other through the metal in one application of power.

Drawing

1) Referring to a heat treating operation. *See Tempering.* 2) Referring to a forging operation in which the cross section of a forging stock is reduced and the stock lengthened between flat or simple contour dies. *See also Fullering.*

Drawing out

A forging operation which produces elongation by mechanical working.

Drifting

In forging the operation of forming or enlarging a hole by the use of a tapered pin. *See also Punching.*

Drop Forging

A metal form or shape wrought in closed or impression dies under a drop or steam hammer.

Ductility

The property of a metal that enables it to stretch before fracturing.

Dye-Penetrant Testing

A method of inspecting for surface discontinuities in forgings by applying a dye to a liquid penetrant.

Elongation

In a tension test, the total amount of permanent extension within the gauge length measured after the specimen has fractured. The term may also refer to the amount of drawing out at any stage of forging.

End-Quench Test

A test for hardenability. *See Jominy Test.*

continued on next page...

F. A. O.

An abbreviation of “finish all over”; it designates that a forging must have sufficient size over the dimensions given on the drawing so that all surfaces may be machined in order to obtain the dimensions shown on the drawing. The amount of additional stock necessary for machining allowance depends on the size and shape of the part, and is agreed on by the vendor and the user.

Flat-Die Forging (Open-Die Forging)

Forging worked between flat or simple contour dies by repeated strokes and manipulation of the workpiece. Also known as “hand” or “smith” forging.

Forging

The hot mechanical forming of metals by use of hammers, presses, or forging machines.

Forging Quality

Term describing stock of sufficiently superior quality to make it suitable for commercially satisfactory forgings.

Forging Plane

The plane that includes the principle die face and that is perpendicular to the direction of the ram stroke when the parting is flat. The forging plane coincides with the parting line.

Forging Reduction

Ratio of the cross-sectional areas before and after forging.

Forging Stresses

Elastic residual stresses induced by forging or by cooling from the forging temperature.

Fracture

The irregular surface produced when a piece of metal is ruptured or broken.

Fracture Test

Breaking a piece of metal for the purpose of examining the fracture surface to determine the structure of the metal or the presence of internal defects.

Free Ferrite

Ferrite that is structurally separate and distinct, such as may be formed without the simultaneous formation of carbide when cooling hypoeutectoid austenite down to the lower critical temperature.

Fullering

Reducing the cross section of a forging between ends of stock, permitting the metal to move outward. The fullering impression is often used in conjunction with an edger (or edging impression).

Grain

The characteristic crystalline structural unit or metals and alloys.

Grain Flow

Fiber-like lines appearing on polished and etched sections of forgings that are caused by orientation of the constituents of the metal in the direction of working during forging. Grain flow can improve required mechanical properties of forgings.

Grain Growth

An increase in the size of grains of a metal with the reduction of the number of grains usually affected during heating at elevated temperatures.

Grain Size

An expression that rates the number of grains per unit area of cross section as determined by metallographic examination.

Grinding

Process of removing metal by abrasion from bar or billet stock to prepare stock surfaces for forging. Occasionally used to remove surface irregularities and flash from forgings.

Hairline Cracks

Fine, tightly-adhering cracks in steel; flakes or thermal flakes.

Hammer Forging

The mechanical forming of metal by means of a hammer. The action of the hammer is that of an instantaneous application of pressure in the form by repeated blows.

Hand Forging

A forging made by hand on an anvil or under a power hammer without dies containing an exact finishing impression of the part. Such forgings approximate each other in size and shape but do not have the commercial exactness of production die forgings. Used where the quantity of forgings required does not warrant expenditure for special dies.

Hardenability

The characteristic of steel that determines its relative depth of hardening when quenched from above the transformation temperature range.

Hardening

Any process for increasing the hardness of a metal. A heat treatment consisting of heating an alloy to a temperature within or above the critical range, maintaining that temperature for the prescribed time, then quenching or otherwise rapidly cooling. For age-hardening alloys, a two-stage process consisting of solution heat treatment and aging.

Heat (Forging)

Amount of forging stock placed in a batch-type furnace at one time.

continued on next page...

Heat Treatment

A combination of controlled heating, holding, and cooling operations applied to a metal or alloy in the solid state to produce desired properties.

Hub

A boss that is in the center of the forging and forms a part of the body of the forging.

Impact Testing

Tests to determine the energy absorbed in fracturing a test bar at high velocity. *See also Charpy Impact Test, Izod Impact Test.*

Impression Die Forging

A forging that is formed to the required shape and size by machined impressions in specially prepared dies that exert three dimensional control on the workpiece.

Inclusion

Impurities in metal, usually in the form of particles in mechanical mixture.

Iron-Carbon Phase Diagram

A diagram showing the relationships existing among constituents in the iron-carbon system when examined under conditions of thermal equilibrium.

Isothermal Annealing

A heat treatment process in which steel is heated above the transformation temperature range, after which it is cooled to and held at a temperature such that the austenite transforms to a relatively soft ferrite-carbide aggregate.

Isothermal Transformation Diagram (IT Diagram, TTT Diagram)

In essence, a concise graphic summary of the process and results of austenite transformation at consistent non-equilibrium temperatures. It is a time-temperature plot showing the time required (log scale), in the case of the specific steel composition depicted, for the austenite to begin, proceed, and complete its transformation at constant sub-critical temperatures.

Izod Impact Test

A type of impact test in which a specially notched specimen, gripped vertically at one end, is broken by the impact of a falling pendulum. *See Charpy Impact Test.*

Jominy Test

A standard test specimen quenched from one end to determine the hardenability characteristics of steel.

Killed Steel

Steel deoxidized with a strong deoxidizing agent, such as aluminum or silicon, or by vacuum treatment, to reduce the oxygen content to a level that no reaction occurs between carbon and the oxygen during solidification.

Lap

A surface defect appearing as a seam caused by the folding over of hot metal, fins, or sharp corners and by subsequent rolling or forging (but not welding) of these into the surface.

Lapping

A process of finishing a surface or slightly reducing the size of a part by means of a soft metal wheel or fixture impregnated with a very fine abrasive.

Macroetch

A testing procedure for conditions such as porosity, inclusions, segregations, carburization, and flow lines from hot working. After applying a suitable etching solution to the polished metal surface, the structure revealed by the action of the reagent can be observed visually.

Macrostructure

The structure and condition of metals as revealed on a suitably prepared and etched sample and visible without the use of a microscope.

Magnaglo

A type of magnetic-particle testing where the magnetic power is fluorescent and the inspection is preformed under black light. *See also Magnetic Particle Testing.* Trade name of Magnaflux Corp.

Magnetic Particle Testing

A nondestructive test method of inspecting areas on or near the surface of ferromagnetic materials. The metal is magnetized, then iron powder is applied. The powder adheres to lines of flux leakage revealing surface and near-surface discontinuities. Magnetic particle testing is used for both raw material acceptance testing and product inspection. Quality levels are usually agreed on in advance by the producer and purchaser.

Mandrel Forging

The process of rolling and forging a hollow blank over a mandrel in order to produce a weldless, seamless ring or tube.

Mechanical Properties

Those properties of a material that reveal the elastic and inelastic reaction when force is applied, or that involve the relationship between stress and strain; for example, the modulus of elasticity, tensile strength, and fatigue limit. Mechanical properties are dependent on chemical composition, forging, and heat treatment.

Microstructure

The structure and internal condition of metals as revealed on a ground and polished (and sometimes etched) surface when observed at high magnification over 10 diameters.

continued on next page...

Nonferrous

Metals or alloys that contain no appreciable quantity of iron; applied to such metals as aluminum, copper, magnesium, and their alloys.

Normalizing

A heat treatment in which porous alloys are heated to approximately 100°F above the critical range, holding that temperature for the required time, and cooling to room temperature in air.

Open-Die Forging

The hot mechanical forming of metals between flat or shaped dies where flow of the metal is not completely restricted.

Overheating

Overheating results when metal temperature exceeds the critical temperature of the alloy involved and a change in phase occurs; this is also known as the transformation temperature. Externally, overheated material will often form blisters or a web of fine cracks: internally, overheating causes precipitation of melted constituents around grain boundaries and the formation of rounded pools of melted constituents often called “rosettes.”

Pearlite

The lamellar aggregate of ferrite and carbide resulting from the direct transformation of austenite.

Photomacrograph

A photographic reproduction of a macro specimen.

Photomicrograph

A photographic reproduction of a structure revealed by the microscope.

Physical Properties

Properties familiarly discussed in physics, excluding those described under mechanical properties, for example, density, electrical conductivity, and coefficient of thermal expansion.

Pickling

The process of removing oxide scale from forgings by treating in a heated acid bath.

Pierce

In ring rolling, the process of providing a through hole in the center of an upset forging as applied to ring blank preparation.

Piercing

See Drifting.

Planing

Machining a straight surface with a single point tool used with a machine called a planer used in reciprocal motion.

Planishing

A finishing operation using frequent, light, forging strokes for the purpose of obtaining closer tolerances or removing trim lines from forgings. Usually done by hammering or pressing, hot or cold.

Precipitation Hardening

A process for hardening an alloy in which a constituent precipitates from a supersaturated solid solution. *See also Age Hardening.*

Precision Forging

A forging produced to closer tolerances than normally considered standard by the industry.

Preform

The forging operation in which stock is preformed or shaped to a predetermined size and contour prior to subsequent die forging operations; the operation may involve drawing, bending, flattening, edging, fullering, rolling, or upsetting.

Preheating

A preliminary heating of ingots, billets, or forgings to reduce the hazards of thermal shock upon subsequent heating to higher temperatures.

Press Forging

The shaping of metal between dies by mechanical or hydraulic pressure. The action is that of kneading the metal by relatively slow application of force as compared with the action of hammering. Usually this is accomplished with a single work stroke of the press for each die station.

Punch (Punching)

A shearing operation to remove a section of metal as outlined by the inner parting line in a blocked or finished forging; the operation is generally performed on a trim press using a punch die. A tool used in punching holes in metal. The movable die in a press or forging machine. *See also Drifting.*

Quenching

Rapid cooling from high temperature by contact with liquids, gases, or solids. The cooling rate during quenching is important in the heat treatment because it controls the degree of hardening of most alloys.

Reduction of Area (Contraction of Area)

The difference in a tension specimen between the size of the original sectional area and that of the area at the point of rupture. It is generally stated as an percentage of decrease of cross-sectional area of a tension specimen after rupture.

continued on next page...

Residual Alloys

Small quantities of unspecified alloying elements found in steel but not added intentionally.

Ring Rolling

The process of shaping welding rings from pierced disks or thick-walled, ring-shaped blanks between rolls that control wall thickness, ring diameter, height, and contour.

Rockwell Hardness Test

A method of determining the relative hardness value of a material by measuring the depth of residual penetration by a steel ball or diamond point indenter under controlled loading.

Rolling

The forging operation of working a bar between contoured dies while turning it between blows to produce a varying circular cross section.

Rough Machining

A machining operation that allows stock for subsequent finish machining.

Sadden

To lightly forge an ingot in the intentional forging operation to break up and refine coarse, as-cast structures at the surface.

Sand Blasting

The process of cleaning forgings by propelling sand against them at high velocity. *See also Blast Cleaning.*

Scarfing

Removal of surface irregularities by use of an oxygen torch. Scarfing of forgings is usually done during the hot working phase of processing.

Scale

The heavy iron oxide layer that forms on the surface of steel at forging temperatures; also the lighter oxide layer formed at heat treating temperatures.

Scleroscope Hardness (Shore)

A hardness test in which the unit of value is a number derived from the height of rebound of a tup falling on the object from a fixed height under the acceleration of gravity.

Seam

An elongated surface defect.

Secondary Hardening

An increase in hardness occurring during temperature operations of certain alloy steels.

Segregation

Non-uniform distribution of alloying elements, impurities, or microphases.

Selective Heating

A process in which only certain portions of an object are heated.

Set-Down

The drop from a heavy sectional area to a lighter sectional area.

Shaping

The process of forming a straight surface with a machine tool in which the work is held stationary and the tool moves on a ram in a horizontal plane.

Shearing

A process of mechanically cutting metal bars to the proper stock length necessary for forging the desired product.

Shot Blasting

A process of cleaning forgings by propelling metal shot at high velocity by air pressure or centrifugal force at the surface of forgings. *See also Blast Cleaning.*

Shrinkage

The contraction of metal during cooling after forging. Die impressions are made oversize according to precise shrinkage scales to allow forgings to shrink to design dimensions and tolerances.

Sizing

A process employed to control precisely a diameter of rings or tubular components.

Smith

A blacksmith, forger, or pressman.

Soaking

Holding steel at a temperature to attain a uniform temperature throughout.

Solution Heat Treatment

A process in which an austenitic stainless steel is heated to a suitable temperature, held at this temperature long enough to permit a constituent to enter solid solution, and then cooled rapidly to retain that constituent in solid solution.

Spalling

The cracking and shelling of small particles from a metal surface.

Spheroidizing

A from of annealing consisting of prolonged heating of iron-base alloys at a temperature in the neighborhood of, but generally slightly below the critical range, usually followed by a relatively slow cooling. Spheroidizing causes the iron carbide to assume a spheroidal shape, hence the name.

continued on next page...

Stainless Steel

Steels that are corrosion- and heat-resistant and contain at least 10 percent chromium. Other alloying elements are often present.

Strain

The elastic or plastic deformation of a steel resulting from stress.

Stress

A load that elastically or plastically deforms a metal.

Stress Relieving

A process for relieving residual stresses in steel forgings by heating to a suitable temperature below the tempering temperature, holding for a sufficient time, and cooling slowly and uniformly. This treatment may be applied to relieve stresses induced by quenching, normalizing, machining, cold working, or welding.

Swage

Operation of reducing or changing the cross-sectional area by revolving the stock under fast impact of blows. Finishing tool with concave working surface; useful for rounding out work after its preliminary drawing to size.

Tears

Surface ruptures in metals.

Tempering

Reheating a quench-hardened or normalized ferrous alloy to a temperature below the transformation temperature range.

Tensile Properties

The mechanical property data obtained from a tension test, such as tensile strength, yield point or yield strength, percent elongation in gauge length, and percent reduction in area.

Tensile Strength

The maximum unit stress, based on the original test cross-sectional area, in a tension test carried to rupture.

Thermal Cracks

Ruptures in metal set up by stresses due to thermal differentials.

Tolerance

The specified permissible deviation from a specified nominal dimension or the permissible variation in size of a part.

Transformation Temperature Range

The range of temperature over which ferrite and pearlite transforms to austenite on heating, and austenite transforms to ferrite and pearlite on cooling.

Trepanning

Removal of a core of metal by a hollow tool. May be performed by a hollow punch at forging temperatures or by a hollow cutting tool by machining at ambient temperatures.

Tumbling

The process for removing scale from forgings in a rotating container by means of impact with each other and abrasive particles and small bits of metal. A process for removing scale and roughness from forgings by impact with each other, together with abrasive material in a rotating container.

Turning

Removing metal from the outside of a part by means of a tool in a lathe or similar machine tool.

Ultrasonic Testing

A nondestructive test applied to sound-conductive materials having elastic properties for the purpose of locating inhomogeneities or structural discontinuities within a material by means of an ultrasonic beam.

Upend Forging

A forging in which the metals is so placed in the die that the direction of the fiber structure is at right angles to the faces of the die.

Upset

Working metal in such a manner that the cross-sectional area of a portion or all of the stock is increased, and length is decreased.

Upset Forging

A forging obtained by set of a suitable length of bar, billet, or bloom; formed by heading or gathering the material by pressure upon hot or cold metal between dies operated in a horizontal plane.

Upsetter (Forging Machine)

A machine, with horizontal action, used for making upset forgings.

Warpage

Term generally applied to distortion that results during quenching from the heat-treating temperature. The condition is governed by applicable straightness tolerances; beyond tolerances, warpage is a defect and cause for rejection. The term is not to be confused with “bend” or “twist.”

Wrought Steel

A descriptive term for any particle of steel which has been produced by hot mechanical working.

continued on next page...

FORGING TERMINOLOGY - *CONTINUED*

Yield Point

The load per unit of original cross section at which a marked increase in the deformation of the specimen occurs without increase of load. The stress in material at which there occurs a marked increase in strain without an increase in stress.

Yield Strength

Stress corresponding to some fixed permanent deformation such as 0.1 or 2.0% offset from the modulus slope.

NOTE: *Sources; Forging Industry Association and A. Finkl & Sons Co.*

PERIODIC TABLE OF ELEMENTS

CODE (Crystal Structure)

Cubic, Face Centered ⊡ Rhombohedral △
Cubic, Body Centered ⊞ Orthorhombic ■
Cubic □ Monoclinic ◊
Diamond ◇ Tetragonal ▯

GROUP IA	IIA	IIIB	IVB	VB	VIB	VIIB	GROUP VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H 1.008																	2 He 4.003
3 Li 6.939	4 Be 9.012											5 B 10.811	6 C 12.001	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.183
11 Na 22.991	12 Mg 24.312											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.064	17 Cl 35.453	18 Ar 39.948
19 K 39.102	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.909	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.905	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.905	46 Pd 106.4	47 Ag 107.870	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.904	54 Xe 131.30
55 Cs 132.905	56 Ba 137.34	57 La 138.91	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.967	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.980	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)															

58 Ce 140.12	59 Pr 140.907	60 Nd 144.24	61 Pm (147)	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.924	66 Dy 162.50	67 Ho 164.930	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu 174.97
90 Th 232.038	91 Pa (231)	92 U 238.03	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (249)	99 Es (254)	100 Fm (253)	101 Md (256)	102 No (254)	103 Lr (257)

CHEMICAL ELEMENTS

Element	Symbol	Specific Gravity	Melting Point °C	Boiling Point °C
Actinium	Ac	10.07[1]	1051	3198
Aluminum	Al	2.6989	660.32	2519
Americium	Am	13.67	1176	2011
Antimony	Sb	6.61	630.63	1587
Argon	Ar	1.7837[2]	-189.35	-185.85
Arsenic (gray)	As	5.73	817	603
Astatine	At	—	302	—
Barium	Ba	3.5	727	1897
Berkelium	Bk	14.00[6]	1050 (*alpha* form)	—
Beryllium	Be	1.848	1287	2471
Bismuth	Bi	9.747	271.40	1564
Bohrium	Bh	—	—	—
Boron	B	2.37[7]	2075	4000
Bromine	Br	3.12[2]	-7.2	58.8
Cadmium	Cd	8.65	321.07	767
Calcium	Ca	1.55	842	1484
Californium	Cf	—	900	-—
Carbon	C	1.8–3.5[5]	4492	3825
Cerium	Ce	6.771	798	3443
Cesium	Cs	1.873	28.5	671
Chlorine	Cl	1.56[2]	-101.5	-34.04
Chromium	Cr	7.18-7.20	1907	2671
Cobalt	Co	8.9	1495	2927
Copper	Cu	8.96	1084.62	2562
Curium	Cm	13.51[1]	1345	3100
Dubnium	Db	—	—	—
Dysprosium	Dy	8.540	1412	2567
Einsteinium	Es	—	860	—
Erbium	Er	9.045	1529	2868
Europium	Eu	5.283	822	1529
Fermium	Fm	—	1527	—
Fluroine	F	1.108[2]	-219.67	-188.12
Francium	Fr	—	27	—
Gadolinium	Gd	7.898	1313	3273
Gallium	Ga	5.904	29.76	2204
Germanium	Ge	5.323	938.25	2833
Gold	Au	19.32	1064.18	2856
Hafnium	Hf	13.31	2233	4603
Hassium	Hs	—	—	—
Helium	He	0.1785[2]	-272.2	-268.934
Holmium	Ho	8.781	1474	2700
Hydrogen	H	0.070[5]	-259.34	-252.87
Indium	In	7.31	156.60	2072
Iodine	I	4.93	113.7	184.4
Iridium	Ir	22.42	2446	4428
Iron	Fe	7.894	1538	2861
Krypton	Kr	3.733[2]	-157.38	-153.22

CHEMICAL ELEMENTS

Element	Symbol	Specific Gravity	Melting Point °C	Boiling Point °C
Lanthanum	La	6.166	918	3464
Lawrencium	Lr	—	1627	—
Lead	Pb	11.35	327.46	1749
Lithium	Li	0.534	180.50	1342
Lutetium	Lu	9.835	1663	3402
Magnesium	Mg	1.738	650	1090
Manganese	Mn	7.21-7.44[6]	1246	2061
Meitnerium	Mt	—	—	—
Mendelvium	Md	—	827	—
Mercury	Hg	13.546	-38.83	356.73
Molybdenum	Mo	10.22	2623	4639
Neodymium	Nd	6.80 & 7.004[6]	1021	3074
Neon	Ne	0.89990 (g/10° C/1 atm)	-248.59	-246.08
Neptunium	Np	20.25	644	—
Nickel	Ni	8.902	1455	2913
Niobium (Columbium)	Nb	8.57	2477	4744
Nitrogen	N	0.808[2]	-210.00	-195.79
Nobelium	No	—	827	—
Osmium	Os	22.57	3033	5012
Oxygen	O	1.14[2]	-218.79	-182.95
Palladium	Pd	12.02	1554.9	2963
Phosphorous (white)	P	1.82	44.15	280.5
Platinum	Pt	21.45	1768.4	38.25
Plutonium	Pu	19.84	640	3228
Polonium	Po	9.32	254	962
Potassium	K	0.862	63.5	759
Praseodymium	Pr	6.772	931	3520
Promethium	Pm	—	1042	3000
Protactinium	Pa	15.37[1]	1572	—
Radium	Ra	5.0?	700	—
Radon	Rn	4.4[5]	-71	-61.7
Rhenium	Re	21.02	3186	5596
Rhodium	Rh	12.41	1964	3695
Rubidium	Rb	1.532	39.30	688
Ruthenium	Ru	12.44	2334	4150
Rutherfordium	Rf	—	—	—
Samarium	Sm	7.536	1074	1794
Scandium	Sc	2.989	1541	2836
Seaborgium	Sg	—	—	—
Selenium (gray)	Se	4.79	220.5	685
Silicon	Si	2.33	1414	3265
Silver	Ag	10.5	961.78	2162
Sodium	Na	0.971	97.80	883
Strontium	Sr	2.54	777	1382
Sulfur	S	2.07[6]	95.3 (rhombic)	444.60

CHEMICAL ELEMENTS

Element	Symbol	Specific Gravity	Melting Point °C	Boiling Point °C
Tantalum	Ta	16.654	3017	5458
Technetium	Tc	11.50[1]	2157	4265
Tellurium	Te	6.24	449.51	988
Terbium	Tb	8.234	1356	3230
Thallium	Tl	11.85	304	1473
Thorium	Th	11.72	1750	4788
Thulium	Tm	9.314	1545	1950
Tin (white)	Sn	7.31	231.93	2602
Titanium	Ti	4.55	1668	3287
Tungsten	W	19.3	3422	5555
Uranium	U	19.05	1135	4131
Vanadium	V	6.11	1910	3407
Xenon	Xe	3.52[2]	-111.79	-108.12
Ytterbium	Yb	6.972	819	1196
Yttrium	Y	4.457	1522	3345
Zinc	Zn	7.133	419.5	907
Zirconium	Zr	6.506[1]	1855	4409

1. Calculated figure.

2. Liquid.

3. Estimated.

4. Amorphous.

5. Depending on whether amorphous, graphite, or diamond.

6. Depending on allotropic form.

NOTES

GERDAU QUICK FACTS

Inquiries and Orders

When inquiring about or ordering Gerdau bars, please have the following information in as much detail as possible. Sufficient information will better enable Gerdau to meet your requirements to your complete satisfaction.

- Steel Grade Specification
- Quality Level
- Diameter and Length
- Size Tolerances (other than standard)
- Packaging Requirements
- Delivery Requirements
- End Use or Application
- End User
- Your Production Process
- Any other information useful in supplying the most suitable product

Available Grades

- Bearing Steels to ASTM A295, A485, A534 and A866 (e.g. 1053, 1070, 4118, 4320, 4820, 5120, 8620)
- Aircraft Quality Steel to AMS 2301 and AMS 2304
- All ASTM A-29 and SAE Carbon, Resulfurized and Rephosphorized Steels (1008 to 1095, 11xx, 12xx, 15xx)
- All ASTM A-29 and SAE Alloy Steels (13xx, 40xx, 41xx, 43xx, 44xx, 46xx, 47xx, 48xx, 50xx, 51xx, 61xx, 81xx, 86xx, 87xx, 92xx, 93xx, 94xx, and EX or PS grades)
- Boron Steels, Micro-alloyed and Calcium Treated Steels
- German (DIN), Japanese (JAS & JIS), and International Standards (ISO)
- Restrictive and special chemistries are welcomed, please inquire

Bar Size and Length Range

Gerdau MACPLUS Bright Cold Finished Bar Size Rangers

Diameter:	⅝" – 5"
Lengths:	15' – 32' (inquire for shorter or longer lengths)

Presicison Hot Rolled Bar Size Ranges

Diameter:	1"– 5"
Lengths:	15' – 40' (inquire for shorter or longer lengths)

Hot Rolled Bar Size Ranges

Diameter:	⅝" – 6 1/16"
Lengths:	15' – 40' (inquire for shorter or longer lengths)

Semi-Finished Bar Size Ranges

Diameter:	7" – 9¼" (178 mm to 235 mm)
Lengths:	12' – 32'

GERDAU QUICK FACTS - *CONTINUED*

Quality

Hot Rolled Bars

Total Decarburization:	0.008” to 0.012” Max. (0.2 mm to 0.3 mm) Max.
Defect Depth:	MFLT* Verification
Size Tolerance:	50% ASTM A-29
Macro ASTM E381:	S1-R1-C2
Micro ASTM E45:	A295, A485, A534 and A866

Precision Hot Rolled Bars

Total Decarburization:	0.008” to 0.012” Max. (0.2 mm to 0.3 mm) Max.
Size Tolerance:	25% AISI and ASTM A-29
Defect Depth:	MFLT* Verification

MACPLUS® Bright Cold Finished Bars

Total Decarburization:	None
Size Tolerance:	See chart page 154
Defect Depth:	None
Finish:	25 Microinches Ra Max.
Quality:	Defect, scale and decarb free surface, offers better merchinability, low residual stress and meets or exceeds SAE specifications for cold drawn bars

Automatic Ultrasonic and Flux Leakage Testing Lines

- Internal core inspection
- Subsurface shear-wave inspection
- Electronic surface inspection

Heat Treatments

- Cold Shear Anneal
- Stress Relieving
- Normalizing
- Lamellar and Structure Annealing
- Spheroidize Annealing
- Quench and Tempering

Heat Size

- 90-100 Ton Heats (85-90 Metric Tons)
- 40-50 Ton Heats (35-45 Metric Tons)

**Magnetic Flux Leakage Test*

Gerdau In-House Value Added Capabilities

- Machine Straightening
- Magnetic Flux Leakage Surface Inspection
- Automatic Ultrasonic Internal Core Inspection
- Automatic Ultrasonic Subsurface Shear-wave Inspection
- MACPLUS® Cold Finished Turning and Polishing
- Circograph Cold Finished Bar Surface Inspection
- Heat Treatments
    - Cold Shear Anneal
    - Stress Relieving
    - Normalizing
    - Lamellar Pearlitic Annealing
    - Spheroidizing
    - Quench and Tempering
- MACPRIME® Automatic Precision Cutting and Gage Inspecting

Straightness Tolerance

Standard Straightness

- ¼" in any 5 ft. or 0.05 inch per foot

Special Straightness

- ⅛" in any 5 ft. or 0.025 inch per foot

Cold Finished Bar Straightness

- For C $\leq$ 0.28%
    - 1/16" in any 10 ft. (Lengths less than 15 ft.)
    - ⅛" in any 10 ft. (Lengths 15 ft. or greater)

- For C $>$ 0.28%
    - ⅛" in any 10 ft. (Lengths less than 15 ft.)
    - 1/16" in any 10 ft. (Lengths 15 ft. or greater)

Fluid Power Straightness

- .065" in any 5 ft. or 0.013 inch per foot

Fluid Power Special Straightness

- .030" in any 5 ft. or 0.006 inch per foot

Length Tolerance

Specified Size (inches)	Tolerance over specified length (inches)		
	10 to under 20 ft.	20 to under 30 ft.	30 to 40 ft.
To 1 incl.	¾	1¼	1¾
Over 1 to 2 incl.	1	1½	2
Over 2 to 5 incl.	1½	1¾	2¼
Over 5 to 10 incl.	2½	2¾	3

Tolerances For Size and Out-Of-Round

Specified Size (inches)	Size Tolerance (inches)		Out-of-Round (Inches)
	Over	Under	
Over 7⁄16 to 5⁄8 incl.	0.007	0.007	0.010
Over 5⁄8 to 7⁄8 incl.	0.008	0.008	0.012
Over 7⁄8 to 1 incl.	0.009	0.009	0.013
Over 1 to 1⅛ incl.	0.010	0.010	0.015
Over 1⅛ to 1¼ incl.	0.011	0.011	0.016
Over 1¼ to 1⅜ incl.	0.012	0.012	0.018
Over 1⅜ to 1½ incl.	0.014	0.014	0.021
Over 1½ to 2 incl.	1⁄64	1⁄64	0.023
Over 2 to 2½ incl.	1⁄32	0	0.023
Over 2½ to 3½ incl.	3⁄64	0	0.035
Over 3½ to 4½ incl.	1⁄16	0	0.046
Over 4½ to 5½ incl.	5⁄64	0	0.058
Over 5½ to 6½ incl.	1⁄8	0	0.070
Over 6½ to 8¼ incl.	5⁄32	0	0.085
Over 8¼ to 9½ incl.	3⁄16	0	0.100

MACPLUS® QUICK FACTS

MACPLUS® Cold Finished Steel Bars Size and Length Range

Rounds:	0.875” to 5” (22 mm to 127 mm)
Lengths:	10 through 32 feet (3m to 9.75m)

MACPLUS® Advantages

— Defect-Free Surface
— Decarb-Free Surface
— Scale-Free Surface
— Improved Machinability
— Tighter Size Tolerances and Concentricity

Dimensional Tolerances (All Minus)

Size, Inches	C to 0.28% Carbon/ Alloy Inches	C 0.28% to 0.55% Carbon/ Alloy Inches	Any Heat Treat and/or C>0.55% Carbon/ Alloy Inches
to 1½ included	.002/.003	.003/.004	.005/.006
>1½ to 2½	.003/.004	.004/.005	.006/.007
>2½ to 4	.004/.005	.005/.006	.007/.008
>4 to 5 included	.005/.006	.006/.007	.008/.009

MACPLUS® Surface Quality

Surface Finish	25 microinches RA max.
Decarburization	None
Defect Depth	None
Surface Appearance	Shiny, clean
Residual Stress, Warp Factor	-0.020” to -0.030”
Typical Customer Yield Improvement	
Carbon and Alloy	6 to 8%
Resulfurized	9 to 11%

Straightness	Deviation from Straightness in 10 ft., in Inches	
Length, Feet	C ≤0.28%	C >0.28% and all Heat Treat
<15	1/16	1/8
15 and Over	1/8	3/16

MACPRIME® QUICK FACTS

MACPRIME® – STEEL BARS CUT TO YOUR SPECIFICATIONS

MACPRIME® Specifications	
TYPICAL GRADES	• MACPRIME® steel bars can be produced from any grade within MACPRIME®'s capability including quench & tempered steels
MACPRIME® SIZES	• Diameters from 5/8" to 6 1/16"
	• Lengths from 3/8" to 60"
MACPRIME® TOLERANCES	• Length tolerances as low as ± 0.005"
	• Gram weight tolerances as low as ± 2 grams (when using MACPLUS®)
	• Perpendicularity tolerances as low as 0.006"
	• TIR tolerances as low as 0.003"

Combine the advantages MACPLUS® Cold Finished Bars with MACPRIME® First Operation Blanks and you get:

- Defect-Free Surface
- Decarb-Free Surface
- Scale-Free Surface
- Low Residual Stress
- Better Machinability
- Diameter, TIR and out-of-round tolerances to meet your specifications 100% of the time
- Length, gram weight and perpendicularity tolerances to meet your specifications 100% of the time
- No shear or saw cut burrs
- No end distortion
- Guaranteed trouble-free product

NOTES

NOTES

NOTES

NOTES

LOCATIONS

Jackson Office
5591 Morrill Road
Jackson, MI 49201
800.876.7833
517.782.0415
517.782.8736 Fax

Jackson Facility
3100 Brooklyn Road
Jackson, MI 49203
517.764.0311

Fort Smith Mill
5225 Planters Road
Fort Smith, AR 72916
479.646.0223

Monroe Mill
3000 E. Front Street
Monroe, MI 48161
734.243.2446

Huntington Facility
25 Commercial Road
Huntington, IN 46750
260.356.9520

GERDAU

gerdau.com/specialsteel