10

Metallic Materials

UNIFIED NUMBERING SYSTEM FOR METALS AND ALLOYS

UNS Series	Metal
Nonferrous metals and alloys	
A00001-A99999	Aluminum and aluminum alloys
C00001-C99999	Copper and copper alloys
E00001-E99999	Rare earth and rare earth-like metals and alloys
L00001-L99999	Low melting metals and alloys
M00001-M99999	Miscellaneous nonferrous metals and alloys
N00001-N99999	Nickel and nickel alloys
P00001-P00999	Gold
P01001-P01999	Iridium
P02001-P02999	Osmium
P03001-P03999	Palladium
P04001-P04999	Platinum
P05001-P05999	Rhodium
P06001-P06999	Ruthenium
P07001-P07999	Silver
R01011-R01999	Boron
R02001-R02999	Hafnium
R03001-R0999	Molybdenum
R04001-R04999	Niobium (Columbium)
R05001-R05999	Tantalum
R06001-R06999	Thorium
R07001-R07999	Tungsten

UNS Series	Metal
R08001-R08999	Vanadium
R10001-R19999	Beryllium
R20001-R29999	Chromium
R30001-R39999	Cobalt
R40001-R49999	Rhenium
R50001-R59999	Titanium
R60001-R69999	Zirconium
Z00001-Z99999	Zinc and zinc alloys
Ferrous metals and alloys	
D00001-D99999	Specified mechanical properties steels
F00001-F99999	Cast irons
G00001-G99999	AISI and SAE carbon and alloys steels (except tool steels)
H00001-H99999	AISI H-steels
J00001-J99999	Cast steels (except tool steels)
K00001-K99999	Miscellaneous steels and ferrous alloys
S00001-S99999	Heat and corrosion resistant (stainless) steels
T00001-T99999	Tool steels
Welding filler metals, classified by weld deposit composition	
W00001-W09999	Carbon steel with no significant alloying elements
W10000-W19999	Manganese-molybdenum low alloy steels
W20000-W29999	Nickel low alloy steels
W30000-W39999	Austenitic stainless steels
W40000-W49999	Ferritic stainless steels
W50000-W59999	Chromium low alloy steels
W60000-W69999	Copper base alloys
W70000-W79999	Surfacing alloys
W80000-W89999	Nickel base alloys

The following tables on composition and mechanical properties of metallic materials were compiled from data given in the indicated API, ASTM, ASME, and UNS standards.

COMMON NAMES OF UNS ALLOYS —Nonferrous

A02420 Al 242.0 A05140 Al 514.0 A91060 Al 1060 A92024 Al 2024 A95083 Al 5083 A96061 Al 6061	A02950 Al 295.0 A05200 Al 520.0 A91100 Al 1100 A93003 Al 3003 A95086 Al 5086 A96063 Al 6063	A03560 Al 356.0 A24430 Al B443.0 A92014 Al 2014 A95052 Al 5052 A95154 Al 5154 A97075 Al 7075
C10200 OF Copper C14200 DPA Copper C26000 Cartridge Brass C44300 Admiralty Brass, As C46500 Naval Brass, As C60800 Aluminum Bronze, 6% C63000 Nickel Aluminum Bronze C68700 Aluminum Brass, As C75200 Nickel Silver C90500 Gun Metal C95800 Cast Ni-Al Bronze	C11000 ETP Copper C22000 Commercial Bronze C27000 Yellow BrassC44400 Admiralty Brass, Sb C51000 Phosphor Bronze A C61300 Aluminum Bronze, 7% C65500 High-Silicon Bronze C70800 90-10 Copper-Nickel C83600 Ounce Metal C92200 M Bronze C96400 Cast 70-30 Cu-Ni	C12200 DHP Copper C23000 Red Brass C28000 Muntz MetalC44500 Admiralty Brass, P C52400 Phosphor Bronze D C61400 Aluminum Bronze D C67500 Manganese Bronze A C71500 70-30 Copper-Nickel C86500 Manganese Bronze C95700 Cast Mn-Ni-Al Bronze
L50045 Common Lead	L51120 Chemical Lead	L55030 50/50 Solder
M11311 Mg AZ31B M13310 Mg HK31A	M11914 Mg AZ91C	M12330 Mg EZ33A
N02200 Nickel 200 N04400 400 Alloy N05502 502 Alloy N06022 C-22 Alloy N06333 RA333 Alloy N06601 601 Alloy N06690 690 Alloy N07001 Waspaloy N07090 90 Alloy N07750 X-750 Alloy N08026 20Mo-6N08330 RA-330 N08700 JS700 N08810 800H Alloy N08904 904L Alloy N09925 925 Alloy N10003 N Alloy N10665 B-2 Alloy	N02201 Nickel 201 N04405 R-405 Alloy N06002 X Alloy N06030 G-30 Alloy N06455 C-4 Alloy N06617 617 Alloy N06975 2550 Alloy N07031 31 Alloy N07716 625 Plus N08020 20Cb-3 N08028 Sanicro 28 N08366 AL-6X N08800 800 Alloy N08811 800HT Alloy N08925 25-6Mo N10001 B Alloy N10004 W Alloy	N02230 Nickel 230 N05500 K-500 Alloy N06007 G Alloy N06110 Allcor N06600 600 Alloy N06625 625 Alloy N06985 G-3 Alloy N07041 Rene 41 N07718 718 Alloy N08024 20Mo-4N08320 20 Mod N08367 AL-6XN N08801 801 Alloy N08825 825 Alloy N09706 706 Alloy N10002 C Alloy N10276 C-276 Alloy

R03600 Molybdenum	R03630 Molybdenum Alloy	R03650 Molybdenum, low C
R04210 Niobium (Columbium)	R05200 Tantalum	R07005Tungsten
R30003 Elgiloy	R30004 Havar R30035 MP35N	R30006 Stellite 6 R30155
R30031 Stellite 31 R30188	R30260 Duratherm 2602	N-155 R30556 HS-556
HS-188 Alloy R30605 L-605	R50250 Titanium, Gr 1 R50700	R50400 Titanium, Gr
Alloy	Titanium, Gr 4 R53400 Titanium,	2 R52250 Titanium, Gr
R50550 Titanium, Gr 3 R52400	Gr 12 R56320 Titanium, Gr 9	11 R54520 Titanium, Gr
Titanium, Gr 7 R58260 Ti6Al-	R60702 Zr 702	6 R56400 Titanium, Gr 5
6Mo2Sn4Zr R58640 Beta-C		R60704 Zr 704
R60705 Zr 705		
Z13000 Zinc Anode Type II	Z32120 Zinc Anode Type I	Z32121 Zinc Anode Type III

COMMON NAMES OF UNS ALLOYS—Ferrous

F10006 Gray Cast Iron	F20000 Malleable Cast	F32800 Ductile Iron 60-
F41000 Ni-Resist Type 1	Iron F41002 Ni-Resist	40-18 F41006 Ni-Resist
F43000 Ductile Ni-Resist D2	Type 2 F43006 Ductile	Type 5 F47003 Duriron
	Ni-Resist D5	
G10200 1020 Carbon Steel	G41300 4130 Steel	G43400 4340 Steel
J91150 CA-15	J91151 CA-15M	J91153 CA-40
J91540 CA-6NM	J91803 CB-30	J92500 CF-3
J92600 CF-8	J92602 CF-20	J92603 HF
J92605 HC	J92615 CC-50	J92701 CF-16F
J92710 CF-8C	J92800 CF-3M	J92900 CF-8M
J93000 CG-8M	J93001 CG-12	J93005 HD
J93370 CD-	J93402 CH-20	J93423 CE-30
4MCu J93503	J94003 HI	J94202 CK-20
HH J94203	J94204 HK-40	J94213 HN
HK-30J94224 HK	N08604 HL	N08002 HT
N08007 CN-7M	N08004 HU	N08705 HP
K01800 A516-55	K02100 A516-60	K02403 A516-65
K02700 A516-70	K02801 A285-C	K03005 A53-B
K03006 A106-B	K11510 0.2Cu Steel	K11522 C-0.5Mo
K11576 HSLA Steel	K11597 1.25Cr-0.5Mo	K21590 2.25Cr-1Mo
K41545 5Cr-0.5Mo	K81340 9Ni Steel	K90941 9Cr-1Mo
K94610 KOVAR		
S13800 PH 13-8 Mo	S15500 15-5 PH	S15700 PH 15-7 Mo
S17400 17-4 PH	S17600 Stainless W	S17700 17-7 PH
S20100 201 SS	S20200 202 SS	S20910 22-13-5
S21400 Tenelon	S21600 216 SS	S21800 Nitronic 60
S21900 21-6-9	S24000 18-3 Mn	S28200 18-18 Plus
S30200 302 SS	S30300 303 SS	S30400 304 SS
S30403 304L SS	S30409 304H SS	S30451 304N SS
S30453 304LN SS	S30500 305 SS	S30800 308 SS

COMMON NAMES OF UNS ALLOYS—Ferrous

S30815 253MA
S31000 310 SS
S31254 254 SMO
S31500 3RE60
S31609 316H SS
S31651 316N SS
S31703 317L SS
S31803 2205 Alloy
S32304 SAF 2304
S32900 329 SS
S34709 347H SS
S35500 AM 355
S40300 403 SS
S41000 410 SS
S41800 Greek Ascoloy
S42400 F6NM
S43100 431 SS
S44002 440A SS
S44200 442 SS
S44625 26-1
S44635 26-4-4
S44735 29-4C
S45500 Custom 455
S50300 7Cr-0.5Mo
S30900 309 SS
S31008 310S SS
S31260 DP-3
S31600 316 SS
S31635 316Ti SS
S31653 316LN SS
S31725 317LM SS
S32100 321 SS
S32404 Uranus 50
S32950 7-Mo Plus
S34800 348 SS
S36200 Almar 362
S40500 405 SS
S41400 414 SS
S42000 420 SS
S42900 429 SS
S43400 434 SS
S44003 440B SS
S44400 18-2
S44626 26-1 Ti
S44660 SC-1
S44800 29-4-2
S50100 5Cr-0.5Mo
S50400 9Cr-1Mo
S30908 309S SS
S31200 44LN
S31400 314 SS
S31603 316L SS
S31640 316Cb SS
S31700 317 SS
S31726 317L4 SS
S32109 321H SS
S32550 Ferralium 255
S34700 347 SS
S35000 AM 350
S38100 18-18-2
S40900 409 SS
S41600 416 SS
S42200 422 SS
S43000 430 SS
S43600 436 SS
S44004 440C SS
S44600 446 SS
S44627 26-1 Cb
S44700 29-4
S45000 Custom 450
S50200 5Cr-0.5Mo
S66286 A286

COMPARABLE ALLOY DESIGNATIONS

UNS	Name	Germany DIN	U.K. BS	France AFNOR	UNS	Name	Germany DIN	U.K. BS	France AFNOR
C22000	Com. Bronze	2.0230	–	–	N08800	800 Alloy	1.4876	NA15	Z5NC35-20
C44300	Adm. Brass, As	2.0470	CZ111	–	N08825	825 Alloy	2.4858	NA16	NFe32C20DU
C61400	Al Bronze D	2.0932	CA106	–	N08904	904L Alloy	1.4539	-	-
C63000	Ni Al Bronze	2.0966	CA105	–	N08925	25-6Mo	1.4529	-	-
C68700	Al Brass, As	2.0460	CZ110	–	N10276	C-276 Alloy	2.4819	-	-
C70600	90-10 Cu-Ni	2.0872	CN102	–	N10665	B-2 Alloy	2.4617	-	-
C71500	70-30 Cu-Ni	2.0882	CN107	UZ30	R50250	Titanium Gr 1	3.7025	-	-
N02200	Nickel 200	2.4066	NA11	–	R50400	Titanium Gr 2	3.7035	-	-
N02201	Nickel 201	2.4068	NA12	–	R50550	Titanium Gr 3	3.7055	-	-
N04400	400 Alloy	2.4360	NA13	NU30	S15700	PH 15-7 Mo	1.4532	-	-
N05500	K-500 Alloy	2.4375	NA18	–	S17700	17-7 PH	14568	-	-
N06002	X Alloy	2.4665	HR204	NC22FeD	S30300	303 SS	1.4305	303S21	Z10CNF 1809
N06022	C-22 Alloy	2.4602	–	–	S30400	304 SS	1.4301	304S18	Z6CN18-9
N06030	G-30 Alloy	2.4603	–	–	S30403	304L SS	1.4306	304S14	Z2CN18-10
N06333	RA333 Alloy	2.4608	–	–	S30409	304H SS	1.4948	-	-
N06455	C-4 Alloy	2.4610	–	–	S30453	304LN SS	1.4311	-	-
N06600	600 Alloy	2.4816	NA14	NC15Fe	S30500	305 SS	1.4303	-	-

UNS	Name	Germany DIN	U.K. BS	France AFNOR	UNS	Name	Germany DIN	U.K. BS	France AFNOR
N06601	601 Alloy	2.4851	–	–	S30800	308 SS	1.4303	–	–
N06625	625 Alloy	2.4856	NA21	NC22DNb	S30900	309 SS	1.4828	–	–
N06985	G-3 Alloy	2.4619	–	–	S30908	309S SS	1.4833	–	Z15CN2413
N07718	718 Alloy	2.4668	–	NC19FeNb	S31000	310 SS	1.4841	310S24	Z12CNS2520
N07750	X-750 Alloy	2.4669	HR505	NC15Fe (Nb)	S31008	310S SS	1.4845	–	–
N08020	20Cb-3	2.4660	–	–	S31200	44LN	1.4460	–	–
N08028	Sanicro 28	1.4563	–	–	S31400	314 SS	1.4841	310S24	Z12CNS2520
S31500	3RE60	1.4417	–	–	S34709	347H SS	1.4550	347S59	–
S31600	316 SS	1.4401	316S16	Z6CND17-11	S34800	348 SS	1.4546	347S17	–
S31603	316L SS	1.4919	316S14	Z2CND17-12	S40500	405 SS	1.4002	405S17	Z6CA13
S31609	316H SS	1.4919	316S59	–	S41000	410 SS	1.4006	–	–
S31651	316N SS	1.4919	–	–	S43000	430 SS	1.4016	430S15	Z8C17
S31653	316LN SS	1.4406	–	–	S43100	431 SS	1.4057	431S29	–
S31700	317 SS	1.4449	–	–	S43400	434 SS	1.4113	434S19	Z8CD1701
S31703	317L SS	1.4438	317S12	Z2CND1915	S44003	440B SS	1.4112	–	–
S31803	2205 Alloy	1.4462	–	–	S44004	440C SS	1.4125	–	–
S32100	321 SS	1.4541	321S12	Z6CNT18-10	S44400	18-2 SS	1.4521	–	–
S32109	321H SS	1.4541	321S59	–	S66286	A286	1.4980	–	–
S34700	347 SS	1.4550	347S17	Z6CNNb18-10					

ASTM	UNS	Name	ASTM	UNS	Name	ASTM	UNS	Name
615	S41800	Greek Ascoloy	P1,T1	K11522	C-0.5Mo	XM-9	S36200	Almar 362
630	S17400	17-4 PH	P5,T5	K41545	5Cr-0.5Mo	XM-10	S21900	21-6-9
631	S17700	17-7 PH	P7,T7	S50300	7Cr-0.5Mo	XM-12	S15500	15-5 PH
632	S15700	PH 15-7 Mo	P9,T9	S50400	9Cr-1Mo	XM-13	S13800	PH 13-8 Mo
634	S35500	AM 355	P11,T11	K11597	1.25Cr-0.5Mo	XM-15	S38100	18-18-2
635	S17600	Stainless W	P22,T22	K21590	2.25Cr-1Mo	XM-16	S45500	Custom 455
660	S66286	A286 alloy				XM-17	S21600	216 SS
						XM-19	S20910	22-13-5
						XM-25	S45000	Custom 450
						XM-27	S44625	26-1
						XM-29	S24000	18-3 Mn
						XM-31	S21400	Tenelon
						XM-33	S44626	26-1 Ti

ALUMINUM ALLOYS—Composition, %

UNS	Common Name	Cr	Cu	Mg	Mn	Si	Zn	Other	UNS
A02420	Al 242.0	0.25 max	3.5–4.5	1.2–1.8	0.35 max	0.7 max	0.35 max	Ni 1.7–2.3	A02420
A02950	Al 295.0	–	4.5–5.0	0.03 max	0.35 max	0.7–1.5	0.35 max	–	A02950
A03560	Al 356.0	–	0.25 max	0.20–0.45	0.35 max	6.5–7.5	0.35 max	–	A03560
A05140	Al 514.0	–	0.15 max	3.5–4.5	0.35 max	0.35 max	0.15 max	–	A05140
A05200	Al 520.0	–	0.25 max	9.5–10.6	0.15 max	0.25 max	0.15 max	–	A05200
A24430	Al B443.0	–	0.15 max	0.05 max	0.35 max	4.5–6.0	0.35 max	–	A24430
A91060	Al 1060	–	0.05 max	0.03 max	0.03 max	0.25 max	0.05 max	Al 99.60 min	A91060
A91100	Al 1100	–	0.05-0.20	–	0.05 max	–	0.10 max	Al 99.00 min	A91100
A92014	Al 2014	0.10 max	3.9–5.0	0.20–0.8	0.40–1.2	0.50–1.2	0.25 max	–	A92014
A92024	Al 2024	0.10 max	3.8–4.9	1.2–1.8	0.30–0.9	0.50 max	0.25 max	–	A92024
A93003	Al 3003	–	0.05-0.20	–	1.0–1.5	0.6 max	0.10 max	–	A93003
A95052	Al 5052	0.15–0.35	0.10 max	2.2–2.8	0.10 max	–	0.10 max	–	A95052
A95083	Al 5083	0.05–0.25	0.10 max	4.0–4.9	0.40–1.0	0.40 max	0.25 max	–	A95083
A95086	Al 5086	0.05–0.25	0.10 max	3.5–4.5	0.20–0.7	0.40 max	0.25 max	–	A95086
A95154	Al 5154	0.15–0.35	0.10 max	3.1–3.9	0.10 max	0.25 max	0.20 max	–	A95154
A96061	Al 6061	0.04–0.35	0.15–0.40	0.8–1.2	0.15 max	0.40–0.8	0.25 max	–	A96061
A96063	Al 6063	0.10 max	0.10 max	0.45–0.9	0.10 max	0.20–0.6	0.10 max	–	A96063
A97075	Al 7075	0.18–0.28	1.2–2.0	2.1–2.9	0.30 max	0.40 max	5.1–6.1	–	A97075
	Al 2090	0.05 max	3.0 max	0.25 max	0.05 max	0.10 max	0.10 max	Li 1.9–2.6	
	Al 8090	0.10 max	1.8–2.5	1.1–1.9	0.10 max	0.20 max	0.25 max	Li 2.2–2.7	

ALUMINUM ALLOYS—Mechanical Properties

UNS	Common Name	ASTM	Form	Temper	YS-ksi	TS-ksi	YS-MPa	TS-MPa	UNS
A02420	Al 242.0	B26	Casting	0	-	23 min	-	159 min	A02420
A02950	Al 295.0	B26	Casting	T6	20 min	32 min	138 min	221 min	A02950
A03560	Al 356.0	B26	Casting	T6	20 min	30 min	138 min	207 min	A03560
A05140	Al 514.0	B26	Casting	F	9.0 min	22 min	62 min	152 min	A05140
A05200	Al 520.0	B26	Casting	T4	22 min	42 min	152 min	290 min	A05200
A24430	Al B443.0	B26	Casting	F	6.0 min	17 min	41 min	117 min	A24430
A91060	Al 1060	B210	Tube	0	2.5 min	8.5–13.5	17 min	59–93	A91060
A91100	Al 1100	B210	Tube	0	3.5 min	11–15.5	24 min	76–107	A91100
A92014	Al 2014	B210	Tube	T6	55 min	65 min	380 min	450 min	A92014
A92024	Al 2024	B210	Tube	T3	42 min	64 min	290 min	440 min	A92024
A93003	Al 3003	B210	Tube	0	5 min	14–19	35 min	95–130	A93003
A95052	Al 5052	B210	Tube	0	10 min	25–35	70 min	170–240	A95052
A95083	Al 5083	B210	Tube	0	16 min	39–51	110 min	270–350	A95083
A95086	Al 5086	B210	Tube	0	14 min	35–46	95 min	240–315	A95086
A95154	Al 5154	B210	Tube	0	11 min	30–41	75 min	205–280	A95154
A96061	Al 6061	B210	Tube	T6	35 min	42 min	240 min	290 min	A96061
A96063	Al 6063	B210	Tube	T6	28 min	33 min	195 min	225 min	A96063
A97075	Al 7075	B210	Tube	T6	66 min	77 min	455 min	530 min	A97075

COPPER ALLOYS—Composition, %

UNS #	Common Name	Cu*	Ai	Fe	Mn	Ni	Si	Sn	Zn	P	Pb	Bi	Other	UNS #
C10200	OF Copper	99.95 min	–	–	–	–	–	–	–	–	–	–	Oxygen 0.0010 max	C10200
C12200	DHP Copper	99.90 min	–	–	–	–	–	–	–	–	–	–		C12200
C14200	Copper	99.40 min	–	–	–	–	–	–	–	–	–	–		C14200
C23000	Red Brass	84.0–86.0	–	0.05 max	–	–	–	–	bal	–	0.05 max			C23000
C51000	Phos. Bronze A	bal	–	0.10 max	–	–	–	4.2–5.8	0.30 max	0.03–0.35	0.05 max	–		C51000
C52400	Phos. Bronze D	bal	–	0.10 max	–	–	–	9.0–11.0	0.20 max	0.03–0.35	0.05 max	–		C52400
C60800	Al Bronze, 5%	bal	5 .0–6.5	0.10 max	–	–	–	–	–	–	0.10 max	–	As 0.2–0.35	C6080
C61300	Al Bronze, 7%	bal	6.0–7.5	2.0–3.0	0.20 max	0.15 max	0.10 max	0.20–0.50	0.10 max	0.015 max	0.01 max	–		C61300
C67500	Mn Bronze A	57.0–60.0	0.25 max	0.8–2.0	0.05–0.50	–	–	0.5–1.5	bal	–	0.20 max	–		C67500
C70600	90–10 Cu-Ni	bal		1.0–1.8	1.0 max	9.0–11.0	–	–	1.0 max	–	0.05 max	–		C70600
C83600	Ounce Metal	84.0–86.0	0.005 max	0.30 max	–	1.0 max	0.005 max	4.0–6.0	4.0–6.0	0.05 max	4.0–6.0	–	S0.08 max, Sb 0.20 max	C83600
C86500	Mn Bronze	55.0–60.0	0.50–1.5	0.40–2.0	0.10–1.5	1.00 max		1.0 max	36.0–42.0	–	0.40 max	–		C86500

UNS #	Common Name	Cu*	Ai	Fe	Mn	Ni	Si	Sn	Zn	P	Pb	Bi	Other	UNS #
C90500	Gun Metal	86.0–89.0	0.005 max	0.20 max	–	1.0 max	0.005 max	9.0–11.0	1.0–3.0	0.05 max	0.30 max	–	S0.05 max, Sb 0.20 max	C90500
C92200	M Bronze	86.0–90.0	0.005 max	0.25 max	–	1.0 max	0.005 max	5.5–6.5	3.0–5.0	0.05 max	1.00–2.00	–	S 0.05 max, Sb 0.25 max	C92200
C95700	Mn-Ni-Al Bronze	71.0 min	7.0–8.5	2.0–4.0	11.0–14.0	1.5–3.0	0.10 max	–	–	–	–	–		C95700
C95800	Ni-Al Bronze	79.0–81.0	8.5–9.5	3.5–4.5	0.8–1.5	4.5–5.0	0.10 max	–	–	–	0.03 max	–		C95800
C96400	Cast 70-30 Cu-Ni	bal	–	0.25–1.5	1.5 max	28.0–32.0	0.50 max	–	–	0.02 max	0.01 max	–	C 0.15 max, Nb 0.5–1.5, S 0.02 max	C96400
C17200	Copper-Beryllium	bal	0.20 max	0.60 max	–	0.20–.060	0.20 max	–	–	–	–	–	Be1.8–2.0, Co 0.20–0.60	C17200
C36000	Free-Cutting Brass	63.0–63.0	–	0.35 max	–	–	–	–	Rem	–	2.5–3.7	–	–	C36000
C89320		87.0–91.0	0.005 max	0.20 max	–	1.0 max	5.0–7.0	1.0 max	0.30 max	0.09 max	4.0–6.0		Sb 0.35 max, S 0.08 max	C89320
C89510	EnviroBrass I	86.0–88.0	0.005 max	0.20 max	–	1.0 max	0.005 max	4.0–6.0	4.0–6.0	0.05 max	0.25 max	0.50–1.5	Sb 0.25 max, Se 0.35–0.75, S 0.08	C89510
C89520	EnviroBrass II	85.0–87.0	0.005 max	0.20 max	–	1.0 max	0.005 max	5.0–6.0	4.0–6.0	0.05 max	0.25 max	1.6–2.2	Sb 0.25 max, Se 0.8–1.1, S 0.08 m	C89520

UNS #	Common Name	Cu*	Ai	Fe	Mn	Ni	Si	Sn	Zn	P	Pb	Bi	Other	UNS #
C89550	EnviroBrass III	58.0–64.0	0.10–6.0	.50 max	–	1.0 max	0.25 max	0.00–1.2	32.0–38.0	0.01 max	0.10 max	0.6–1.2	Sb 0.05 max, Se 0.1–0.10, S 0.05	C89550
C89831		87.0–91.0	0.005 max	0.30 max	–	1.0 max	0.005 max	2.7–3.7	2.0–4.0	0.050 max	0.10 max	2.7–3.7	Sb 0.25 max, S0.08 max,	C89831
C89833		87.0–91.0	0.005 max	0.30 max	–	1.0 max	0.005 max	4.0–6.0	2.0–4.0	0.050 max	0.10 max	1.7–2.7	Sb 0.25 max, S0.08 max,	C89833
C89835		85.0–89.0	0.005 max	0.20 max	–	1.0 max	0.005 max	6.0–7.5	2.0–4.0	0.10 max	0.10 max	1.7–2.7	Sb 0.35 max, S0.08 max,	C89835
C89837		84.0–88.0	0.005 max	0.30 max	–	1.0 max	0.005 max	3.0–4.0	6.0–10.0	0.050 max	0.10 max	0.7–1.2	Sb 0.25 max, S0.08 max,	C89837
C89844		83.0–86.0	0.005 max	0.30 max	–	1.0 max	0.005 max	3.0–5.0	7.0–10.0	0.050 max	0.20 max	2.0–4.0	Sb 0.25 max, S0.08 max,	C89844

(*) Cu value includes Ag.

COPPER ALLOYS—Mechanical Properties

UNS #	Common Name	ASTM	Form	Temper	Size	YS-ksi(*)	TS-ksi	YS-MPa(*)	TS-MPa	Hardness	UNS #
C11000	ETP Copper	B 152/B 152M	Plate, Sheet	–	–	–	30–38	–	205–260	65 HRF max	C11000
C26000	Cartidge Brass	B 135	Tube	–	–	–	–	–	–	80 HRF max	C26000
C46500	Navel Brass	B 171/B171M	Plate, Sheet	M20-025	=<3	–	–	–	–	–	C46500
C51000	Phosphors Bronze A	B 139	Bar	–	–	–	–	–	275–400	–	C51000
C52400	Phosphors Bronze D	B 139	Bar	–	–	–	–	–	415–515	–	C52400
C61300	Aluminum Bronze 7 %	B 171/B171M	Plate, Sheet	M20-025	=<2	37 min	–	255 min	520 min	–	C61300
C61400	Aluminium Bronze D	B 315	Pipe,Tube	M30-061	–	–	–	193 min	447 min	–	C61400
C63000	Nickel Aluminum Bronze	B 171/B171M	Plate, Sheet	M20-025	=<2	36 min	–	250 min	–	–	C63000
C65500	High-Silicon Bronze	B315	Pipe, Tube	030-061	–	–	–	–	–	–	C65500
C67500	Manganese Bronze A	B138	Bar	060	–	–	–	–	–	–	C67500
C83600	Ounce Metal	B 62	Casting	M01	–	–	–	95 min	–	–	C83600
C90500	Gun Metal	B 584	Casting	M01	–	–	–	–	–	–	C90500
C10200	Oxygen FreeCu	B 152/B152M	Plate, Sheet	025	–	–	30–38	–	205–260	–	C10200
C12200	DHP Copper	B 111	Tube	H55	–	30 min	36 min	205 min	250 min	–	C12200
C14200	DPA Copper	B 111	Tube	H55	–	30 min	36 min	205 min	250 min	–	C14200
C17200	Copper-Beryllium	B 196	Bar	TF00	–	125 min(**)	150 min	860 min(**)	1,034 min	32 HRC min	C17200
C60800	Al Bronze 6%	B 111	Tube	061	–	19 min	50 min	130 min	345 min	–	C60800
C61300	Al Bronze 7%	B 315	Pipe, Tube	M30-061	–	28 min	65 min	193 min	447 min	–	C61300
C61400	Al Bronze D	B 171/B171M	Plate, Sheet	M20-025	=<2	30 min	70 min	205 min	485 min	–	C61400
C36000	Free-cutting Brass	B16/B16M	Bar	016	=<1	20 min	48 min	140 min	330 min	–	C36000

UNS #	Common Name	ASTM	Form	Temper	Size	YS-ksi(*)	TS-ksi	YS-MPa(*)	TS-MPa	Hardness	UNS #
C89320		B 505	Casting	M01	-	18 min	35 min	124 min	241 min	-	C89320
C89510	EnviroBrass I	B 584	Casting	M01	-	17 min	27 min	119 min	185 min	66 HB500	C89510
C89520	EnviroBrass II	B 584	Casting	M01	-	18 min	21 min	121 min	176 min	68 HB500	C89520
C89550	EnviroBrass III	-	Casting	M01	-	21 min	35 min	140 min	240 min	60 HB500	C89550
C89831		-	Casting	M01	-	15 typ	34 typ	103 typ	234 typ	55 HB500	C89831
C89833		-	Casting	M01	-	17 typ	37 typ	120 typ	255 typ	60 HB500	C89833
C89835		-	Casting	M01	-	18 typ	35 typ	124 typ	241 typ	65 HB500	C89835
C89837		-	Casting	M01	-	17 typ	37 typ	120 typ	255 typ	60 HB500	C89837
C89844		B 584	Casting	M01	-	13 min	28 min	90 min	193 min	-	C89844

(*) 0.5% Extension Under Load. (**) 0.2% Offset.

CARBON AND LOW ALLOY STEELS—Composition, %

UNS	Common Name	C	Cr	Cu	Mn	Mo	Ni	P	S	Si	UNS
G10200	1020 Carbon Steel	0.17–0.23	–	–	0.30–0.60	–	–	0.040 max	0.050 max	–	G10200
G41300	4130 Steel	0.28–0.33	0.80–1.10	–	0.40–0.60	0.15–0.25	–	0.035 max	0.040 max	0.15–0.35	G41300
G43400	4340 Steel	0.38–0.43	0.70–0.90	–	0.60–0.80	0.20–0.30	1.65–2.00	0.035 max	0.040 max	0.15–0.30	G43400
K02001	A515–55 Steel	0.20 max	–	–	0.90 max	–	–	0.04 max	0.05 max	0.15–0.30	K02001
K02401	A515–60 Steel	0.24 max	–	–	0.90 max	–	–	0.04 max	0.05 max	0.15–0.30	K02401
K02800	A515–65 Steel	0.28 max	–	–	0.90 max	–	–	0.035 max	0.04 max	0.13–0.45	K02800
K03101	A515–70 Steel	0.31 max	–	–	0.90 max	–	–	0.035 max	0.04 max	0.13–0.33	K03101
K01800	A516-55 Steel	0.18 max	–	–	0.55–0.98	–	–	0.035 max	0.04 max	0.13–0.45	K01800
K02100	A516–60 Steel	0.21 max	–	–	0.55–0.98	–	–	0.035 max	0.04 max	0.13–0.45	K02100
K02403	A516–65 Steel	0.24 max	–	–	0.79–1.30	–	–	0.035 max	0.04 max	0.13–0.45	K02403
K02700	A516–70 Steel	0.27 max	–	–	0.79–1.30	–	–	0.035 max	0.04 max	0.13–0.45	K02700
K02801	A285–C Steel	0.28 max	–	–	0.90 max	–	–	0.035 max	0.40 max	–	K02801
K03005	A53–B Steel	0.30 max	–	–	1.20 max	–	–	0.05 max	0.06 max	–	K03005
K03006	A106–B Steel	0.30 max	–	–	0.29–1.06	–	–	0.048 max	0.058 max	0.10 min	K03006
K11510	0.2Cu Steel	0.15 max	–	0.20 min	1.00 max	–	–	0.15 max	0.05 max	–	K11510

UNS	Common Name	C	Cr	Cu	Mn	Mo	Ni	P	S	Si	UNS
K11576	HSLA Steel	0.10–0.20	0.40–0.65	0.15–0.50	0.60–1.00	0.40–0.60	0.70–1.00	0.035 max	0.040 max	0.15–0.35	K11576
K11522	C-0.5Mo Steel	0.10–0.20	–	–	0.30–0.80	0.44-0.65	–	0.045 max	0.045 max	0.10–0.50	K11522
K11597	1.25Cr–0.5Mo Steel	0.15 max	1.00–1.50	–	0.30–0.60	0.44–0.65	–	0.030 max	0.030 max	0.50–1.00	K11597
K21590	2.25Cr-1Mo Steel	0.15 max	2.00–2.50	–	0.30–0.60	0.90–1.10	–	0.030 max	0.030 max	0.50 max	K21590
K41545	5Cr-0.5Mo Steel	0.15 max	4.00–6.00	–	0.30–0.60	0.45–0.65	–	0.030 max	0.030 max	0.50 max	K41545
K81340	9Ni Steel	0.13 max	–	–	0.90 max	–	8.4–9.6	0.045 max	0.045 max	0.13–0.32	K81340
K90941	9Cr-1Mo Steel	0.15 max	8.0–10.0	–	0.30-0.60	0.90–1.10	–	0.030 max	0.030 max	0.50–1.00	K90941
S50300	7Cr-0.5Mo Steel	0.15 max	6.0-8.0	–	1.00 max	0.45–0.65	–	0.040 max	0.040 max	1.00 max	S50300
S50400	9Cr-1Mo Steel	0.15 max	8.0–10.0	–	1.00 max	0.90–1.10	–	0.040 max	0.040 max	1.00 max	S50400
K94610	Kovar	0.04 max	0.20 max	0.20 max	0.50 max	0.20 max	29. nom	–	–	0.20 max	K94610

CARBON AND LOW ALLOYS STEELS—Mechanical Properties

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	UNS
G10200	1020 Carbon Steel	A519 Gr 1020	Tube	ANN	28 typ	48 typ	193 typ	331 typ	G10200
K02001	A515-55 Steel	A515 Gr 55	Plate	–	30 min	55–75	205 min	380–515	K02001
K02401	A515-60 Steel	A515 Gr 60	Plate	–	32 min	60–80	220 min	414–550	K02401
K02800	A515-65 Steel	A515 Gr 65	Plate	–	35 min	65–85	240 min	450–585	K02800
K03101	A515-70 Steel	A515 Gr 70	Plate	–	38 min	70–90	260 min	485–620	K03101
K01800	A516-55 Steel	A516 Gr 55	Plate	–	30 min	55–75	205 min	380–515	K01800
K02100	A516-60 Steel	A516 Gr 60	Plate	–	32 min	60–80	220 min	415–550	K02100
K02403	A516-65 Steel	A516 Gr 65	Plate	–	35 min	65–85	240 min	450–585	K02403
K02700	A516-70 Steel	A516 Gr 70	Plate	–	38 min	70–90	260 min	485–620	K02700
K02801	A285-C Steel	A285 Gr C	Plate	–	30 min	55–75	205 min	380–515	K02801
K03005	A53-B Steel	A53 Gr B	Pipe	–	35 min	60 min	240 min	414 min	K03005
K03006	A106-B Steel	A106 Gr B	Pipe	–	35 min	60 min	240 min	414 min	K03006
K11510	0.2Cu Steel	A242	Plate	–	50 min	70 min	345 min	480 min	K11510
K11576	HSLA Steel	A517 Gr F	Plate	QT	100 min	115-135	690 min	795-930	K11576
K11522	C-0.5Mo Steel	A335 Gr P1	Pipe	ANN, NT	30 min	55 min	207 min	379 min	K11522
K11597	1.25Cr-0.5Mo Steel	A335 Gr P11	Pipe	ANN, NT	30 min	60 min	207 min	414 min	K11597
K21590	2.25Cr-1Mo Steel	A335 Gr P22	Pipe	ANN, NT	30 min	60 min	207 min	414 min	K21590
K41545	5Cr-0.5Mo Steel	A335 Gr P5	Pipe	ANN, NT	30 min	60 min	207 min	414 min	K41545
K81340	9Ni Steel	A333 Gr 8	Pipe	QT, DNT	75 min	100 min	517 min	689 min	K81340
S50300	7Cr-0.5Mo Steel	A335 Gr P7	Pipe	ANN, NT	30 min	60 min	207 min	414 min	S50300
S50400	9Cr-1Mo Steel	A335 Gr P9	Pipe	ANN, NT	30 min	60 min	207 min	414 min	S50400

CAST IRONS—Composition, %

UNS	Common Name	C	Cr	Cu	Mn	Mo	Ni	Si	UNS
F10006	Gray Cast Iron	3.10–3.40	–	–	0.60–0.90	–	–	2.30–1.90	F10006
F20000	Malleable Cast Iron	2.20–2.90	–	–	0.15–1.25	–	–	0.90–1.90	F20000
F32800	Ductile Iron. 60-40-18	–	–	–	–	–	–	–	F32800
F41000	Ni-Resist Type 1	3.00 max	1.5–2.5	5.50–7.50	0.5–1.5	–	13.5–17.5	1.00–2.80	F41000
F41002	Ni-Resist Type 2	3.00 max	1.5–2.5	0.50 max	0.5–1.5	–	18.0–22.0	1.00–2.80	F41002
F41006	Ni-Resist Type 5	2.40 max	0.10 max	0.50 max	0.5–1.5	–	34.0–36.0	1.00–2.00	F41006
F43000	Ductile Ni-Resist Type D2	3.00 max	1.75–2.75	–	0.70–1.25	–	18.0–22.0	1.50–3.00	F43000
F43006	Ductile Ni-Resist Type D5	2.40 max	0.10 max	–	1.00 max	–	34.0–36.0	1.00–2.80	F43006
F47003	Duriron	0.70–1.10	0.50 max	0.50 max	1.50 max	0.50 max	–	14.20–14.75	F47003

CAST IRONS—Mechanical Properties

UNS	Common Name	ASTM	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	Hardness	UNS
F10006	Gray Cast Iron. G3000	A159	As cast	–	30 min	–	210 min	187–241 HB	F10006
F20000	Malleable Cast Iron. M3210	A602	ANN	32 min	50 min	221 min	345 min	156 HB max	F20000
F32800	Ductile Iron. 60-40-18	A395	–	40 min	60 min	276 min	414 min	143–187 HB	F32800
F41000	Ni-Resist Type 1	A436	As cast	–	25 min	–	172 min	131–183 HB	F41000
F41002	Ni-Resist Type 2	A436	As cast	–	25 min	–	172 min	118–174 HB	F41002
F41006	Ni-Resist Type 5	A436	As cast	–	20 min	–	138 min	99–124 HB	F41006
F43000	Ductile Ni-Resist Type D2	A439	As cast	30 min	58 min	207 min	400 min	139–202 HB	F43000
F43006	Ductile Ni-Resist Type D5	A439	As cast	30 min	55 min	207 min	379 min	131–185 HB	F43006

TOOL STEELS—Composition, %

UNS	Common Name	C	Mn	Si	Cr	Ni	Mo	W	V	Co
T11301	M1	0.78–0.88	0.15–0.40	0.20–0.50	3.5–4.0	0.30 max	8.2–9.2	1.4–2.1	1.0–1.25	–
T11330	M30	0.75–0.85	0.15–0.40	0.20–0.45	3.50–4.25	0.30 max	7.75–9.00	1.3–2.3	1.0–1.4	4.5–5.5
T11394	M44	1.10–1.20	0.20–0.40	0.30–0.55	4.0–4.75	0.30 max	6.0–7.0	5.0–5.75	1.85–2.20	11.0–12.2
T12001	T1	0.65–0.80	0.10–0.40	0.20–0.40	3.75–4.50	0.30 max	–	17.25–18.75	0.90–1.30	–
T12006	T6	0.75–0.85	0.20–0.40	0.20–0.40	4.0–4.75	0.30 max	0.40–1.0	18.50–21.0	1.5–2.1	11.0–13.0
T11350	M50	0.78–0.88	0.15–0.45	0.20–0.60	3.75–4.50	0.30 max	3.90–4.75	–	0.80–1.25	–
T20810	H10	0.35–0.45	0.25–0.70	0.80–1.20	3.0–3.75	0.30 max	2.00–3.00	–	0.25–0.75	–
T20826	H26	0.45–0.55	0.15–0.40	0.15–0.40	3.75–4.50	0.30 max	–	17.25–19.00	0.75–1.25	–
T20842	H42	0.55–0.70	0.15–0.40	0.15–0.40	3.75–4.50	0.30 max	4.5–5.5	5.50–6.75	1.75–2.20	–
T30110	A10	1.25–1.50	1.60–2.10	1.00–1.50	–	1.55–2.05	1.25–1.75	–	–	–
T30407	D7	2.15–2.50	0.60 max	0.60 max	11.5–13.5	0.30 max	0.70–1.20	–	3.80–4.40	–
T31507	O7	1.10–1.30	1.0 max	0.60 max	0.35–0.85	0.30 max	0.30 max	1.00–2.00	0.40 max	–
T41907	S7	0.45–0.55	0.20–0.90	0.20–1.00	3.00–3.50	–	1.30–1.80	–	0.20–0.30	–
T61206	L6	0.65–0.75	0.25–0.80	0.50 max	0.60–1.20	1.25–2.00	0.50 max	–	0.20–0.30	–
T51620	P20	0.28–0.40	0.60–1.00	0.20–0.80	1.4–2.0	–	0.30–0.55	–	–	–
T72305	W5	1.05–1.15	0.10–0.40	0.10–0.40	0.40–0.60	0.20 max	0.40 max	0.15 max	0.10 max	–

GENERAL PROPERTIES OF TOOL STEELS

Major Factors[a]				Minor Factors				
AISI Designation	Wear Resistance[b]	Toughness [c]	Hot Hardness	Usual Working Hardness HRC	Depth of Hardness Surface diam.	Finest grain Size at Full Hardness, Shepherd Standard	As-quenched Surface Hardening[d] HRC	Core Hardness (25 mm, or Hardness, 1 in., Round), HRC
M1	7	3	8	63–65	D	9.5	64–66	64–66
M30	7	2	8	63–65	D	9.5	64–66	64–66
M44	8	1	9	66–70	D	9.5	63–65	63–65
T1	7	3	8	63–65	D	9.5	64–66	64–66
T6	8	1	9	63–65	D	9.5	64–66	64–66
M50	6	3	6	61–63	D	8.5	63–65	63–65
H10	3	9	6	39–56	D	8	52–59	52–59
H26	6	4	8	50–58	D	9	51–59	51–59
H42	6	4	7	45–62	D	8.5	54–62	54–62
A10	3	3	3	55–62	D	8	60–63	60–63
D7	9	1	6	58–66	D	7.5	64–68	64–68
07	5	3	3	58–64	M	9	61–64	59–61
S7	3	8	5	47–57	D	8	59–61	59–61
L6	3	6	2	45–62	M	8	58–63	58–63
P20	1(e)	8	2(e)	30–50	M	7.5	52–54	45–50
W5	3–4	3–7	1	58–65	S	9	65–67	38–43

(a) Rating range from 1 (low) to 9 (high). (b) Wear resistance increases with increasing carbon content. (c) Toughness decreases with increasing carbon content and depth of hardening. (d) S: shallow, M: medium, and D: deep. (e) After carburizing.

CAST HEAT RESISTANT STAINLESS STEELS—Composition, %

UNS	ACI	C	Cr	Ni	Mo	Si	Mn	UNS
J92603	HF	0.20–0.40	18.0–23.0	8.0–12.0	0.50 max	2.00 max	2.00 max	J92603
J92605	HC	0.50 max	26.0–30.0	4.00 max	0.50 max	2.00 max	1.00 max	J92605
J93005	HD	0.50 max	26.0–30.0	4.0–7.0	0.50 max	2.00 max	1.50 max	J93005
J93503	HH	0.20–0.50	24.0–28.0	11.0–14.0	0.50 max	2.00 max	2.00 max	J93503
J94003	HI	0.20–0.50	26.0–30.0	14.0–18.0	0.50 max	2.00 max	2.00 max	J94003
J94203	HK-30	0.25–0.35	23.0–27.0	19.0–22.0	–	1.75 max	1.50 max	J94203
J94204	HK-40	0.35–0.45	23.0–27.0	19.0–22.0	–	1.75 max	1.50 max	J94204
J94213	HN	0.20–0.50	19.0–23.0	23.0–27.0	0.50 max	2.00 max	2.00 max	J94213
J94224	HK	0.20–0.60	24.0–28.0	18.0–22.0	0.50 max	2.00 max	2.00 max	J94224
N08604	HL	0.20–0.60	28.0–32.0	18.0–22.0	0.50 max	2.00 max	2.00 max	N08604
N08002	HT	0.35–0.75	15.0–19.0	33.0–37.0	–	2.50 max	2.00 max	N08002
N08004	HU	0.35–0.75	17.0–21.0	37.0–41.0	0.50 max	2.50 max	2.00 max	N08004
N08705	HP	0.35–0.75	24.0–28.0	35.0–37.0	0.50 max	2.50 max	2.00 max	N08705
N08001	HW	0.35–0.75	10.0–14.0	58.0–62.0	–	2.50 max	2.00 max	N08001
N06006	HX	0.35–0.75	15.0–19.0	64.0–68.0	–	2.50 max	2.00 max	N06006

CAST HEAT RESISTANT STAINLESS STEELS—Mechanical Properties

UNS	ACI	ASTM	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	UNS
J92603	HF	A297	As cast	35 min	70 min	240 min	485 min	J92603
J92605	HC	A297	As cast	–	55 min	–	380 min	J92605
J93005	HD	A297	As cast	35 min	75 min	240 min	515 min	J93005
J93503	HH	A297	As cast	35 min	75 min	240 min	515 min	J93503
J94003	HI	A297	As cast	35 min	70 min	240 min	485 min	J94003
J94203	HK-30	A608	As cast	–	26 min*	–	179 min*	J94203
J94204	HK-40	A608	As cast	–	29 min*	–	200 min*	J94204
J94213	HN	A297	As cast	–	63 min	–	435 min	J94213
J94224	HK	A297	As cast	35 min	65 min	240 min	450 min	J94224
N08604	HL	A297	As cast	35 min	65 min	240 min	450 min	N08604
N08002	HT	A297	As cast	–	65 min	–	450 min	N08002
N08004	HU	A297	As cast	–	65 min	–	450 min	N08004
N08705	HP	A297	As cast	34 min	62.5 min	235 min	430 min	N08705
N08001	HW	A297	As cast	36 min	68 min	250 min	470 min	N08001
N06006	HX	A297	As cast	36 min	65 min	250 min	450 min	N06006

*At 760˚C (1,400˚F)

CAST CORROSION RESISTANT STAINLESS STEELS—Composition, %

UNS	ACI	(AISI)	C	Cr	Ni	Mo	Cu	Si	Mn	UNS
J91150	CA-15	410	0.15 max	11.5–14.0	1.00 max	0.50 max	–	1.50 max	1.00 max	J91150
J91151	CA-15M	–	0.15 max	11.5–14.0	1.00 max	0.15–1.0	–	0.65 max	1.00 max	J91151
J91153	CA-40	420	0.20–0.40	11.5–14.0	1.00 max	0.5 max	–	1.50 max	1.00 max	J91153
J91540	CA-6NM	–	0.06 max	11.5–14.0	3.5–4.5	0.40–1.0	–	1.00 max	1.00 max	J91540
J91803	CB-30	431	0.30 max	18.0–21.0	2.00 max	–	–	1.50 max	1.00 max	J91803
J92500	CF-3	304L	0.03 max	17.0–21.0	8.0–12.0	–	–	2.00 max	1.50 max	J92500
J92600	CF-8	304	0.08 max	18.0–21.0	8.0–11.0	–	–	2.00 max	1.50 max	J92600
J92602	CF-20	302	0.20 max	18.0–21.0	8.0–11.0	–	–	2.00 max	1.50 max	J92602
J92615	CC-50	446	0.50 max	26.0–30.0	4.00 max	–	–	1.50 max	1.00 max	J92615
J92701	CF-16F	303	0.16 max	18.0–21.0	9.0–12.0	–	–	2.00 max	1.50 max	J92701
J92710	CF-8C	347	0.08 max	18.0–21.0	9.0–12.0	–	–	2.00 max	1.50 max	J92710
J92800	CF-3M, 3F	316L	0.03 max	17.0–21.0	9.0–13.0	2.0–3.0	–	1.50 max	1.50 max	J92800
J92900	CF-8M	316	0.08 max	18.0–21.0	9.0–12.0	2.0–3.0	–	2.00 max	1.50 max	J92900
J93000	CG-8M	317	0.08 max	18.0–21.0	9.0–13.0	3.0–4.0	–	1.50 max	1.50 max	J93000
J93001	CG-12	–	0.12 max	20.0–23.0	10.0–13.0	–	–	2.00 max	1.50 max	J93001
J93370	CD-4MCu	–	0.04 max	24.5–26.5	4.75–6.00	1.75–2.25	2.75–3.25	1.00 max	1.00 max	J93370
J93402	CH-20	309	0.20 max	22.0–26.0	12.0–15.0	–	–	2.00 max	1.50 max	J93402
J93423	CE-30	312	0.30 max	26.0–30.0	8.0–11.0	–	–	2.00 max	1.50 max	J93423
J94202	CK-20	310	0.20 max	23.0–27.0	19.0–22.0	–	–	2.00 max	2.00 max	J94202
N08007	CN-7M	–	0.07 max	19.0–22.0	27.5–30.5	2.0–3.0	3.0–4.0	1.50 max	1.50 max	N08007
–	CT-15C	–	0.15 max	19.0–21.0	31.0–34.0	(0.5–1.5 V)	–	1.50 max	1.50 max	–

CAST CORROSION RESISTANT STAINLESS STEELS—Mechanical Properties

UNS	ACI	ASTM	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	UNS
J91150	CA-15	A743	ACT	65 min	90 min	450 min	620 min	J91150
J91151	CA-15M	A743	ACT	65 min	90 min	450 min	620 min	J91151
J91153	CA-40	A743	ACT	70 min	100 min	485 min	690 min	J91153
J91540	CA-6NM	A487	QT	80 min	110–135	550 min	760–930	J91540
J91803	CB-30	A743	ANN	30 min	65 min	205 min	450 min	J91803
J92500	CF-3	A743	STQ	30 min	70 min	205 min	485 min	J92500
J92600	CF-8	A743	STQ	30 min	70 min	205 min	485 min	J92600
J92602	CF-20	A743	STQ	30 min	70 min	205 min	485 min	J92602
J92615	CC-50	A743	ANN	–	55 min	–	380 min	J92615
J92701	CF-16F	A743	STQ	30 min	70 min	205 min	485 min	J92701
J92710	CF-8C	A743	STQ	30 min	70 min	205 min	485 min	J92710
J92800	CF-3F	A743	STQ	30 min	70 min	205 min	485 min	J92800
J92900	CF-8M	A743	STQ	30 min	70 min	205 min	485 min	J92900
J93000	CG-8M	A743	STQ	35 min	75 min	240 min	520 min	J93000
J93001	CG-12	A743	STQ	28 min	70 min	195 min	485 min	J93001
J93370	CD-4MCu	A743	STQ	70 min	100 min	485 min	690 min	J93370
J93402	CH-20	A743	STQ	30 min	70 min	205 min	485 min	J93402
J93423	CE-30	A743	STQ	40 min	80 min	275 min	550 min	J93423
J94202	CK-20	A743	STQ	28 min	65 min	195 min	450 min	J94202
N08007	CN-7M	A743	STQ	25 min	62 min	170 min	425 min	N08007

AUSTENITIC STAINLESS STEELS—Composition, %

UNS	Common Name	C	Cr	Mn	Mo	N	Ni	P	S	Si	Other	UNS
S30200	302 SS	0.15 max	17.0–19.0	2.00 max	–	–	8.0–10.0	0.045 max	0.030 max	1.00 max	–	S30200
S30300	303 SS	0.15 max	17.0–19.0	2.00 max	–	–	8.0–10.0	0.20 max	0.15–0.35	1.00 max	–	S30300
S30400	304 SS	0.06 max	18.0–20.0	2.00 max	–	–	8.0–10.5	0.045 max	0.030 max	1.00 max	–	S30400
S30403	304L SS	0.03 max	18.0–20.0	2.00 max	–	–	8.0–12.0	0.045 max	0.030 max	1.00 max	–	S30403
S30409	304H SS	0.04–0.10	18.0–20.0	2.00 max	–	–	8.0–11.0	0.040 max	0.030 max	1.00 max	–	S30409
S30451	304N SS	0.06 max	18.0–20.0	2.00 max	–	0.10–0.16	8.0–10.5	0.045 max	0.030 max	1.00 max	–	S30451
S30453	304LN SS	0.030 max	18.0–20.0	2.00 max	–	0.10–0.16	8.0–12.0	0.045 max	0.030 max	1.00 max	–	S30453
S30500	305 SS	0.12 max	17.0–19.0	2.00 max	–	–	10.0–13.0	0.045 max	0.030 max	1.00 max	–	S30500
S30800	308 SS	0.06 max	19.0–21.0	2.00 max	–	–	10.0–12.0	0.045 max	0.030 max	1.00 max	–	S30800
S30815	253MA	0.10 max	20.0–22.0	0.80 max	–	0.14–0.20	10.0–12.0	0.040 max	0.030 max	1.40–2.00	Ce 0.03–0.08	S30815
S30900	309 SS	0.20 max	22.0–24.0	2.00 max	–	–	12.0–15.0	0.045 max	0.030 max	1.00 max	–	S30900
S30908	309S SS	0.06 max	22.0–24.0	2.00 max	–	–	12.0–15.0	0.045 max	0.030 max	1.00 max	–	S30908
S31000	310 SS	0.25 max	24.0–26.0	2.00 max	–	–	19.0–22.0	0.045 max	0.030 max	1.50 max	–	S31000
S31008	310S SS	0.08 max	24.0–26.0	2.00 max	–	–	19.0–22.0	0.045 max	0.030 max	1.50 max	–	S31008
S31254	254 SMO	0.020 max	19.5–20.5	1.00 max	6.0–6.5	0.18–0.22	17.5–18.5	0.030 max	0.010 max	0.80 max	Cu 0.50–1.00	S31254

UNS	Common Name	C	Cr	Mn	Mo	N	Ni	P	S	Si	Other	UNS
S31400	314 SS	0.25 max	23.0–26.0	2.00 max	–	–	19.0–22.0	0.045 max	0.030 max	1.50–3.00	–	S31400
S31600	316 SS	0.08 max	16.0–18.0	2.00 max	2.0–3.0	–	10.0–14.0	0.045 max	0.030 max	1.00 max	–	S31600
S31603	316LSS	0.03 max	16.0–18.0	2.00 max	2.0–3.0	–	10.0–14.0	0.045 max	0.030 max	1.00 max	–	S31603
S31609	316H SS	0.04–0.10	16.0–18.0	2.00 max	2.0–3.0	–	10.0–14.0	0.040 max	0.030 max	1.00 max	–	S31609
S31635	316Ti SS	0.06 max	16.0–18.0	2.00 max	2.0–3.0	0.10 max	10.0–14.0	0.045 max	0.030 max	1.00 max	Ti 5XC + N-0.70	S31635
S31640	316Cb SS	0.08 max	16.0–18.0	2.00 max	2.0–3.0	0.10 max	10.0–14.0	0.045 max	0.030 max	1.50 max	–	S31640
S31651	316N SS	0.08 max	16.0–18.0	2.00 max	2.0–3.0	0.10–0.16	10.0–14.0	0.045 max	0.030 max	1.00 max	–	S31651
S31653	316LN SS	0.03 max	16.0–18.0	2.00 max	2.0–3.0	0.10–0.16	10.0–14.0	0.045 max	0.030 max	1.00 max	–	S31653
S31700	317 SS	0.08 max	18.0–20.0	2.00 max	3.0–4.0	–	11.0–15.0	0.045 max	0.030 max	1.00 max	–	S31700
S31703	317L SS	0.030 max	18.0–20.0	2.00 max	3.0–4.0	–	11.0–15.0	0.045 max	0.030 max	1.00 max	–	S31703
S31725	317LM SS	0.03 max	18.0–20.0	2.00 max	4.0–5.0	0.10 max	13.0–17.0	0.045 max	0.030 max	0.75 max	Cu 0.75 max	S31725
S31726	317L4 SS	0.03 max	17.0–20.0	2.00 max	4.0–5.0	0.10–0.20	13.5–17.5	0.045 max	0.030 max	0.75 max	Cu 0.75 max	S31726
S32100	321 SS	0.08 max	17.0–19.0	2.00 max	–	–	9.0–12.0	0.045 max	0.030 max	1.00 max	Ti 5XC min	S32100
S32109	321H SS	0.04–0.10	17.0–20.0	2.00 max	–	–	9.0–12.0	0.040 max	0.030 max	1.00 max	Ti 4XC-0.60	S32109
S34700	347 SS	0.08 max	17.0–19.0	2.00 max	–	–	9.0–13.0	0.045 max	0.030 max	1.00 max	Cb 10XC min	S34700
S34709	347H SS	0.04–0.10	17.0–20.0	2.00 max	–	–	9.0–13.0	0.040 max	0.030 max	1.00 max	Cb 8XC-1.00	S34709
S34800	348 SS	0.08 max	17.0–19.0	2.00 max	–	–	9.0–13.0	0.045 max	0.030 max	1.00 max	Cb 10XC min	S34800
S38400	384 SS	0.08 max	17.0–19.0	2.00 max	–	–	17.5–18.5	0.045 max	0.030 max	1.50–2.50	–	S38400

AUSTENITIC STAINLESS STEELS—Mechanical Properties

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	UNS
S30200	302 SS	A240	Plate	STQ	30 min	75 min	205 min	515 min	S30200
S30300	303 SS	A320	Bolting	STQ	30 min	75 min	205 min	515 min	S30300
S30400	304 SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S30400
S30403	304L SS	A312	Pipe	STQ	25 min	70 min	170 min	485 min	S30403
S30409	304H SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S30409
S30451	304N SS	A312	Pipe	STQ	35 min	80 min	240 min	550 min	S30451
S30453	304LN SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S30453
S30500	305 SS	A249	Tube	STQ	30 min	75 min	205 min	515 min	S30500
S30800	308 SS	A473	Forging	STQ	30 min	75 min	205 min	515 min	S30800
S30815	253NA	A312	Pipe	STQ	45 min	87 min	310 min	600 min	S30815
S30900	309 SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S30900
S30908	309S SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S30908
S31000	310 SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S31000
S31008	310S SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S31008
S31254	254 SMO	A312	Pipe	STQ	44 min	94 min	300 min	650 min	S31254
S31400	314 SS	A473	Forging	STQ	30 min	75 min	205 min	515 min	S31400
S31600	316 SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S31600

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	UNS
S31603	316L SS	A312	Pipe	STQ	25 min	70 min	170 min	485 min	S31603
S31609	316H SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S31609
S31635	316Ti SS	A240	Plate	STQ	30 min	75 min	205 min	515 min	S31635
S31651	316N SS	A312	Pipe	STQ	35 min	80 min	240 min	550 min	S31651
S31653	316LN SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S31653
S31700	317 SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S31700
S31703	317LM SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S31703
S31725	317LM SS	A312	Tube	STQ	30 min	75 min	205 min	515 min	S31725
S31726	317L4 SS	A312	Pipe	STQ	35 min	80 min	240 min	550 min	S31726
S32100	321 SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S32100
S32109	321H SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S32109
S34700	347 SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S34700
S34709	347H SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S34709
S34800	348 SS	A312	Pipe	STQ	30 min	75 min	205 min	515 min	S34800
S38400	384 SS	A493	Wire	STQ	35 min	80 min	240 min	550 min	S38400

AUSTENITIC STAINLESS STEELS (High Mn)—Composition, %

UNS	Common Name	C	Cr	Mn	Mo	N	Ni	P	S	Si	Other	UNS
S20100	201 SS	0.15 max	16.0–18.0	5.5–7.5	–	0.25 max	3.5–5.5	0.060 max	0.030 max	1.00 max	–	S20100
S20200	202 SS	0.15 max	17.0–19.0	7.5–10.0	–	0.25 max	4.0–6.0	0.060 max	0.030 max	1.00 max	–	S20200
S20910	22-13-5 SS	0.06 max	20.5–23.5	4.0–6.0	1.50–3.0	0.20–0.40	11.5–13.5	0.040 max	0.030 max	1.00 max	Cb 0.10–0.30 V 0.10–0.30	S20910
S21400	Tenelon	0.12 max	17.0–18.5	14.5–16.0	–	0.35 max	0.75 max	0.045 max	0.030 max	0.30–1.00	–	S21400
S21600	216 SS	0.06 max	17.5–22.0	7.5–9.0	2.0–3.0	0.25–0.50	5.0–7.0	0.045 max	0.030 max	1.00 max	–	S21600
S21800	Nitronic 60	0.10 max	16.0–18.0	7.0–9.0	–	0.08–0.18	8.0–9.0	0.040 max	0.030 max	3.5–4.5	–	S21800
S21900	21-6-9 SS	0.08 max	19.0–21.5	8.0–10.0	–	0.15–0.40	5.5–7.5	0.060 max	0.030 max	1.00 max	–	S21900
S24000	18-3 Mn	0.08 max	17.0–19.0	11.5–14.5	–	0.20–0.40	2.50–3.75	0.060 max	0.030 max	1.00 max	–	S24000
S28200	18-8 Plus	0.15 max	17.0–19.0	17.0–19.0	0.50–1.50	0.40–0.60	–	0.045 max	0.030 max	1.00 max	Cu 0.50–1.50	S28200

AUSTENITIC STAINLESS STEELS (High Mn)—Mechanical Properties

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	UNS
S20100	201 SS	A412	Plate	STQ	38 min	95 min	260 min	655 min	S20100
S20200	202 SS	A473	Forging	STQ	45 min	90 min	310 min	620 min	S20200
S20910	22-13-5 SS	A312	Pipe	STQ	55 min	100 min	380 min	690 min	S20910
S21400	Tenelon	A240	Plate	STQ	70 min	125 min	485 min	860 min	S21400
S21600	216 SS	A479	Bar	STQ	50 min	90 min	345 min	620 min	S21600
S21800	Nitronic 60	A479	Bar	STQ	50 min	95 min	345 min	655 min	S21800
S21900	21-6-9 SS	A473	Forging	STQ	50 min	90 min	345 min	620 min	S21900
S24000	18-3 Mn	A312	Pipe	STQ	55 min	100 min	380 min	690 min	S24000
S28200	18-18 Plus	A473	Forging	STQ	60 min	110 min	410 min	760 min	S28200

MARTENSITIC STAINLESS STEELS—Composition, %

UNS	Common Name	C	Cr	Mn	Mo	Ni	P	S	Si	V	W	UNS
S40300	403 SS	0.15 max	11.5–13.0	1.00 max	–	–	0.040 max	0.030 max	0.50 max	–	–	S40300
S41000	410 SS	0.15 max	11.5–13.5	1.00 max	–	–	0.040 max	0.030 max	1.00 max	–	–	S41000
S41400	414 SS	0.15 max	11.5–13.5	1.00 max	–	1.25–2.50	0.040 max	0.030 max	1.00 max	–	–	S41400
S41600	416 SS	0.15 max	12.0–14.0	1.25 max	–	–	0.060 max	0.15 min	1.00 max	–	–	S41600
S41800	Greek Ascoloy	0.15–0.20	12.0–14.0	0.50 max	–	1.80–2.20	0.040 max	0.030 max	0.50 max	–	2.50–3.50	S41800
S42000	420 SS	0.15 min	12.0–14.0	1.00 max	–	–	0.040 max	0.030 max	1.00 max	–	–	S42000
S42200	422 SS	0.20–0.25	11.5–13.5	1.00 max	0.75–1.25	0.50–1.00	0.040 max	0.030 max	0.75 max	0.15–0.03	0.75–1.25	S42200
S42400	F6NM	0.06 max	12.0–14.0	0.50–1.00	0.30–0.70	3.50–4.50	0.03 max	0.03 max	0.30–0.60	–	–	S42400
S43100	431 SS	0.20 max	15.0–17.0	1.00 max	–	1.25–2.50	0.040 max	0.030 max	1.00 max	–	–	S43100
S44002	440A SS	0.60–0.75	16.0–18.0	1.00 max	0.75 max	–	0.040 max	0.030 max	1.00 max	–	–	S44002
S44003	440B SS	0.75–0.95	16.0–18.0	1.00 max	0.75 max	–	0.040 max	0.030 max	1.00 max	–	–	S44003
S44004	440C SS	0.95–1.20	16.0–18.0	1.00 max	0.75 max	–	0.040 max	0.030 max	1.00 max	–	–	S44004
S44020	440F SS	0.95–1.20	16.0–18.0	1.25 max	0.40 max	0.75	–	0.35 max	1.00 max	–	–	S44020

MARTENSITIC STAINLESS STEELS—Mechanical Properties

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	Hardness	UNS
S40300	403 SS	A176	Plate	–	30 min	70 min	205 min	485 min	88 HRB max	S40300
S41000	410 SS	A268	Tube	ANN	30 min	60 min	205 min	415 min	95 HRB max	S41000
S41400	414 SS	A473	Forging	OQT	90 min	115 min	620 min	795 min	321 HB max	S41400
S41600	416 SS	A473	Forging	ANN	40 min	70 min	275 min	485 min	223 HB max	S41600
S41800	Greek Ascoloy	A565	Forging	Q2T	110 min	140 min	760 min	965 min	302–352 HB	S41800
S42000	420 SS	A473	Forging	ANN	–	–	–	–	223 HB max	S42000
S42200	422 SS	A565	Forging	QT	110 min	140 min	760 min	965 min	302–352 HB	S42200
S42400	F6NM	A182	Forging	NT	90 min	110 min	620 min	760 min	235–285 HB	S42400
S43100	431 SS	A473	Forging	OQT	90 min	115 min	620 min	795 min	321 HB max	S43100
S44002	440A SS	A473	Forging	ANN	–	–	–	–	269 HB max	S44002
S44003	440B SS	A473	Forging	ANN	–	–	–	–	269 HB max	S44003
S44004	440C SS	A473	Forging	ANN	–	–	–	–	269 HB max	S44004
S44020	440F SS	A473	Forging	ANN	65 min	110 min	448 min	758 min	97 HRB max	S44020

FERRITIC STAINLESS STEELS—Composition, %

UNS	Common Name	C	Cr	Mn	Mo	N	Ni	P	S	Si	Other
S40500	405 SS	0.08 max	11.5–14.5	1.00 max	–	–	–	0.040 max	0.030 max	1.00 max	Al 0.10–0.30
S40900	409 SS	0.08 max	10.50–11.75	1.00 max	–	–	–	0.045 max	0.030 max	1.00 max	Ti 6XC – 0.75
S42900	429 SS	0.12 max	14.0–16.0	1.00 max	–	–	–	0.040 max	0.030 max	1.00 max	–
S43000	430 SS	0.12 max	16.0–18.0	1.00 max	–	–	–	–	0.030 max	1.00 max	–
S43400	434 SS	0.12 max	6.0–18.0	1.00 max	0.75–1.25	–	0.040 max	–	0.030 max	1.00 max	Cb + Ta 5XC – 0.70
S43600	436 SS	0.12 max	16.0–18.0	1.00 max	0.75–1.25	–	0.040 max	–			–
S44200	442 SS	0.20 max	18.0–23.0	1.00 max	–	–	–	0.040 max	0.030 max	1.00 max	–
S44400	18-2	0.025 max	17.5–19.5	1.00 max	1.75–2.50	0.025 max	1.00 max	0.040 max	0.030 max	1.00 max	Cb + Ti 0.20 + 4 (C + N) – 0.80
S44600	446 SS	0.20 max	23.0–27.0	1.50 max	–	0.25 max	–	0.040 max	0.030 max	1.00 max	–
S44625	26-1	0.01 max	25.0–27.5	0.40 max	0.75–1.50	0.015 max	0.50 max	0.020 max	0.020 max	0.40 max	Ni + Cu 0.50 max. Cu 0.20 max
S44626	26-1 Ti	0.06 max	25.0–27.0	0.75 max	0.75–1.50	0.04 max	0.50 max	0.040 max	0.020 max	0.75 max	Ti 0.20–1.00, 7X (C + N) min
S44627	26-1 Cb	0.010 max	25.0–27.0	0.40 max	0.75–1.50	0.015 max	0.50 max	0.020 max	0.020 max	0.40 max	Cb 0.05–0.20
S44635	26-4-4	0.025 max	24.5–26.0	1.00 max	3.50–4.50	0.035 max	3.50–4.50	0.040 max	0.030 max	0.75 max	Cb + Ti 0.20 + 4 (C + N) – 0.80
S44660	SC-1	0.025 max	25.0–27.0	1.00 max	2.50–3.50	0.035 max	1.50–3.50	0.040 max	0.030 max	1.00 max	Cb + Ti 0.20 + 4 (C + N) – 0.80

UNS	Common Name	C	Cr	Mn	Mo	N	Ni	P	S	Si	Other
S44700	29-4	0.010 max	28.0–30.0	0.30 max	3.5–4.2	0.020 max	0.15 max	0.025 max	0.020 max	0.20 max	C + N 0.025 max
S44735	29-4C	0.030 max	28.0–30.0	1.00 max	3.60–4.20	0.045 max	1.00 max	0.040 max	0.030 max	1.00 max	Cb + Ti 6(C + N) 0.20-1.00
S44800	29-4-2	0.010 max	28.0–30.0	0.30 max	3.5–4.2	0.020 max	2.0–2.5	0.025 max	0.020 max	0.20 max	C + N 0.025 max, Cu 0.15 max

FERRITIC STAINLESS STEELS—Mechanical Properties

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	Hardness	UNS
S40500	405 SS	A268	Tube	ANN	30 min	60 min	205 min	415 min	95 HRB max	S40500
S40900	409 SS	A176	Plate	–	30 min	55 min	205 min	380 min	80 HRB max	S40900
S42900	429 SS	A268	Tube	ANN	35 min	60 min	240 min	415 min	90 HRB max	S42900
S43000	430 SS	A268	Tube	ANN	35 min	60 min	240 min	415 min	90 HRB max	S43000
S43400	434 SS		Plate	ANN	53 min	77 min	365 min	530 min	83 HRB max	S43400
S43600	436 SS		Sheet	ANN	53 min	77 min	365 min	530 min	83 HRB max	S43600
S44200	442 SS	A176	Plate	–	40 min	65 min	275 min	515 min	95 HRB max	S44200
S44400	18-2	A268	Tube	ANN	40 min	60 min	275 min	415 min	95 HRB max	S44400
S44600	446 SS	A268	Tube	ANN	40 min	70 min	275 min	485 min	95 HRB max	S44600
S44626	26-1 Ti	A268	Tube	ANN	45 min	68 min	310 min	470 min	100 HRB max	S44626
S44627	26-1 Cb	A268	Tube	ANN	40 min	65 min	275 min	450 min	90 HRB max	S44627
S44635	26-4.4	A268	Tube	ANN	75 min	90 min	515 min	620 min	27 HRC max	S44635
S44660	SC-1	A268	Tube	ANN	65 min	85 min	450 min	585 min	25 HRC max	S44660
S44700	29-4	A268	Tube	ANN	60 min	80 min	415 min	550 min	100 HRB max	S44700
S44735	29-4C	A268	Tube	ANN	60 min	75 min	415 min	515 min	100 HRB max	S44735
S44800	29-4-2	A268	Tube	ANN	60 min	80 min	415 min	550 min	100 HRB min	S44800

DUPLEX STAINLESS STEELS—Composition, %

UNS	Common Name	C	Cr	Cu	Mn	Mo	N	Ni	P	S	Si	W
S31200	44LN	0.030 max	24.0–26.0	–	2.00 max	1.2–2.0	0.14–0.20	5.5–6.5	0.045 max	0.030 max	1.00 max	
S31260	DP-3	0.030 max	24.0–26.0	0.20–0.80	1.00 max	2.5-3.5	0.10–0.30	5.5–7.5	0.030 max	0.030 max	0.75 max	0.10–0.50
S31500	3RE60	0.030 max	18.0–19.0	–	1.20–2.00	2.5–3.0	–	4.25–5.25	0.030 max	0.030 max	1.40–2.00	
S31803	2205 Alloy	0.030 max	21.0–23.0	–	2.0 max	2.5–3.5	0.08–0.20	4.5–6.5	0.030 max	0.020 max	1.00 max	
S32304	SAF 2304	0.030 max	21.5–24.5	0.05–0.60	2.50 max	0.05–0.60	0.05–0.20	3.0–5.5	0.040 max	0.040 max	1.0 max	
S32404	Uranus 50	0.04 max	20.5–22.5	1.0–2.0	2.0 max	2.0–3.0	0.20 max	5.5–8.5	0.030 max	0.010 max	1.0 max	
S32520	Uranus 52N+	0.03 max	24.0–26.0	0.5–3.0	1.5 max	3–5	0.20–0.35	5.5–8.0	–	–	0.8 max	–
S32550	Ferralium 255	0.04 max	24.0–27.0	1.5–2.5	1.50 max	2.0–4.0	0.10–0.25	4.5–6.5	0.04 max	0.03 max	1.00 max	
S32750	SAF 2507	0.03 max	24–26	0.5	1.2 max	3–5	0.24–0.32	6–8	0.035 max	0.020 max	0.8 max	–
S32760	Zeron 100	–	25	0.7	1.0 max	3–5	0.25	6–8	0.035 max	0.010 max	0.8 max	0.7
S32900	329 SS	0.20 max	23.0–28.0	–	1.00 max	1.0–2.0	–	2.5–5.0	0.040 max	0.030 max	0.75 max	
S32950	7-Mo Plus	0.030 max	26.0–29.0	–	2.00 max	1.0–2.5	0.15–0.35	3.5–5.2	0.035 max	0.010 max	0.60 max	

DUPLEX STAINLESS STEELS—Mechanical Properties

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	Hardness	UNS
S31200	44LN	A790	Pipe	STQ	65 min	100 min	450 min	690 min	280 HB max	S31200
S31260	DP-3	A790	Pipe	STQ	64 min	92 min	440 min	630 min	30.5 HRC max	S31260
S31500	3RE60	A790	Pipe	STQ	64 min	92 min	440 min	630 min	30.5 HRC max	S31500
S31803	2205 Alloy	A790	Pipe	STQ	65 min	90 min	450 min	620 min	30.5 HRC max	S31803
S32304	SAF 2304	A790	Pipe	STQ	58 min	87 min	400 min	600 min	30.5 HRC max	S32304
S32550	Ferralium 255	A790	Pipe	STQ	80 min	110 min	550 min	760 min	31.5 HRC max	S32550
S32750	SAF 2507	A790	Pipe	STQ	80 min	116 min	550 min	800 min	270 HB max	S32750
S32760	Zeron 100	A790	Pipe	STQ	77 min	100 min	530 min	730 min	270 HB max	S32760
S32900	329 SS	A789	Tube	STQ	70 min	90 min	485 min	620 min	28 HRC max	S32900
S32950	7-Mo Plus	A790	Pipe	STQ	70 min	90 min	480 min	620 min	30.5 HRC max	S32950

PRECIPITATION-HARDENABLE STAINLESS STEELS—Composition, %

UNS	Common Name	C	Al	Cr	Cu	Mn	Mo	Ni	Si	P	S	Other
S13800	PH 13-8 Mo	0.05 max	0.90–1.35	12.25–13.25	–	0.20 max	2.00–2.50	7.50–8.50	0.10 max	0.01 max	0.008 max	N 0.01 max
S15500	15-5 PH	0.07 max	–	14.0–15.5	2.50–4.50	1.00 max	–	3.50–5.50	1.0 max	0.040 max	0.030 max	Cb 0.15–0.45
S15700	PH 15-7 Mo	0.09 max	0.75–1.50	14.0–16.0	–	1.00 max	2.00–3.00	6.50–7.75	1.00 max	0.04 max	0.03 max	–
S17400	17-4 PH	0.07 max	–	15.5–17.5	3.00–5.00	1.00 max	–	3.00–5.00	1.00 max	0.040 max	0.030 max	Cb 0.15–0.45
S17600	Stainless W	0.08 max	0.40 max	15.0–17.5	–	1.00 max	–	6.00–7.50	1.00 max	0.040 max	0.030 max	Ti 0.40–1.20
S17700	17-7 PH	0.09 max	0.75–1.50	16.0–18.0	–	1.00 max	–	6.50–7.75	1.00 max	0.040 max	0.040 max	–
S35000	AM 350	0.07–0.11	–	16.0–17.0	–	0.50–1.25	2.50–3.25	4.00–5.00	0.50 max	0.040 max	0.030 max	N 0.07–0.13
S35500	AM 355	0.10–0.15	–	15.0–16.0	–	0.50–1.25	2.50–3.25	4.00–5.00	0.50 max	0.040 max	0.030 max	N 0.07–0.13
S36200	Almar 362	0.05 max	0.10 max	14.0–15.0	–	0.50 max	–	6.00–7.00	0.30 max	0.30 max	0.030 max	Ti 0.55–0.90
S45000	Custom 450	0.05 max	–	14.0–16.0	1.25–1.75	1.00 max	0.50–1.00	5.00–7.00	1.00 max	0.030 max	0.030 max	Cb 8XC min
S45500	Custom 455	0.05 max	–	11.0–12.5	1.50–2.50	0.50 max	0.50 max	7.50–9.50	0.50 max	0.040 max	0.030 max	Cb 0.10–0.50 Ti 0.80–1.40
S66286	A286	0.08 max	0.35 max	13.5–16.0	–	2.00 max	1.00–1.50	24.0–27.0	1.00 max	0.040 max	0.030 max	Ti 1.90–2.35 V 0.10–0.50 B.001–0.01

PRECIPITATION-HARDENABLE STAINLESS STEELS—Mechanical Properties

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	Hardness	UNS
S13800	PH 13-8 Mo	A705	Forging	H1150	90 min	135 min	620 min	931 min	30 HRC min	S13800
S15500	15-5 PH	A705	Forging	H1150	105 min	135 min	725 min	930 min	28 HRC min	S15500
S15700	PH 15-7 Mo	A705	Forging	TH1050	160 min	180 min	1,100 min	1,240 min	375 HB min	S15700
S17400	17-4 PH	A705	Forging	H1150	105 min	135 min	725 min	930 min	28 HRC min	S17400
S17600	Stainless W	A705	Forging	H1050	150 min	170 min	1,030 min	1,170 min	35 HRC min	S17600
S17700	17-7 PH	A705	Forging	TH1050	140 min	170 min	965 min	1,170 min	38 HRC min	S17700
S35500	AM 355	A705	Forging	H1000	155 min	170 min	1,070 min	1,170 min	37 HRC min	S35500
S36200	Almar 362	A705	Forging	IS	145 min	155 min	1,000 min	1,070 min	33 HRC min	S36200
S45000	Custom 450	A705	Forging	H1150	75 min	125 min	515 min	860 min	26 HRC min	S45000
S45500	Custom 455	A705	Forging	H1000	185 min	205 min	1,275 min	1,410 min	40 HRC min	S45500
S66286	A286	A638	Forging	STA	85 min	130 min	585 min	895 min	248 HB min	S66286

NICKEL ALLOYS—Mechanical Properties

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	Hardness	UNS
N02200	Nickel 200	B161	Pipe, Tube	ANN	15 min	55 min	105 min	380 min	–	N02200
N02201	Nickel 201	B161	Pipe, Tube	ANN	12 min	50 min	80 min	345 min	–	N02201
N04400	400 Alloy	B165	Pipe, Tube	ANN	28 min	70 min	195 min	480 min	–	N04400
N04405	R-405 Alloy	B164	Bar	ANN	25 min	70 min	170 min	480 min	–	N04405
N06600	600 Alloy	B167	Pipe, Tube	HR	30 min	80 min	205 min	550 min	–	N06600
N06690	690 Alloy	B167	Pipe, Tube	HR	30 min	85 min	205 min	586 min	–	N06690
N07750	X-750 Alloy	B637	Forging	STA	130 min	185 min	896 min	1,276 min	27–40 HRC	N07750
N08330	RA-330	B535	Pipe	ANN	30 min	70 min	207 min	483 min	–	N08330
N08800	800 Alloy	B407	Pipe, Tube	ANN	25 min	65 min	170 min	450 min	–	N08800
N08810	800H Alloy	B407	Pipe, Tube	ANN	25 min	65 min	170 min	450 min	–	N08810
N10001	B Alloy	B333	Plate	STQ	45 min	100 min	315 min	690 min	–	N10001
N10665	B-2 Alloy	B333	Plate	STQ	51 min	110 min	352 min	758 min	100 HRB max	N10665

NICKEL ALLOYS—Composition, %

UNS	Common Name	Ni	Co	Cr	Cu	Fe	Mo	Al	C	Mn	UNS
N02200	Nickel 200	99.0 min	–	–	0.25 max	0.40 max	–	–	0.15 max	0.35 max	N02200
N02201	Nickel 201	99.0 min	–	–	0.25 max	0.40 max	–	–	0.02 max	0.35 max	N02201
N02230	Nickel 230	99.0 min	–	–	0.10 max	0.10 max	–	–	0.15 max	0.15 max	N02230
N04400	400 Alloy	63.0–70.0	–	–	bal	2.50 max	–	–	0.30 max	2.00 max	N04400
N04405	R-405 Alloy	63.0–70.0	–	–	bal	2.5 max	–	–	0.30 max	2.0 max	N04405
N05500	K-500 Alloy	63.0–70.0	–	–	bal	2.00 max	–	2.30–3.15	0.25 max	1.50 max	N05500
N05502	502 Alloy	63.0–70.0	–	–	bal	2.00 max	–	2.50–3.50	0.10 max	1.50 max	N05502
N06600	600 Alloy	72.0 min	–	14.0–17.0	0.50 max	6.0–10.0	–	–	0.15 max	1.00 max	N06600
N06601	601 Alloy	58.0–63.0	–	21.0–25.0	1.0 max	bal	–	1.0–1.7	0.1 max	1.0 max	N06601
N06690	690 Alloy	58.0 min	–	27.0–31.0	0.50 max	7.0–11.0	–	–	0.05 max	0.50 max	N06690
N07090	90 Alloy	bal	15.0–21.0	18.0–21.0	–	3.0 max	–	0.8–2.0	0.13 max	1.0 max	N07090
N07750	X-750 Alloy	70.0 min	–	14.0–17.0	0.5 max	5.0–9.0	–	0.40–1.0	0.08 max	1.0 max	N07750
N08330	RA-330	34.0–37.0	–	17.0–20.0	1.00 max	bal	–	–	0.08 max	2.00 max	N08330
N08800	800 Alloy	30.0–35.0	–	19.0–23.0	0.75 max	bal	–	0.15–0.60	0.10 max	1.5 max	N08800
N08801	801 Alloy	30.0–34.0	–	19.0–22.0	0.5 max	bal	–	–	0.10 max	1.5 max	N08801
N08810	800 H Alloy	30.0–35.0	–	19.0–23.0	0.75 max	bal	–	0.15–0.60	0.05–0.10	1.5 max	N08810
N08811	800HT Alloy	30.0–35.0	–	19.0–23.0	0.75 max	39.5 min	–	0.15–0.60	0.06–0.10	1.5 max	N08811
N09706	706 Alloy	39.0–44.0	–	14.5–17.5	0.30 max	bal	–	0.40 max	0.06 max	0.35 max	N09706
N10001	B Alloy	bal	2.50 max	1.00 max	–	6.00 max	26.0–33.0	–	0.12 max	1.00 max	N10001
N10665	B-2 Alloy	bal	1.00 max	1.00 max	–	2.00 max	26.0–30.0	–	0.020 max	1.00 max	N10665

NICKEL ALLOYS—Composition, %

UNS	Common Name	Si	P	S	Ti	Other	UNS
N02200	Nickel 200	0.35 max	–	0.010 max	–	–	N02200
N02201	Nickel 201	0.35 max	–	0.010 max	–	–	N02201
N02230	Nickel 230	0.010–0.035	–	0.008 max	0.005 max	Mg 0.04–0.08	N02230
N04400	400 Alloy	0.50 max	–	0.024 max	–	–	N04400
N04405	R-405 Alloy	0.50 max	–	0.025–0.06	–	–	N04405
N05500	K-500 Alloy	0.50 max	–	0.01 max	0.35–0.85	–	N05500
N05502	502 Alloy	0.5 max	–	0.010 max	0.50 max	–	N05502
N06600	600 Alloy	0.50 max	–	0.015 max	–	–	N06600
N06601	601 Alloy	0.50 max	–	0.015 max	–	–	N06601
N06690	690 Alloy	0.50 max	–	0.015 max	–	–	N06690
N07090	90 Alloy	1.5 max	–	–	1.8–3.0	–	N07090
N07750	X-750 Alloy	0.50 max	–	0.01 max	2.25–2.75	–	N07750
N08330	RA-330	0.75–1.50	0.03 max	0.03 max	–	Pb 0.005 max, Sn 0.025 max	N08330
N08800	800 Alloy	1.0 max	–	0.015 max	0.15–0.60	–	N08800
N08801	801 Alloy	1.0 max	–	0.015 max	0.75–1.5	–	N08801
N08810	800H Alloy	1.0 max	–	0.015 max	0.15–0.60	–	N08810
N08811	800HT Alloy	1.0 max	–	0.015 max	0.15–0.60	–	N08811
N09706	706 Alloy	0.35 max	0.020 max	0.015 max	1.5–2.0	B 0.006 max	N09706
N10001	B Alloy	1.00 max	0.040 max	0.030 max	–	V 0.60 max	N10001
N10665	B-2 Alloy	0.10 max	0.04 max	0.03 max	–	–	N10665

See also CrMo NICKEL ALLOYS, page ###.

CrMo NICKEL ALLOYS-Composition, %

UNS	Common Name	Ni	Co	Cr	Cu	Fe	Mo	Al	C	Mn	UNS
N06002	X Alloy	bal	0.5-2.5	20.5-23.0	-	17.0-20.0	8.0-10.0	-	0.05-0.15	1.00 max	N06002
N06007	G Alloy	bal	**2.5 max**	21.0-23.5	1.5-2.5	18.0-21.0	5.5-7.5	-	0.05 max	1.0-2.0	N06007
N06022	C-22 Alloy	bal	2.50 max	20.0-22.5	-	2.0-6.0	12.5-14.5	-	0.015 max	0.50 max	N06022
N06030	G-30 Alloy	bal	**5.0 max**	28.0-31.5	1.0-2.4	13.0-17.0	4.0-6.0	-	0.03 max	1.5 max	N06030
N06059	59 Alloy	bal	-	22.0-24.0	-	1.0 max	16	-	0.010 max		N06059
N06110	**Allcor**	bal	12.0 max	27.0-33.0	-	-	8.0-12.0	1.50 max	0.15 max		N06110
N06333	RA333 Alloy	44.0-47.0	2.50-4.00	24.0-27.0	0.50 max	bal	2.5-4.0		0.08 max	2.00 max	N06333
N06455	C-4 Alloy	bal	2.0 max	14.0-18.0	-	3.0 max	14.0-17.0		0.015 max	1.00 max	N06455
N06617	617 Alloy	**44.5 min**	10.0-15.0	20.0-24.0	0.50 max	3.0 max	8.0-10.0	0.80-1.50	0.05-0.15	1.00 max	N06617
N06625	625 Alloy	bal		20.0-23.0	-	5.0 max	8.0-10.0	0.40 max	0.10 max	0.50 max	N06625
N06686	686 Alloy	bal		19.0-23.0		1.0 max	15.0-17.0		0.Q1 max	0.75 max	N06686
N06690	690 Alloy	bal		27-31	0.5 max	7-11			0.05 max	0.5 max	N06690
N06975	2550 Alloy	47.0-52.0		23.0-26.0	0.70-1.20	bal	5.0-7.0		0.03 max	1.00 max	N06975
N06985	G-3 Alloy	bal	5.0 max	21.0-23.5	1.5-2.5	18.0-21.0	6.0-8.0		0.015 max	1.00 max	N06985

UNS	Common Name	Ni	Co	Cr	Cu	Fe	Mo	Al	C	Mn	UNS
N07001	Waspaloy	bal	12.0-15.0	18.0-21.0	0.50 max	2.00 max	3.5-6.0	1.20-1.60	0.03-0.10	1.00 max	N07001
N07031	Alloy 31	30.0-32.0	-	26.0-28.0	0.60-1.20	bal	1.70-2.30	1.00-1.70	0.015 max	0.20 max	N07031
N07041	**Rene 41**	bal	10.0-12.0	18.0-20.0		5.00 max	9.0-10.5	1.40-1.80	0.12 max	0.10 max	N07041
N07716	625Plus	59.0-63.0	-	19.0-22.0	-	bal	7.0-9.5	**0.35max**	0.03max	0.20 max	N07716
N07718	718Alloy	50.0-65.0	1.00 max	17.0-21.0	0.30 max	bal	2.80-3.30	0.20-0.80	0.08max	0.35 max	N07718
N07725	725Alloy	55.0-69.0	-	19.0-22.5	-	bal	7.0-9.5	0.35max	0.03max	0.35max	N07725
N08020	20Cb-3	32.0-38.0	-	19.0-21.0	3.00-4.00	bal	2.00-3.00	-	0.07max	2.00max	N08020
N08024	20Mo-4	35.0-40.0	-	22.5-25.0	0.50-1.50	bal	3.50-5.00	-	0.03max	1.00max	N08024
N08026	20Mo-6	33.0-37.2		22.0-26.0	2.00-4.00	bal	5.00-6.70		0.030 max	1.00 max	N08026
N08028	**Sanicro 28**	29.5-32.5		26.0-28.0	0.6-1.4	bal	3.0-4.0		0.030 max	2.50 max	N08028
N08320	20 Mod	25.0-27.0		21.0-23.0		bal	4.0-6.0		0.05 max	2.5 max	N08320
N08366	AL-6X	23.5-25.5		20.0-22.0		bal	6.0-7.0		0.035 max	2.00 max	N08366
N08367	AL-6XN	23.5-25.5		20.0-22.0		bal	6.00-7.00		0.030 max	2.00 max	N08367
N08700	JS700	24.0-26.0		19.0-23.0	0.50 max	bal	4.3-6.0		0.04 max	2.00 max	N08700
N08825	825Alloy	38.0-46.0	-	19.5-23.5	1.5-3.0	bal	2.5-3.5	0.2 max	0.05max	1.0max	N08825
N08904	904L Alloy	23.0-28.0	-	19.0-23.0	1.0-2.0	bal	4.0-5.0		0.020 max	2.00max	N08904
N08925	25-8Mo	24.0-26.0	-	19.0-21.0	0.05-1.50	bal	6.0-7.0	-	0.20max	1.00 max	N08925
N09925	925 Alloy	38.0-46.0	-	19.5-23.5	1.50-3.00	**20.0min**	2.50-3.50	0.10-0.50	0.03max	1.00 max	N09925
N10002	CAiiey	bal	**2.5max**	14.5-16.5	-	4.0-7.0	15.0-17.0	-	0.08max	1.00 max	N10002
N10003	N Aiiey	bal	0.20 max	6.0-8.0	0.35 max	5.00 max	15.0-18.0	0.50 max	0.04-0.08	1.00 max	N10003
N10004	W Aiiey	bal	-	4.0-6.0	-	4.0-7.0	23.0-26.0	-	0.12max	1.00 max	N10004
N10276	C-276 Alloy	bal	2.5max	14.5-16.5	-	4.0-7.0	15.0-17.0		0.02max	1.0max	N10276

UNS	Common Name	Si	P	S	B	Ti	Cb	V	W	N	Zr	UNS
N06002	X Alloy	1.00 max	0.040 max	0.030 max	–	–	–	–	0.20–1.0	–	–	N06002
N06007	G Alloy	1.0 max	0.04 max	0.03 max	–	–	–	–	1.0 max	–	–	N06007
N06022	C-22 Alloy	0.08 max	0.02 max	0.02 max	–	–	–	0.35 max	2.5–3.5	–	–	N06022
N06030	G-30 Alloy	0.8 max	0.04 max	0.02 max	–	–	–	–	1.5–4.0	–	–	N06030
N06110	Allcor	–	–	–	–	1.50 max	–	–	4.00 max	–	–	N06110
N06333	RA333 Alloy	0.75–1.50	0.030 max	0.30 max	–	–	–	–	2.50–4.00	–	–	N06333
N06455	C-4 Alloy	0.08 max	0.04 max	0.03 max	–	0.70 max	–	–	–	–	–	N0645
N06617	617 Alloy	1.00 max	–	0.015 max	0.006 max	0.60 max	–	–	–	–	–	N06617
N06625	625 Alloy	0.50 max	0.015 max	0.015 max	–	0.40 max	3.15–4.15	–	–	–	–	N06625
N06975	2550 Alloy	1.00 max	0.03 max	0.03 max	–	0.70–1.50	–	–	–	–	–	N06975
N06985	G-3 Alloy	1.00 max	0.04 max	0.03 max	–	–	0.50 max	–	1.5 max	–	–	N06985
N07001	Waspaloy	0.75 max	0.030 max	0.030 max	0.003–0.01	2.75–3.25	–	–	–	–	0.02–0.12	N07001
N07031	Alloy 31	0.20 max	0.015 max	0.015 max	0.003–0.007	2.10–2.60	–	–	–	–	–	N07031
N07041	Rene 41	0.50 max	–	0.015 max	0.003–0.010	3.00–3.30	–	–	–	–	–	N07041
N07716	625 Plus	0.20 max	0.015 max	0.010 max	–	1.00–1.60	2.75–4.00	–	–	–	–	N07716
N07718	718 Alloy	0.35 max	0.015 max	0.015 max	0.006 max	0.65–1.15	4.75–5.50	–	–	–	–	N07718
N08020	20Cb-3	1.00 max	0.045 max	0.035 max	–	–	–	–	–	–	–	N08020
N08024	20Mo-4	0.50 max	0.035 max	0.035 max	–	–	–	–	–	–	–	N08024
N08026	20Mo-6	0.50 max	0.03 max	0.03 max	–	–	–	–	–	–	–	N08026
N08028	Sanicro 28	1.00 max	0.030 max	0.030 max	–	–	–	–	–	–	–	N08028
N08320	20 Mod	1.0 max	0.04 max	0.03 max	–	4 × C min	–	–	–	–	–	N08320
N08366	AL-6X	1.00 max	0.030 max	0.030 max	–	–	–	–	–	–	–	N08366

UNS	Common Name	Si	P	S	B	Ti	Cb	V	W	N	Zr	UNS
N08367	AL-6XN	1.00 max	0.040 max	0.030 max	–	–	–	–	–	0.18–0.25	–	N08367
N08700	JS700	1.00 max	0.04 max	0.03 max	–	–	–	–	–	–	–	N08700
N08825	825 Alloy	0.5 max	–	0.03 max	–	0.6–1.2	–	–	–	–	–	N08825
N08904	904L Alloy	1.00 max	0.045 max	0.035 max	–	–	–	–	–	–	–	N08904
N08925	25-6Mo	0.50 max	0.045 max	0.030 max	–	–	–	–	–	0.10–0.20	–	N08925
N09925	925 Alloy	0.50 max	–	0.03 max	–	1.90–2.40	–	–	–	–	–	N09925
N10002	C Alloy	1.00 max	0.040 max	0.030 max	–	–	–	0.35 max	3.0–4.5	–	–	N10002
N10003	N Alloy	1.00 max	0.015 max	0.020 max	0.010 max	–	–	0.50 max	0.50 max	–	–	N10003
N10004	W Alloy	1.00 max	0.050 max	0.050 max	–	–	–	0.60 max	–	–	–	N10004
N10276	C-276 Alloy	0.05 max	0.030 max	0.030 max	–	–	–	0.35 max	3.0–4.5	–	–	N10276
N06690	690 Alloy	0.5 max	0.007 max	0.015 max	–	–	–	–	–	–	–	N06690
N07725	725 Alloy	0.20 max	0.315 max	0.010 max	–	–	2.75–4.0	–	–	–	–	N07725
N06686	686 Alloy	0.08 max	0.04 max	0.02 max	–	0.02–0.25	–	–	3.0–4.4	–	–	N06686

*Cb + Ta.

See also NICKEL ALLOYS, page ###.

CrMo NICKEL ALLOYS—Mechanical Properties

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	Hardness	UNS
N06002	X Alloy	B435	Plate	STQ	35 min	95 min	240 min	660 min	–	N06002
N06007	G Alloy	B582	Plate	STQ	35 min	90 min	241 min	621 min	100 HRB max	N06007
N06022	C-22 Alloy	B575	Plate	STQ	45 min	100 min	310 min	690 min	100 HRB max	N06022
N06030	G-30 Alloy	B622	Pipe, Tube	STQ	35 min	85 min	241 min	586 min	–	N06030
N06333	RA333 Alloy	B722	Pipe, Tube	ANN	35 min	80 min	241 min	551 min	75–95 HRB	N06333
N06455	C-4 Alloy	B575	Plate	STQ	40 min	100 min	276 min	690 min	100 HRB max	N06455
N06625	625 Alloy	B444	Pipe, Tube	ANN	60 min	120 min	414 min	827 min	–	N06625
N06686	686 Alloy	B575	Plate	ANN	53 min	105 min	364 min	722 min	–	N06686
N06690	690 Alloy	B564	Plate	STQ	41 min	103 min	283 min	714 min	88 HRB max	N06690
N06975	2550 Alloy	B582	Plate	STQ	32 min	85 min	221 min	586 min	100 HRB max	N06975
N06985	G-3 Alloy	B582	Plate	STQ	35 min	90 min	241 min	621 min	100 HRB max	N06985
N07718	718 Alloy	B637	Forging	STA	150 min	185 min	1,034 min	1,275 min	331 HB min	N07718
N07725	725 Alloy	B575	Plate	ANN	62 min	124 min	427 min	855 min	–	N07725
N08020	20Cb-3	B464	Pipe	ANN	35 min	80 min	241 min	551 min	–	N08020
N08024	20Mo-4	B464	Pipe	ANN	35 min	80 min	241 min	551 min	–	N08024
N08026	20Mo-6	B464	Pipe	STQ	35 min	80 min	241 min	551 min	–	N08026

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	Hardness	UNS
N08028	Sanicro 28	B668	Tube	STQ	31 min	73 min	214 min	500 min	–	N08028
N08320	20 Mod	B622	Pipe, Tube	STQ	28 min	75 min	193 min	517 min	–	N08320
N08366	AL-6X	B690	Pipe	STQ	30 min	75 min	206 min	517 min	–	N08366
N08367	AL-6XN	B690	Pipe	STQ	46 min	104 min	317 min	717 min	–	N08367
N08700	JS700	B599	Plate	STQ	35 min	80 min	240 min	550 min	75–90 HRB	N08700
N08825	825 Alloy	B423	Pipe, Tube	ANN	25 min	75 min	172 min	517 min	–	N08825
N08904	904L Alloy	B677	Pipe, Tube	STQ	31 min	71 min	220 min	490 min	–	N08904
N08925	25-6Mo	B677	Pipe, Tube	STQ	43 min	87 min	300 min	600 min	–	N08925
N10003	N Alloy	B434	Plate	ANN	40 min	100 min	280 min	690 min	–	N10003
N10276	C-276 Alloy	B575	Plate	STQ	41 min	100 min	283 min	690 min	100 HRB max	N10276

COBALT ALLOYS—Composition, %

UNS	Common Name	Co	Ni	Cr	Fe	Mo	W	C	Mn	Si	UNS
R30003	Elgiloy	39.0–41.0	15.0–16.0	19.0–21.0	bal	6.0–8.0	–	0.15 max	1.5–2.5	–	R30003
R30004	Havar	41.0–44.0	12.0–14.0	19.0–21.0	bal	2.0–2.8	2.3–3.3	0.17–0.23	1.35–1.80	–	R30004
R30006	Stellite 6	bal	3.0 max	27.0–31.0	3.0 max	1.5 max	3.5–5.5	0.9–1.4	1.0 max	1.5 max	R30006
R30031	Stellite 31	bal	9.5–11.5	24.5–26.5	2.0 max	–	7.0–8.0	0.45–0.55	1.0 max	1.00 max	R30031
R30035	MP35N	bal	33.0–37.0	19.0–21.0	1.0 max	9.0–10.5	–	0.025 max	0.15 max	0.15 max	R30035
R30155	N-155	18.5–21.0	19.0–21.0	20.0–22.5	bal	2.5–3.5	2.0–3.0	0.08–0.16	1.0–2.0	1.00 max	R30155
R30188	HS-188	bal	20.0–24.0	20.0–24.0	3.0 max	–	13.0–16.0	0.05–0.15	1.25 max	0.20–0.50	R30188
R30260	Duratherm 2602	–	bal	11.7–12.3	9.8–10.4	3.7–4.3	3.6–4.2	0.05 max	0.4–1.1	–	R30260
R30556	HS-556	16.0–21.0	19.0–22.5	21.0–23.0	bal	2.5–4.0	2.0–3.5	0.05–0.15	0.5–2.0	0.20–0.80	R30556
R30605	L-605	bal	9.0–11.0	19.0–21.0	3.0 max	–	14.0–16.0	0.05–0.15	2.0 max	1.00 max	R30605

		Be	Cb	Cu	La	Sn	Ti	P	S	Other	
R30003	Elgiloy	1.00 max	–	–	–	–	–	–	–	–	R30003
R30004	Havar	0.02–0.06	–	–	–	–	–	–	–	–	R30004
R30006	Stellite 6	–	–	–	–	–	–	–	–	–	R30006
R30031	Stellite 31	–	–	–	–	–	–	–	–	–	R30031
R30035	MP35N	–	–	–	–	–	1.00 max	0.015 max	0.010 max	–	R30035
R30155	N-155	–	0.75–1.25	–	–	–	–	0.040 max	0.030 max	–	R30155
R30188	HS-188	–	–	–	0.03–0.15	–	–	–	–	–	R30188
R30260	Duratherm 2602	0.20–0.30	0.10 max	0.30 max	–	0.20–0.60	0.80–1.20	–	–	–	R30260
R30556	HS-556	–	0.30 max	–	0.005–0.10	–	–	0.04 max	0.015 max	Al 0.10–0.50 B 0.02 max N 0.10–0.30 Ta 0.30–1.25 Zr 0.001–0.10	R30556
R30605	L-605	–	–	–	–	–	–	–	–	–	R30605

COBALT ALLOYS—Mechanical Properties

UNS	Common Name	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	Hardness	UNS
R30155	N-155	Forging	STA	50 min	110 min	345 min	760 min	192 HB min	R30155
R30605	L-605	Bar	ANN	45 min	125 min	310 min	860 min	–	R30605
R30003	Elgiloy	Sheet	ANN	70 min	100 min	480 min	690 min	–	R30003
R30016	Stellite 6B	Sheet	AC	92 min	146 min	635 min	1,010 min	40 HRC	R30016
R30035	MP35 N	Bar	AC	235 min	294 min	1,620 min	2,025 min	90 HRB	R30035
R30159	MP159	Bar	AC	265 min	275 min	1,825 min	1,895 min	–	R30159
–	HS150	Sheet	ANN	46 min	134 min	317 min	925 min	–	–
R30188	HS188	Sheet	AC	70 min	139 min	485 min	960 min	98 HRC	R30188
–	MAR-M918	Sheet	AC	130 min	135 min	895 min	930 min	–	–
R31233	Ultimet	Sheet	AC	79 min	148 min	545 min	1021 min	30 HRC	R31233

REFRACTORY ALLOYS—Composition, %

UNS	Common Name	Cb	Mo	Ta	W	Zr	C	Fe	Ni	UNS
R03600	Molybdenum	–	bal	–	–	–	0.01–0.04	0.010 max	0.005 max	R03600
R03630	Molybdenum alloy	–	bal	–	–	0.06–0.12	0.01–0.4	0.010 max	0.005 max	R03630
R03650	Molybdenum, low C	–	bal	–	–	–	0.010 max	0.010 max	0.005 max	R03650 bal
R04210	Columbium	0.005 max	0.2 max	0.05 max	0.01 max	0.01 max	0.01 max	0.005 max	R04210	
R05200	Tantalum	0.05 max	0.01 max	bal	0.03 max	–	0.01 max	0.01 max	0.01 max	R05200
R07005	Tungsten Zr 702	–	–	–	99.95 min	–	–	–	–	R07005
R60702		–	–	–	–	–Hf99.2 min	0.05 max	+Cr 0.2 max	–	R60702
R60704	Zr 704	–	–	–	–	–Hf97.5 min	0.05 max	+Cr 0.20–0.40	–	R60704
R60705	Zr 705	2.0–3.0	–	–	–	–Hf95.5 min	0.05 max	–	–	R60705

UNS	Common Name	H	N	D	Si	Other	UNS
R03600	Molybdenum	–	0.0010 max	0.0030 max	0.010 max	–	R03600
R03630	Molybdenum alloy	–	0.001 max	0.003 max	0.010 max	–	R03630
R03650	Molybdenum, low C	–	0.001 max	0.003 max	0.010 max	–	R03650
R04210	Columbium	0.001 max	0.01 max	0.025 max	0.005 max	Hf0.01 max	R04210
R05200	Tantalum	0.001 max	0.01 max	0.015 max	0.005 max	–	R05200
R07005	Tungsten	–	–	–	–	ea 0.01 max. for 0.05 max	R07005
R60702	Zr 702	0.005 max	0.025 max	–	–	Hf 4.5 max	R60702
R60704	Zr 704	0.005 max	0.025 max	–	–	Hf 4.5 max; Sn 1.00–2.00	R60704
R60705	Zr 705	0.005 max	0.025 max	0.018 max	–	Hf 4.5 max	R60705

REFRACTORY ALLOYS—Mechanical Properties

UNS	Common Name	ASTM	Form	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	UNS
R03600	Molybdenum	B386	Plate	RX	25 min	55 min	170 min	380 min	R03600
R03630	Molybdenum alloy	B386	Plate	SRA	100 min	120 min	690 min	830 min	R03630
R03650	Molybdenum, low C	B386	Plate	SRA	80 min	100 min	550 min	690 min	R03650
R04210	Columbium	B394	Tube	ANN	12 min	18 min	85 min	125 min	R04210
R05200	Tantalum	B365	Rod	–	20 min	25 min	138 min	172 min	R05200
R60702	Zr 702	B523	Tube	ANN	30 min	55 min	207 min	380 min	R60702

TITANIUM ALLOYS—Composition, %

UNS #	ASTM Grade	Al	C	Fe	H	Mo	N	O	Other	UNS #
R50250	Titanium, Gr 1	–	0.10 max	0.20 max	0.015 max	–	0.03 max	0.18 max	–	R50250
R50400	Titanium, Gr 2	–	0.10 max	0.30 max	0.015 max	–	0.03 max	0.25 max	–	R50400
R50550	Titanium, Gr 3	–	0.10 max	0.30 max	0.015 max	–	0.05 max	0.35 max	–	R50550
R50700	Titanium, Gr 4	–	0.10 max	0.50 max	0.015 max	–	0.05 max	0.40 max	–	R50700
R56400	Titanium, Gr 5	5.5–6.75	0.10 max	0.40 max	0.015 max	–	0.05 max	0.20 max	V 3.5–4.5	R55400
R54250	Titanium, Gr 6	4.0–6.0	0.10 max	0.50 max	0.020 max	6	0.05 max	0.20 max	Sn 2.0–3.0	R54250
R52400	Titanium, Gr 7	–	0.10 max	0.30 max	0.015 max	–	0.03 max	0.25 max	Pd 0.12–0.25	R52400
R56320	Titanium, Gr 9	2.5–3.5	0.05 max	0.25 max	0.013 max	–	0.02 max	0.12 max	V 2.0–3.0	R56320
R52250	Titanium, Gr 11	–	0.10 max	0.20 max	0.015 max	–	0.03 max	0.18 max	Pd 0.12–0.25	R52250
R53400	Titanium, Gr 12	–	0.08 max	0.30 max	0.015 max	0.2–0.4	0.03 max	0.25 max	Ni 0.6–0.9	R53400

UNS #	ASTM Grade	Al	C	Fe	H	Mo	N	O	Other	UNS #
R53413	Titanium, Gr 13	–	0.08 max	0.20 max	0.015 max	–	0.03 max	0.10 max	Ni 0.4–0.6, Ru 0.04–0.06	R53413
R53414	Titanium, Gr 14	–	0.08 max	0.30 max	0.015 max	–	0.03 max	0.15 max	Ni 0.4–0.6, Ru 0.04–0.06	R53414
R53415	Titanium, Gr 15	–	0.08 max	0.30 max	0.015 max	–	0.05 max	0.25 max	Ni 0.4–0.6, Ru 0.04–0.06	R53415
R52402	Titanium, Gr 16	–	0.08 max	0.30 max	0.015 max	–	0.03 max	0.25 max	Pd 0.0.04–0.08	R52402
R52252	Titanium, Gr 17	–	0.08 max	0.20 max	0.015 max	–	0.03 max	0.18 max	Pd 0.0.04–0.08	R52252
R56322	Titanium, Gr 18	2.5–3.5	0.08 max	0.25 max	0.015 max	–	0.03 max	0.15 max	V 2.0–3.0, Ru 0.04–0.08	R56322
R58640	Titanium, Gr 19	3.0–4.0	0.05 max	0.30 max	0.02 max	3.5–4.5	0.03 max	0.12 max	V 7.5–8.5, Cr 5.5–6.5, Zr 3.5–4.5	R58640
R58645	Titanium, Gr 20	3.0–4.0	0.05 max	0.30 max	0.02 max	0.5–4.5	0.03 max	0.12 max	V 7.5–8.5, Cr 5.5–6.5, Zr 3.5–4.5, Pd 0.04–0.08	R58645
R58210	Titanium, Gr 21	2.5–3.5	0.05 max	0.40 max	0.015 max	14.0–16.0	0.03 max	0.17 max	Nb 2.2–3.2, Si 0.15–0.25	R58210
R56407	Titanium, Gr 23	5.5–6.5	0.08 max	0.25 max	0.0125 max	–	0.03 max	0.13 max	V 3.5–4.5	R56407
R56405	Titanium, Gr 24	5.5–6.75	0.08 max	0.40 max	0.015 max	–	0.05 max	0.20 max	V 3.5–4.5, Pd 0.04–0.08	R56405

UNS #	ASTM Grade	Al	C	Fe	H	Mo	N	O	Other	UNS #
R56403	Titanium, Gr 25	5.5–6.75	0.08 max	0.40 max	0.0125 max	–	0.05 max	0.20 max	V 3.5–4.5, Pd 0.04–0.08, Ni 0.03–0.8	R56403
R52404	Titanium, Gr 26	–	0.08 max	0.30 max	0.015 max	–	0.03 max	0.25 max	Ru 0.08–0.14	R52404
R52254	Titanium, Gr 27	–	0.08 max	0.20 max	0.015 max	–	0.03 max	0.18 max	Ru 0.08–0.14	R52254
R56323	Titanium, Gr 28	2.5–3.5	0.08 max	0.25 max	0.015 max	–	0.03 max	0.15 max	V 2.0–3.0, Ru 0.08–0.14	R56323
R56404	Titanium, Gr 29	5.5–6.5	0.08 max	0.25 max	0.015 max	–	0.03 max	0.13 max	V 3.5–4.5, Ru 0.08–0.14	R56404
–	Titanium, Gr 30	–	0.08 max	0.30 max	0.015 max	–	0.03 max	0.25 max	Co 0.20–0.80, Pd 0.04–0.08	–
–	Titanium, Gr 31	–	0.08 max	0.30 max	0.015 max	–	0.05 max	0.35 max	Co 0.20– 0.80, Pd 0.04–0.08	–
R55111	Titanium, Gr 32	4.5–5.5	0.08 max	0.25 max	0.015 max	0.6–1.2	0.03 max	0.11 max	V 0.6–1.4, Sn 6.0–1.4, Zr 0.5–1.4, Si 0.06–0.14	R55111
–	Titanium, Gr 33	–	0.08 max	0.30 max	0.015 max	–	0.03 max	0.25 max	Ru 0.02–0.04, Pd 0.01–0 .02, Cr 0.1–0.2 , Ni 0.35–0.55	–
–	Titanium, Gr 34	–	0.08 max	0.30 max	0.015 max	–	0.05 max	0.35 max	Ru 0.02–0.04, Pd 0.01–0.02, Cr 0.1–0.2 , Ni 0.35–0.55	–

TITANIUM ALLOYS—Mechanical Properties

UNS #	ASTM Grade	ASTM	Form	Heat Tr.	YS-ksi	YS-Mpa	UTS-ksi	UTS-Mpa	% E min.	UNS #
R50250	Titanium, Gr. 1	B265	Plate	ANN	25–45	170–310	35 min	240 min	24	R50250
R50400	Titanium, Gr. 2	B265	Plate	ANN	40–65	275–450	50 min	345 min	20	R50400
R50550	Titanium, Gr. 3	B265	Plate	ANN	55–80	380–550	65 min	450 min	18	R50550
R50700	Titanium, Gr. 4	B265	Plate	ANN	70–95	483–655	80 min	550 min	15	R50700
R56400	Titanium, Gr. 5	B265	Plate	ANN	120 min	828 min	130 min	895 min	10	R56400
R54250	Titanium, Gr. 6	B265	Plate	ANN	115 min	793 min	120 min	828 min	10	R54250
R52400	Titanium, Gr. 7	B265	Plate	ANN	40–65	275–450	50 min	345 min	20	R52400
R56320	Titanium, Gr. 9	B265	Plate	ANN	70 min	483 min	90 min	620 min	15	R56320
R52250	Titanium, Gr. 11	B265	Plate	ANN	25–45	170–310	35 min	240 min	24	R52250
R53400	Titanium, Gr. 12	B265	Plate	ANN	50 min	345 min	70 min	483 min	18	R53400
R53413	Titanium, Gr. 13	B265	Plate	ANN	25 min	170 min	40 min	275 min	24	R53413
R53414	Titanium, Gr. 14	B265	Plate	ANN	40 min	275 min	60 min	410 min	20	R53414
R53415	Titanium, Gr. 15	B265	Plate	ANN	55 min	380 min	70 min	483 min	18	R53415
R52402	Titanium, Gr. 16	B265	Plate	ANN	40–65	275–450	50 min	345 min	20	R52402
R52252	Titanium, Gr. 17	B265	Plate	ANN	25–45	170–310	35 min	240 min	24	R52252
R56322	Titanium, Gr. 18	B265	Plate	ANN	70 min	483 min	90 min	620 min	15	R56322

UNS #	ASTM Grade	ASTM	Form	Heat Tr.	YS-ksi	YS-Mpa	UTS-ksi	UTS-Mpa	% E min.	UNS #
R58640	Titanium, Gr. 19	B265	Plate	ANN	110 min	759 min	115 min	793 min	15	R58640
R58645	Titanium, Gr. 20	B265	Plate	ANN	110 min	759 min	115 min	793 min	15	R58645
R58210	Titanium, Gr. 21	B265	Plate	ANN	110 min	759 min	115 min	793 min	15	R58210
R56407	Titanium, Gr. 23	B265	Plate	ANN	110 min	759 min	120 min	828 min	10	R56407
R56405	Titanium, Gr. 24	B265	Plate	ANN	120 min	828 min	130 min	895 min	10	R56405
R56403	Titanium, Gr. 25	B265	Plate	ANN	120 min	828 min	130 min	895 min	10	R56403
R52404	Titanium, Gr. 26	B265	Plate	ANN	40–65	275–450	50 min	345 min	20	R52404
R52254	Titanium, Gr. 27	B265	Plate	ANN	25–45	170–310	35 min	240 min	24	R52254
R56323	Titanium, Gr. 28	B265	Plate	ANN	70 min	483 min	90 min	620 min	15	R56323
R56404	Titanium, Gr. 29	B265	Plate	ANN	110 min	759 min	120 min	828 min	10	R56404
–	Titanium, Gr. 30	B265	Plate	ANN	40–65	275–450	50 min	345 min	20	–
–	Titanium, Gr. 31	B265	Plate	ANN	55–80	380–550	65 min	450 min	18	–
R55111	Titanium, Gr. 32	B265	Plate	ANN	85 min	586 min	100 min	689 min	10	R55111
–	Titanium, Gr. 33	B265	Plate	ANN	40–65	275–450	50 min	345 min	20	–
–	Titanium, Gr. 34	B265	Plate	ANN	55–80	380–550	65 min	450 min	18	–

LEAD ALLOYS—Composition, %

UNS	Common Name	Pb	Ag	As	Bi	Cu	Fe	Sb	Sn	Zn	UNS
L50045	Common Lead	99.94 min	0.005 max	–	0.050 max	0.0015 max	0.002 max	–	–	0.001 max	L50045
L51120	Chemical Lead	99.94 min	0.002–0.02	–	0.005 max	0.04–0.08	0.002 max	–	–	0.001 max	L51120
L55030	50/50 Solder	50 nom	–	0.03 max	0.25 max	0.08 max	0.02 max	0.12 max	50 nom	0.005 max	L55030

MAGNESIUM ALLOYS—Composition, %

UNS	Common Name	Mg	Al	Cu	Fe	Mn	Ni	Zn	Other	UNS
M11311	Mg AZ31B	bal	2.5–3.5	0.05 max	0.005 max	0.20 min	0.005 max	0.6–1.4	Ca 0.04 max	M11311
M11914	Mg AZ91C	bal	8.1–9.3	0.10 max	–	0.13 min	0.01 max	0.40–1.0	tot 0.30 max	M11914
M12330	Mg EZ33A	bal	–	0.10 max	–	–	0.01 max	2.0–3.1	Rare Earths 2.5–4.0	M12330
M13310	Mg HK31A	bal	–	0.10 max	–	–	0.01 max	0.30 max	Th 2.5–4.0	M13310
	Mg AM60A	bal	6.0	0.10 max	–	0.13	–	–	–	
	Mg AS41A	bal	4.3	0.10 max	–	0.35	–	–	Si 1.0	

MAGNESIUM ALLOYS—Mechanical Properties

UNS	Common Name	ASTM	Form	Temper	YS-ksi	TS-ksi	YS-MPa	TS-MPa	UNS
M11311	Mg AZ31B	B91	Forging	F	19 min	34 min	131 min	234 min	M11311
M11914	Mg AZ91C	B80	Casting	F	11 min	23 min	76 min	158 min	M11914
M12330	Mg EZ33A	B80	Casting	T5	14 min	20 min	96 min	138 min	M12330
M13310	Mg HK31A	B80	Casting	T6	13 min	27 min	89 min	186 min	M13310
	Mg AM60A		Casting	F	17 min	30 min	115 min	205 min	
	Mg AS41A		Casting	F	22 min	32 min	150 min	220 min	

PRECIOUS METALS AND ALLOYS—Composition, %

UNS	Common Name	Ag	Cu	Other	UNS
P00020	Refined gold	0.035 max	0.02 max	Au 99.95 min; Pd 0.02 max	P00020
P03980	Refined palladium	–	–	Ir 0.05 max; Pt 0.15 max; Rh 0.10 max; Ru 0.05 max	P03980
P04995	Refined platinum	0.005 max	0.01 max	0.01 Au, Ru; 0.02 Pd; 0.005 Bi, Ca, Te; 0.015l r; 0.03 Rh max	P04995
P07015	Refined silver	99.95 min	0.04 max	Bi 0.001 max	P07015
P07931	Sterling silver	92.10–93.50	6.50–7.90	0.06 max	P07931

ZINC ALLOYS—Composition, %

UNS	Common Name	ASTM	MILSPEC	Al	Cd	Cu	Fe	Pb	Si	UNS
Z13000	Zinc Anode Type II	B418	–	0.005 max	0.003 max	–	0.0014 max	–	–	Z13000
Z32120	Zinc Anode Type I	B418	–	0.10–0.4	0.03–0.10	–	0.005 max	–	–	Z32120
Z32121	Zinc Anode Type III	B418	MIL-A-18001H	0.10–0.50	0.025–0.15	0.005 max	0.005 max	0.006 max	0.125 max	Z32121
Z35636	Zinc Anode-8	B791	–	0.6–8.8	0.006 max	0.8–1.3	0.075 max	0.006 max	–	Z35636
Z35631	Zinc Anode-12	B791	–	10.5–11.5	0.006 max	0.5–1.2	0.075 max	0.006 max	–	Z35631
Z35841	Zinc Anode-27	B791	–	25.0–28.0	0.006 max	2.0–2.5	0.075 max	0.006 max	–	Z35841
Z33521	AG 40A	B86	–	3.5–4.3	0.004 max	0.25 max	0.10 max	0.005 max	–	Z33521
Z35541	AC 43A	B86	–	3.5–4.3	0.004 max	2.5–3.0	0.10 max	0.005 max	–	Z35541

API GRADES OF CASING AND TUBING—Composition, %

Common Name	C	Cr	Cu	Mn	Mo	Ni	P	S	Si	Common Name
H40	–	–	–	–	–	–	0.040 max	0.060 max	–	H40
J55	–	–	–	–	–	–	0.040 max	0.060 max	–	J55
K55	–	–	–	–	–	–	0.040 max	0.060 max	–	K55
N80	–	–	–	–	–	–	0.040 max	0.060 max	–	N80
C75 Type 1	0.50 max	[a]	[a]	1.90 max	0.15–0.40	[a]	0.040 max	0.060 max	0.45 max	C75 Type 1
C75 Type 2	0.43 max	–	–	1.50 max	–	–	0.040 max	0.060 max	0.45 max	C75 Type 2
C75 Type 3	0.38–0.48	0.80–1.10	–	0.75–1.00	0.15–0.25	–	0.040 max	0.040 max	–	C75 Type 3
C75 9Cr	0.15 max	8.0–10.0	0.25 max	0.30–0.60	0.90–1.10	0.5 max	0.020 max	0.010 max	1.0 max	C75 9Cr
C75 13Cr	0.15–0.22	12.0–14.0	0.25 max	0.25–1.00	–	0.5 max	0.020 max	0.010 max	1.0 max	C75 13Cr
L80 Type 1	0.43 max[c]	–	0.35 max	1.90 max	–	0.25 max	0.040 max	0.060 max	0.45 max	L80 Type 1
L80 9Cr	0.15 max	8.0–10.0	0.25 max	0.30–0.60	0.90–1.10	0.5 max	0.020 max	0.010 max	1.0 max	L80 9Cr
L80 13Cr	0.15–0.22	12.0–14.0	0.25 max	0.25–1.00	–	0.5 max	0.020 max	0.010 max	1.0 max	L80 13Cr
C90 Type 1	0.35 max	1.20 max	–	1.00 max	0.75 max	0.99 max	0.020 max	0.010 max	–	C90 Type 1
C90 Type 2	0.50 max	[b]	–	1.90 max	[b]	0.99 max	0.030 max	0.010 max	–	C90 Type 2
C95	0.45 max[c]	–	–	1.90 max	–	–	0.040 max	0.060 max	0.45 max	C95
P105	–	–	–	–	–	–	0.040 max	0.060 max	–	P105

Common Name	C	Cr	Cu	Mn	Mo	Ni	P	S	Si	Common Name
P110	–	–	–	–	–	–	0.040 max	0.060 max	–	P110
Q125 Type 1	0.35 max	1.20 max	–	1.00 max	0.75 max	0.99 max	0.020 max	0.010 max	–	Q125 Type 1
Q125 Type 2	0.35 max	[b]	–	1.00 max	[b]	0.99 max	0.020 max	0.020 max	–	Q125 Type 2
Q125 Type 3	0.50 max	[b]	–	1.90 max	[b]	0.99 max	0.030 max	0.010 max	–	Q125 Type 3
Q125 Type 4	0.50 max	[b]	–	1.90 max	[b]	0.99 max	0.030 max	0.020 max	–	Q125 Type 4

(a) Cr+Ni + Cu shall not exceed 0.50%.

(b) No limit. Elements shown must be reported in product analysis.

(c) Carbon content may be increased to 0.50% max if product is oil quenched.

(d) Carbon content may be increased to 0.55% max if product is oil quenched.

Source: Some material gathered from API Specification 5CT "Specification for Casing and Tubing" (Washington, DC, USA: American Petroleum Institute, 1988).

API GRADES OF CASING AND TUBING—Mechanical Properties

Common Name	Form	Mfr. Proc.	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	Hardness*	Common Name
H40	Casing,Tubing	SMLS, EW	None	40–80	60 min	276–552	414 min	–	H40
J55	Casing,Tubing	SMLS, EW	None, N, NT,QT	55–80	75 min	379–552	517 min	–	J55
K55	Casing	SMLS, EW	None, N, NT,QT	55–80	95 min	379–552	655 min	–	K55
N80	Casing Tubing	SMLS, EW	None, N, NT,QT N, NT,QT	80–110	100 min	552–758	689 min	–	N80
N80		SMLS, EW		80–110	100 min	552–758	689 min	–	N80
C75 Type 1	Casing,Tubing	SMLS, EW	NT (1,150 F min)	75–90	95 min	517–620	655 min	–	C75 Type 1
C75 Type 2	Casing,Tubing	SMLS, EW	QT (1,150 F min)	75–90	95 min	517–620	655 min	–	C75 Type 2
C75 Type 3	Casing,Tubing	SMLS, EW	NT (1,150 F min)	75–90	95 min	517–620	655 min	–	C75 Type 3
C75 9Cr	Casing,Tubing	SMLS	QT (1,100 F min)	75–90	95 min	517–620	655 min	22 HRC max	C75 9Cr
C75 13Cr	Casing,Tubing	SMLS	QT (1,100 F min)	75–90	95 min	517–620	655 min	22 HRC max	C75 13Cr
L80 Type 1	Casing,Tubing	SMLS, EW	QT (1,050 F min)	80–95	95 min	552–655	655 min	22 HRC max	L80 Type 1
L80 9Cr	Casing,Tubing	SMLS	QT (1,100 F min)	80–95	95 min	522–655	655 min	23 HRC max	L80 9Cr
L80 13 Cr	Casing,Tubing	SMLS	QT (1,100 F min)	80–95	95 min	522–655	655 min	23 HRC max	L80 13Cr
C90 Type 1	Casing,Tubing	SMLS	QT (1,150 F min)	90–105	100 min	620–724	690 min	25.4 HRC max	C90 Type 1
C90 Type 2	Casing,Tubing	SMLS	QT (1,150 F min)	90–105	100 min	620–724	690 min	25.4 HRC max	C90 Type 2
C95	Casing,Tubing	SMLS, EW	QT (1,000 F min)	95–110	105 min	655–758	724 min	–	C95

Common Name	Form	Mfr. Proc.	Heat Tr.	YS-ksi	TS-ksi	YS-MPa	TS-MPa	Hardness*	Common Name
P105	Tubing	SMLS	QT,NT	105–135	120 min	724–931	827 min	–	P105
P110	Casing	SMLS	QT,NT	110–140	125 min	758–965	862 min	–	P110
Q125 Type 1	Casing	SMLS, EW	QT	125–150	135 min	860–1,035	930 min	–	Q125 Type 1
Q125 Type 2	Casing	SMLS, EW	QT	125–150	135 min	860–1,035	930 min	–	Q125 Type 2
Q125 Type 3	Casing	SMLS, EW	QT	125–150	135 min	860–1,035	930 min	–	Q125 Type 3
Q125 Type 4	Casing	SMLS, EW	QT	125–150	135 min	860–1,035	930 min	–	Q125 Type 4

See Specification 5CT for allowable hardness variations.

Source: Some material gathered from API Specification 5CT "Specification for Casing and Tubing" (Washington, DC, USA: American Petroleum Institute, 1988).

MAXIMUM ALLOWABLE STRESS IN TENSION FOR ALUMINUM ALLOY TUBES—ksi

Summarized from ASME Pressure Vessel Code, Section VIII, Table UNF-23.1 (1989) (ksi × 6.895 = MPa)

UNS	Common Name	ASME	Temper	SMYS	100 ˚F	150 ˚F	200 ˚F	250 ˚F	300 ˚F	350 ˚F	400 ˚F	UNS
A91060	Al 1060	SB210	0	2.5	1.7	1.7	1.6	1.5	1.3	1.1	0.8	A91060
A93003	Al 3003	SB210	0	5.0	3.4	3.4	3.4	3.0	2.4	1.8	1.4	A93003
A95052	Al 5052	SB210	0	10.	6.2	6.2	6.2	6.2	5.6	4.1	2.3	A95052
A96061	Al 6061	SB210	T6	35.	10.5	10.5	10.5	9.9	8.4	6.3	4.5	A96061
A96063	Al 6063	SB210	T6	28.	8.3	8.3	7.9	7.4	5.5	3.4	2.0	A96063

MAXIMUM ALLOWABLE STRESS IN TENSION FOR COPPER ALLOY TUBES—ksi

Summarized from ASME Pressure Vessel Code, Section VIII, Table UNF-23.2 (1989) (ksi × 6.895 = MPa)

UNS	Common Name	ASME	Temper	SMYS	100 °F	150 °F	200 °F	250 °F	300 °F	350 °F	400 °F	450 °F	500 °F	550 °F	600 °F	650 °F	700 °F	UNS
C10200	OF Copper	SB111	H55	30.	9.0	9.0	9.0	9.0	8.7	8.5	8.2							C10200
C12200	DHP Copper	SB111	H04	40.	11.3	11.3	11.3	11.3	11.0	10.3	4.3							C12200
C23000	Red Brass	SB111	061	12.	8.0	8.0	8.0	8.0	8.0	7.0	5.0	2.0						C23000
C28000	Muntz Metal	SB111	061	20.	12.5	12.5	12.5	12.5	12.5	10.8	5.3							C28000
C44300	Adm. Brass, As	SB111	061	15.	10.0	10.0	10.0	10.0	10.0	9.8	3.5	2.0						C44300
C60800	Al Bronze, 6%	SB111	061	19.	12.5	12.4	12.2	11.9	11.6	10.0	6.0	4.0	2.0					C60800
C68700	Al Brass, As	SB111	061	18.	12.0	11.9	11.8	11.7	11.7	6.5	3.3	1.8						C68700
C70600	90-10 Cu-Ni	SB111	061	15.	10.0	9.7	9.5	9.3	9.0	8.7	8.5	8.2	8.0	7.0	6.0			C70600
C71500	70-30 Cu-Ni	SB111	061	18.	12.0	11.6	11.3	11.0	10.8	10.6	10.3	10.1	9.9	9.8	9.6	9.5	9.4	C71500

MAXIMUM ALLOWABLE STRESS IN TENSION FOR CARBON AND LOW ALLOY STEELS—ksi

Summarized from ASME Pressure Vessel Code, Section VIII, Table UCS-23 (1989) (ksi × 6.895 = MPa)

UNS	Common Name	Form	ASME	SMYS	650 ˚F	700 ˚F	750 ˚F	800 ˚F	850 ˚F	900 ˚F	950 ˚F	1,000 ˚F	1,050 ˚F	1,100 ˚F	1,150 ˚F	1,200 ˚F
K01800	A516-55	Plate	SA516-55	30	13.8	13.3	12.1	10.2	8.4	6.5	4.5	2.5				
K02100	A516-60	Plate	SA516-60	32	15.0	14.1	13.0	10.8	8.7	6.5	4.5	2.5				
K02403	A516-65	Plate	SA516-65	35	16.3	15.5	13.9	11.4	9.0	6.5	4.5	2.5				
K02700	A516-70	Plate	SA516-70	38	17.5	16.6	14.8	12.0	9.3	6.5	4.5	2.5				
K02801	A285-C	Plate	SA285-C	30	13.8	13.3	12.1	10.2	8.4	6.5						
K03005	A53-B	Pipe	SA53-B	35	15.0	14.4	13.0	10.8	8.7	6.5						
K03006	A106-B	Pipe	SA106-B	35	15.0	14.4	13.0	10.8	8.7	6.5	4.5	2.5				
K11522	C-0.5Mo	Pipe	SA335-P1	30	13.8	13.8	13.8	13.5	13.2	12.7	8.2	4.8				
K11597	1.25Cr-0.5Mo	Pipe	SA335-P11	30	15.0	15.0	14.8	14.4	14.0	12.1	9.3	6.3	4.2	2.8	1.9	1.2
K21590	2.25Cr-1Mo	Pipe	SA335-P22	30	15.0	15.0	15.0	15.0	14.4	13.1	11.0	7.8	5.8	4.2	3.0	2.0
K41545	5Cr-0.5Mo	Pipe	SA335-P5	30		13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0
S50400	9Cr-1Mo	Pipe	SA335-P9	30		13.7	13.2	12.8	12.1	11.4	10.6	7.4	5.0	3.3	2.2	1.5

MAXIMUM ALLOWABLE STRESS IN TENSION FOR STAINLESS STEEL PIPE/TUBE—ksi

Summarized from ASME Pressure Vessel Code, Section VIII, Table UHA-23 (1989) (ksi × 6.895 = MPa)

UNS	Common Name	ASME	SMYS	−20/100 °F	200 °F	300 °F	400 °F	500 °F	600 °F	650 °F	700 °F	750 °F	800 °F	850 °F	900 °F	Notes	UNS
S30400	304 SS	SA312	30	18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7		S30400
S30403	304L SS	SA312	25	16.7	16.5	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0				S30403
S30451	304N SS	SA312	35	20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.1	16.9	16.6	16.3	15.9		S30451
S30900	309 SS	SA312	30	18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9		S30900
S31000	310 SS	SA312	30	18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9		S31000
S31254	254 SMO	SA312	44	23.5	23.5	21.4	19.9	18.5	17.9	17.7	17.5	17.3					S31254
S31600	316 SS	SA312	30	18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6		S31600
S31603	316L SS	SA312	25	16.7	14.1	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4			S31603
S31651	316N SS	SA312	35	20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1		S31651
S32100	321 SS	SA312	30	18.7	17.8	16.7	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4		S32100
S34700	347 SS	SA312	30	18.8	17.9	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4		S34700

UNS	Common Name	ASME	SMYS	−20/100 ˚F	200 ˚F	300 ˚F	400 ˚F	500 ˚F	600 ˚F	650 ˚F	700 ˚F	750 ˚F	800 ˚F	850 ˚F	900 ˚F	Notes	UNS
S40500	405 SS	SA268	30	15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	11.7	11.1	10.4	9.7	[a]	S40500
S41000	410 SS	SA268	30	15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	11.7	11.1	10.4	9.7		S41000
S43000	430 SS	SA268	35	15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	11.7	11.1	10.4	9.7	[a]	S43000
S44600	446 SS	SA268	40	17.5	16.6	16.1	15.6	15.0	14.5	14.3							S44600
S31500	3RE60	SA790	64	23.0	22.2	21.3	21.2	21.2	21.2	21.2	21.2	21.2				[a]	S31500
S31803	2205 alloy	SA790	65	22.5	22.5	21.7	20.9	20.4	20.2							[b]	S31803
S32550	Ferralium 255	SA790	80	27.5	27.4	25.7	24.7	24.7								[a]	S32550

Notes:

(a) This material may be expected to develop embrittlement after service at moderately elevated temperatures.
(b) This material may be expected to exhibit embrittlement at room temperature after service above 600 ˚F.

MAXIMUM ALLOWABLE STRESS IN TENSION FOR STAINLESS STEEL PIPE/TUBE—ksi

UNS	Common Name	ASME	950 °F	1,000 °F	1,050 °F	1,100 °F	1,150 °F	1,200 °F	1,250 °F	1,300 °F	1,350 °F	1,400 °F	1,450 °F	1,500 °F	UNS
S30400	304 SS	SA312	14.4	14.1	12.4	9.8	7.7	6.1	4.7	3.7	2.9	2.3	1.8	1.4	S30400
S30451	304N SS	SA312	15.6	15.0	12.4	9.8	7.7	6.1							S30451
S30900	309 SS	SA312	12.4	10.5	8.5	6.5	5.0	3.8	2.9	2.3	1.8	1.3	0.9	0.8	S30900
S31000	310 SS	SA312	12.5	11.0	7.1	5.0	3.6	2.5	1.5	0.8	0.5	0.4	0.3	0.2	S31000
S31600	316 SS	SA312	15.4	11.3	11.2	11.0	9.8	7.4	5.5	4.1	3.1	2.3	1.7	1.3	S31600
S31651	316N SS	SA312	17.8	13.2	12.7	12.2	9.8	7.4							S31651
S32100	321 SS	SA312	16.3	13.8	9.6	6.9	5.0	3.6	2.6	1.7	1.1	0.8	0.5	0.3	S32100
S34700	347 SS	SA312	16.4	14.4	12.1	9.1	6.1	4.4	3.3	2.2	1.5	1.2	0.9	0.8	S34700
S40500	405 SS	SA268	8.4	4.0											S40500
S41000	410 SS	SA268	8.4	6.4	4.4	2.9	1.8	1.0							S41000
S43000	430 SS	SA268	8.5	6.5	4.5	3.2	2.4	1.8							S43000

MAXIMUM ALLOWABLE STRESS IN TENSION FOR ANNEALED NICKEL ALLOY PIPE/TUBE—ksi

Summarized from ASME Pressure Vessel Code, Section VIII, Table UNF 23.3 (1989) (ksi × 6.895 = MPa)

UNS	Common Name	ASME	SMYS	100 °F	500 °F	600 °F	700 °F	800 °F	900 °F	1,000 °F	1,100 °F	1,200 °F	1,300 °F	1,400 °F	1,500 °F	Notes	UNS
N02200	Nickel 200	SB163	15	10.0	10.0	10.0											N02200
N04400	400 Alloy	SB163	28	17.5	14.7	14.7	14.7	14.2	8.0								N04400
N06002	X Alloy	SB619	40	19.8	14.0	13.3	12.7	12.5	12.3	12.1	12.1	9.6	6.5				N06002
N06022	C-22 Alloy	SB619	45	21.2	18.0	17.1	16.3	15.8									N06022
N06030	G-30 Alloy	SB619	35	18.1	13.9	13.4	12.9	12.4									N06030
N06455	C-4 Alloy	SB619	40	21.2	17.8	17.1	16.7	16.2									N06455
N06600	600 Alloy	SB163	35	20.0	20.0	20.0	19.6	19.1	16.0	7.0	3.0	2.0					N06600
N06625	625 Alloy	SB444	60	30.0	27.0	26.4	26.0	26.0	26.0	26.0	26.0	13.2				[a]	N06625
N06985	G-3 Alloy	SB619	35	19.1	13.8	13.1	12.4	11.9									N06985
N08020	20Cb-3	SB464	35	17.0	15.5	15.1	14.7	14.3									N08020

UNS	Common Name	ASME	SMYS	100 ˚F	500 ˚F	600 ˚F	700 ˚F	800 ˚F	900 ˚F	1,000 ˚F	1,100 ˚F	1,200 ˚F	1,300 ˚F	1,400 ˚F	1,500 ˚F	Notes	UNS
N08028	Sanicro 28	SB668	31	18.2	14.5	13.3											N08028
N08800	800 Alloy	SB163	30	18.7	16.7	16.3	15.9	15.5	15.1	14.7	13.0	6.6	2.0	1.1			N08800
N08810	800H Alloy	SB163	25	16.2	12.9	12.2	11.7	11.1	10.7	10.3	10.0	7.4	4.7	3.0	1.9		N08810
N08825	825 Alloy	SB163	35	21.2	18.3	17.8	17.3	17.1	16.8	16.6							N08825
N10276	C-276 Alloy	SB619	41	21.2	17.0	16.0	15.1	14.5	14.1	14.0	12.7	8.3					N10276
N10665	B-2 Alloy	SB619	51	23.4	23.4	23.1	22.6	21.8									N10665

Notes:

(a)Alloy N06625 in the annealed condition is subject to severe loss of impact strength at room temperature after exposure in the range of 1,000 ˚F to 1,400 ˚F

MAXIMUM ALLOWABLE STRESS IN TENSION FOR TITANIUM AND ZIRCONIUM ALLOY TUBES—ksi

Summarized from ASME Pressure Vessel Code, Section VIII, Tables UNF-23.4 and –23.5 (1989) (ksi × 6.895 = MPa)

UNS	Common Name	ASME	SMYS	100 °F	150 °F	200 °F	250 °F	300 °F	350 °F	400 °F	450 °F	500 °F	550 °F	600 °F	700 °F	UNS
R50250	Titanium, Gr 1	SB338	25.	8.8	8.1	7.3	6.5	5.8	5.2	4.8	4.5	4.1	3.6	3.1		R50250
R50400	Titanium, Gr 2	SB338	40.	12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7		R50400
R50550	Titanium, Gr 3	SB338	55.	16.3	15.6	14.3	13.0	11.7	10.4	9.3	8.3	7.5	6.7	6.0		R50550
R52400	Titanium, Gr 7	SB338	40.	12.5	12.0	10.9	9.9	9.0	8.4	7.7	7.2	6.6	6.2	5.7		R52400
R53400	Titanium, Gr 12	SB338	50.	17.5	17.5	16.4	15.2	14.2	13.3	12.5	11.9	11.4	11.1	10.8		R53400
R60702	Zirconium 702	SB523	30.	13.0		11.0		9.3		7.0		6.1		6.0	4.8	R60702

APPLICATIONS, SPECIFICATIONS, AND NOMINAL COMPOSITIONS OF SELECTED TIN-BASE SOLDER MATERIALS

Common Name	Specifications				Nominal Composition, %	Liquidus Temperature		Solidus Temperature		Typical Applications
	ASTM	Government	British	German		°C	°F	°C	°F	
Commercially pure tin	B 339, Grade A	QQ-T-371, Grade A	BS 3252, Grade T	DIN 1704, Grade A2	–	–	–	–	–	Soldering side seams of cans for foods or aerosols
Antimonial-tin solder	B 32, Grade S65	–	–	–	95 Sn, 5 Sb	240	464	234	452	Soldering of electrical equipment, joints in copper tubing, and cooling coils for refriger- ators. Resistant to SO_2
Tin-silver solder	B 32, Grade Sn95	–	–	–	95 Sn, 5 Ag	245	473	221	430	Soldering of components for electrical and high- temperature service
Tin-silver eutectic alloy	B 32, Grade Sn96	QQ-S-571, Grade Sn96	–	–	96 Sn, 3.5 Ag	221	430	221	430	Popular choice with proper- ties similar to those of ASTM B 32, Grade Sn95
Soft solder (70–30 solder)	B 32, Grade Sn70	QQ-S-571, Grade Sn70	–	–	70 Sn, 30 Pb	192	378	183	361	Joining and coating of metals
Eutectic solder (63–37 soft solder)	B 32, Grade Sn63	QQ-S-571, Grade Sn63	–	DIN 1707, LSn 63Pb	63 Sn, 37 Pb	183	361	183	361	Lowest-melting (eutectic) sol- der for electronics
Soft solder (60–40 solder)	B 32, Grade Sn60	QQ-S-571, Grade Sn60	BS 219, Grade K	DIN 1707, LSn 60Pb(Sb)	60 Sn, 40 Pb	190	374	183	361	Solder for electronic and elec- trical work, especially mass soldering of printed circuits

Source: GEM 2001, "Guide to Engineering Materials: Advanced Materials and Processes" (Materials Park, OH, USA: ASM International, 2000), p. 146. Reprinted with permission from ASM International.

ELECTRICAL AND MECHANICAL PROPERTIES OF SELECTED TIN-BASE SOLDERS

Solder Type	Tensile Properties	Shear Strength	Impact Strength and/or Hardness	Electrical Conductivity	Electrical Resistivity
Antimonial-tin solder (95Sn-5Sb)	Cast: typical tensile strength, 40.7 MPa (5.9 ksi); elongation in 100 mm (4 in.), 38%. Soldered copper joint: typical tensile strength, 97.9 MPa (14.2 ksi)	Cast: 41.4 MPa (6.0 ksi). Soldered copper joint: 76.5 MPa (11.1 ksi)	Impact strength: Cast (Izod test), 27 J (20 ft.·lbf)	Volumetric, 11.9% IACS at 20 °C (68 °F)	145 nΩ·m at 25 °C (77 °F)
Tin-silver solder (95Sn-5Ag)	Sheet, 1.02 mm (0.040 in.) thick, aged 14 days at room temperature: typical tensile strength, 31.7 MPa (4.6 ksi); yield strength, 24.8 MPa (3.6 ksi); elongation in 50 mm (2 in.), 49%. Soldered copper joint: typical tensile strength, 96.5 MPa (14 ksi)	Soldered copper joint: 73.1 MPa (10.6 ksi)	N/A	Volumetric, 16.6% IACS at 20 °C (68 °F)	104 nΩ·m at 0 °C (32 °F). Temperature coefficient of electrical resistivity: 0–100 °C (32–212 °F), 42.3 pΩ·m/K
70-30 soft solder (70Sn-30Pb)	Cast: typical tensile strength, 46.9 MPa (6.8 ksi)	N/A	Hardness. 12 HB	Volumetric, 11.8% IACS	146 nΩ·m
Eutectic solder (63Sn–37Pb)	Cast: typical tensile strength, 51.7 MPa (7.5 ksi); elongation in 100 mm (4 in.), 32%. Soldered copper joint: typical tensile strength, 200 MPa (2g ksi)	Cast: 42.7 MPa (6.2 ksi). Soldered copper joint: 55.2 MPa (8 ksi)	Impact strength: Cast (Izod test), 20 J (15 ft.·lbf). Hardness: Cast, 14 HB	Volumetric, 11.9% IACS	145 nΩ·m
60–40 soft solder (60Sn–40Pb)	Bulk solder at room temperature (measurements depend greatly on conditions of casting and testing): mean tensile strength, 52.5 MPa (7.61 ksi); elongation, 30–60%.	Mean: 37.1 MPa (5.38 ksi) (depends greatly on conditions of casting and testing)	Hardness: 16 HV (depends on casting conditions)	Volumetric, 11.5% IACS	149.9 nΩ·m

Source: GEM 2001, "Guide to Engineering Materials: Advanced Materials and Processes" (Materials Park, OH, USA: ASM International, 2000), p. 145. Reprinted with permission from ASM International.

DIFFUSION (COATINGS) TREATMENTS

Process	Type of Case	Process Temperature, C (F)	Typical Case Depth, mm (mils)	Case Hardness, HRC	Typical Base Metals
Carburizing					
Pack	Diffused carbon	815–1,090 (1,500–2,000)	125–1.5 (5–60)	50–63[a]	Low-carbon steels
Gas	Diffused carbon	815–980 (1,500–1,800)	75–1.5 (3–60)	50–63[a]	Low-carbon steels, low-carbon alloy steels
Liquid	Diffused carbon and possibly nitrogen	815–980 (1,500–1,800)	50–1.5 (2–60)	50–65[a]	Low-carbon steels, low-carbon alloy steels
Vacuum	Diffused carbon	815–1,090 (1,500–2,000)	75–1.5 (3–60)	50–63[a]	Low-carbon steels, low-carbon alloy steels
Nitriding					
Gas	Diffused nitrogen, nitrogen compounds	480–590 (900–1,100)	125–0.75 (5–30)	50–70	Alloy steels, nitriding steels, stainless steels
Salt	Diffused nitrogen, nitrogen compounds	510–565 (950–1,050)	2.5–0.75 (0.1–30)	50–70	Most ferrous metals including cast irons
Ion	Diffused nitrogen, nitrogen compounds	340–565 (650–1,050)	75–0.75 (3–30)	50–70	Alloy steels, nitriding, stainless steels
Carbonitriding					
Gas	Diffused carbon and nitrogen	760–870 (1,400–1,600)	75–0.75 (3–30)	50–65[a]	Low-carbon steels, low-carbon alloy steels, stainless steel

Process	Type of Case	Process Temperature, C (F)	Typical Case Depth, mm (mils)	Case Hardness,HRC	Typical Base Metals
Liquid (cyaniding) Ferritic	Diffused carbon and nitrogen	760–870 (1,400–1,600)	2.5–125 (0.1–5)	50–65[a]	Low-carbon steels
nitro-carbu-rizing	Diffused carbon and nitrogen	565–675 (1,050–1,250)	2.5–25 (0.1–1)	40–60[a]	Low-carbon steels
Other					
Aluminizing	Diffused (pack) aluminum				
Siliconizing by chemical vapor deposition	Diffused silicon				high-carbon steel
Chromizing by chemical vapor deposition	Diffused chromium	(1,800–2,000)	(1-2)	50–60	High- and low-carbon steels
Titanium carbide	Diffused carbon and titanium, TiC compound	900–1,010 (1,650–1,850)	2.5–12.5 (0.1-0.5)	>70[a]	Alloy steels, tool steels
Boriding	Diffused boron, boron, compound	400–1,150 (750–2,100)	12.5–50 (0.5-2)	40–>70	Alloy steels,tool steels, cobalt and nickel alloys

(a) Requires quench from austenitizing temperature.

Source: GEM 2001, "Guide to Engineering Materials: Advanced Materials and Processes" (Materials Park, OH, USA: ASM International, 2000), p. 171. Reprinted with permission from ASM International.

CREEP STRENGTH OF METALS

Material	Form, Condition	Stress (ksi) for 0.01% Creep per 1,000 h at Indicated Temp.					Stress (ksi) for 0.1% Creep per 1,000 h at Indicated Temp.				
		300 ˚F	400	500	600	800	300	400	500	600	800 ˚F
		149 ˚C	204	260	315	426	149	204	260	315	426 ˚C
NONFERROUS METALS											
Coppers	Wrought (annealed)	3–8	1.5–5	0.4–2.6	–	–	–	–	–	–	–
Nonleaded Brasses	Wrought (annealed)	0.9–19	2–11	0.3–23	–	–	25	5–9	1–2	–	–
Bronzes	Wrought (annealed)	14–23	5–10	2–5	–	–	–	–	–	–	–
Cupro-Nickel	Wrought (water quenched, aged)	25–40	15–30	8–30	–	–	–	22	13	–	–
Aluminum 2024-T	Sheet	23	9.5	2.5	1.5	–	30	13	3	2	–
Aluminum 7075-T	Sheet	12	4	2.5	1.5	–	16	6	3	2	–
Titanium (commercial)	Sheet (annealed)	–	38	–	32	10	37	40	37	32	13
Ti-6Al-4V	Sheet (annealed)	–	–	–	–	–	–	–	–	80	–
Ti-7Al-4Mo	Bar or Forging (annealed)	–	–	–	–	–	–	–	–	85	18

Material	Form, Condition	Stress (ksi) for 0.01% Creep per 1,000 h at Indicated Temp.					Stress (ksi) for 0.1% Creep per 1,000 h at Indicated Temp.				
		1,000 ˚F	1,100	1,200	1,500	1,600	1,000	1,100	1,200	1,500	1,600 ˚F
		538 ˚C	593	648	816	871	538	593	648	816	891 ˚C
CARBON AND LOW ALLOY STEELS											
Low Carbon Steel	Wrought, Cast	1.8	–	0.1	–	–	3.3–5	–	0.5	–	–
Carbon-Molybdenum Steels	Wrought, Cast	5.7	3	1	–	–	10–12	4	2	–	–
Chromium-Molybdenum Steels (0.5–3%)	Wrought, Cast	6–12	2–4	1–2.5	–	–	10–20	3–8	2–4.5	–	–
Chromium Steels											
4–6%	Wrought, Cast	6–7	2.5–3.5	1–2	–	–	8–11	5–6.5	2–3.5	–	–
6–10%	Wrought, Cast	5–9	2.5–4	1–2	–	–	8–12	4–6	2.5–3	–	–
(405,430)	Wrought	4.2–7	2.3–4.5	1.0–1.6	–	–	6–8.5	3–5	1.5–2.2	–	–
310, 314	Wrought	17	13	8	2	–	17	13–14	9	1–2.5	–
STAINLESS STEELS	Wrought	8	2.5	1.3	–	–		9.2	4.2	2	–
Martensitic Chromium Steels (403, 410, 416, 420, 440) Ferritic Chromium Steels											

Material	Form, Condition	Stress (ksi) for 0.01% Creep per 1,000 h at Indicated Temp.					Stress (ksi) for 0.1% Creep per 1,000 h at Indicated Temp.				
		1,000 ˚F 538 ˚C	1,100 593	1,200 648	1,500 816	1,600 871	1,000 538	1,100 593	1,200 648	1,500 816	1,600 ˚F 891 ˚C
Nickel-Chromium Steels											
304, 316, 321, 347	Wrought	12–17	7.5–11.5	4.5–7	1–2	-	17–25	12–18.2	7–12.7	1.2–2.8	-
309	Wrought	-	-	4	0.5	-	15.9	11.6	8	1.0	-
HEAT RESISTANT CAST HIGH ALLOYS											
Iron-Chromium Alloys (HA, HC, HD)	Cast	-	-	-	-	-	-	-	1.2–3.5[a]	0.7–1.9	
Iron-Chromium-Nickel Alloys (HE, HF, HH, HI, HK, HL)	Cast	-	-	-	-	-	-	-	3.5–7[a]	2-4.3	
Nickel-Chromium Alloys (HN, HT, HU, HW, HX)	Cast	-	-	-	-	-	-	-	6–8.5[a]	3-5	

[a]At 760 ˚C (1400˚F).

Source: J.W. Davis, J.A. McCarthy, J.N. Schrub, *Materials in Design Engineering* (1964), p. 35.

TEMPER DESIGNATIONS FOR COPPERS AND COPPER ALLOYS

Cold-Worked Tempers

H00	1/8 hard
H01	1/4 hard
H02	1/2 hard
H03	3/4 hard
H04	Hard
H06	Extra hard
H08	Spring
H10	Extra spring
H12	Special spring
H13	Ultra spring
H14	Super spring
H50	Extruded and drawn
H52	Pierced and drawn
H55	Light drawn; light cold rolled
H58	Drawn general purpose
H60	Cold heading; forming
H63	Rivet
H64	Screw
H66	Bolt
H70	Bending
H80	Hard drawn
H85	Medium-hard-drawn electrical wire
H86	Hard-drawn electrical wire

Cold-Worked and Stress-relieved Tempers

HR01	H01 and stress relieved
HR02	H02 and stress relieved
HR04	H04 and stress relieved
HR06	H06 and stress relieved
HR08	H08 and stress relieved
HR10	H10 and stress relieved
HR50	Drawn and stress relieved

Cold-Worked and Order-strengthened Tempers

HT04	H04 and order heat treated
HT06	H06 and order heat treated
HT08	H08 and order heat treated

Solution-Treated Temper

TB00	Solution heat treated

Solution-Treated and Cold-Worked Tempers

TD00	TB00 cold worked to 1/4 hard
TD01	TB00 cold worked to 1/4 hard
TD02	TB00 cold worked to 1/2 hard
TD03	TB00 cold worked to 3/4 hard
TD04	TB00 cold worked to full hard

As-manufactured Tempers

M01	As sand cast
M02	As centrifugal cast
M03	As plaster cast
M04	As pressure die cast
M05	As permanent mold cast
M06	As investment cast
M07	As continuous cast
M10	As hot forged and air cooled
M11	As hot forged and quenched
M20	As hot rolled
M30	As hot extruded
M40	As hot pierced
M45	As hot pierced and rerolled

Annealed Tempers(a)

O10	Cast and annealed(b)
O20	Hot forged and annealed
O25	Hot rolled and annealed
O30	Hot extruded and annealed
O40	Hot pierced and annealed
O50	Light annealed
O60	Soft annealed
O61	Annealed
O65	Drawing annealed
O68	Deep drawing annealed
O70	Dead soft annealed
O80	Annealed to temper–1/8 hard
O81	Annealed to temper–1/4 hard
O82	Annealed to temper–1/2 hard

Annealed Tempers(c)

OS005	Average grain size 0.005 mm
OS010	Average grain size 0.010 mm
OS015	Average grain size 0.015 mm
OS025	Average grain size 0.025 mm
OS035	Average grain size 0.035 mm
OS050	Average grain size 0.050 mm
OS070	Average grain size 0.070 mm
OS100	Average grain size 0.100 mm
OS120	Average grain size 0.120 mm
OS150	Average grain size 0.150 mm
OS200	Average grain size 0.200 mm

Precipitation-Hardened Temper

TF00	TB00 and precipitation hardened

Cold-Worked and Precipitation-Hardened Tempers

TH01	TD01 and precipitation hardened
TH02	TD02 and precipitation hardened
TH03	TD03 and precipitation hardened
TH04	TD04 and precipitation hardened

Precipitation-Hardened and Cold-Worked Tempers

TL00	TF00 cold worked to 1/8 hard
TL01	TF00 cold worked to 1/4 hard
TL02	TF00 cold worked to 1/2 hard
TL04	TF00 cold worked to full hard
TL08	TF00 cold worked to spring
TL10	TF00 cold worked to extra spring
TR01	TL01 and stress relieved
TR02	TL02 and stress relieved
TR04	TL04 and stress relieved

Mill-Hardened Tempers

TM00	AM
TM01	1/4 HM
TM02	1/2 HM
TM04	HM
TM06	XHM
TM08	XHMS

Quench-Hardened Tempers

TQ00	Quench hardened
TQ50	Quench hardened and temper annealed
TQ75	Interrupted quench hardened

Tempers of Welded Tubing[(d)]

WH00	Welded and drawn to 1/8 hard
WH01	Welded and drawn to 1/4 hard
WM01	As welded from H01 strip
WM02	As welded from H02 strip
WM03	As welded from H03 strip
WM04	As welded from H04 strip
WM06	As welded from H06 strip
WM08	As welded from H08 strip
WM10	As welded from H10 strip
WM15	WM50 and stress relieved
WM20	WM00 and stress relieved
WM21	WM01 and stress relieved
WM22	WM02 and stress relieved
WM50	As welded from O60 strip
WO50	Welded and light annealed
WR00	WM00; drawn and stress relieved
WR01	WM01; drawn and stress relieved

[(a)] To produce specified mechanical properties. [(b)] Homogenization anneal. [(c)] To produce prescribed average grain size. [(d)] Tempers of fully finished tubing that has been drawn or annealed to produce specified mechanical properties or that has been annealed to produce a prescribed average grain size are commonly identified by the appropriate H, O, or OS temper designation.

Source: D. Benjamin, ed., *Metals Handbook,* 9th ed., vol. 2 (Materials Park, OH, USA: ASM International, 1979), p. 527. Reprinted with permission from ASM International.

TEMPER DESIGNATIONS FOR MAGNESIUM ALLOYS

F	As fabricated
O	Annealed
H10, H11	Slightly strain hardened
H23, H24, H26	Strain hardened and partially annealed
T4	Solution heat treated
T5	Artificially aged only
T6	Solution heat treated and artificially aged
T8	Solution heat treated, cold-worked, and artificially aged

Source: D. Benjamin, ed., *Metals Handbook*, 9th ed., vol. 2 (Materials Park, OH, USA: ASM International, 1979), p. 527. Reprinted with permission from ASM International.

TEMPER DESIGNATIONS FOR ALUMINUM ALLOYS

Basic Temper Designations

F **as fabricated.** Applies to the products of shaping processes in which no special control over thermal conditions or strain-hardening is employed. For wrought products, there are no mechanical property limits.

O **annealed.** Applies to wrought products which are annealed to obtain the lowest strength temper, and to cast products which are annealed to improve ductility and dimensional stability. The O may be followed by a digit other than zero.

H **strain-hardened (wrought products only).** Applies to products which have their strength increased by strain-hardening, with or without supplementary thermal treatments to produce some reduction in strength. The H is always followed by two or more digits.

W **solution heat-treated.** An unstable temper applicable only to alloys which spontaneously age at room temperature after solution heat-treatment. This designation is specific only when the period of natural aging is indicated; for example: W 1/2h.

T **thermally treated to produce stable tempers other than F, O, or H.** Applies to products which are thermally treated, with or without supplementary strain-hardening, to produce stable tempers. The T is always followed by one or more digits.

Subdivision of H Temper: Strain-Hardened

The first digit following the H indicates the specific combination of basic operations, as follows:

H1 **strain-hardened only.** Applies to products which are strain-hardened to obtain the desired strength without supplementary thermal treatment. The number following this designation indicates the degree of strain-hardening.

H2 **strain-hardened and partially annealed.** Applies to products which are strain-hardened more than the desired final amount and then reduced in strength to the desired level by partial annealing. For alloys that age-soften at room temperature, the H2 tempers have the same minimum ultimate tensile strength as the corresponding H3 tempers. For other alloys, the H2 tempers have the same minimum ultimate tensile strength as the corresponding H1 tempers and slightly higher elongation. The number following this designation indicates the degree of strain-hardening remaining after the product has been partially annealed.

H3 **strain-hardened and stabilized.** Applies to products which are strain-hardened and whose mechanical properties are stabilized either by a low temperature thermal treatment or as a result of heat introduced during fabrication. Stabilization usually improves ductility. This designation is applicable only to those alloys which, unless stabilized, gradually age-soften at room temperature. The number following this designation indicates the degree of strain-hardening remaining after the stabilization treatment.

The digit following the designations H1, H2, and H3 indicates the degree of strain-hardening.

Subdivision of T Temper: Thermally Treated

Numerals 1 through 10 following the T indicate specific sequences of basic treatments, as follows:

T1 **cooled from an elevated temperature shaping process and naturally aged to a substantially stable condition.** Applies to products which are not cold-worked after cooling from an elevated temperature shaping process, or in which the effect of cold-work in flattening or straightening may not be recognized in mechanical property limits.

T2 **cooled from an elevated temperature shaping process, cold-worked, and naturally aged to a substantially stable condition.** Applies to products that are cold-worked to improve strength after cooling from an elevated temperature shaping process, or in which the effect of cold-work in flattening or straightening is recognized in mechanical property limits.

T3 **solution heat-treated, cold-worked, and naturally aged to a substantially stable condition.** Applies to products which are cold-worked to improve strength after solution heat-treatment, or in which the effect of cold-work in flattening or straightening is recognized in mechanical property limits.

T4 **solution heat-treated and naturally aged to a substantially stable condition.** Applies to products which are not cold-worked after solution heat-treatment, or in which the effect of cold-work in flattening or straightening may not be recognized in mechanical property limits.

T5 **cooled from an elevated temperature shaping process and then artificially aged**. Applies to products which are not cold-worked after cooling from an elevated temperature shaping process, or in which the effect of cold-work in flattening or straightening may not be recognized in mechanical property limits.

T6 **solution heat-treated and then artificially aged**. Applies to products which are not cold-worked after solution heat-treatment, or in which the effect of cold-work in flattening or straightening may not be recognized in mechanical property limits.

T7 **solution heat-treated and overaged/stabilized.** Applies to wrought products that are artificially aged after solution heat treatment to carry them beyond a point of maximum strength to provide control of some significant characteristic. Applies to cast products that are artificially aged after solution heat treatment to provide dimensional and strength stability.

T8 **solution heat-treated, cold-worked, and then artificially aged.** Applies to products which are cold-worked to improve strength, or in which the effect of cold-work in flattening or straightening is recognized in mechanical property limits.

T9 **solution heat-treated, artificially aged, and then cold-worked.** Applies to products which are cold-worked to improve strength.

T10 **cooled from an elevated temperature shaping process, cold-worked, and then artificially aged.** Applies to products which are cold-worked to improve strength, or in which the effect of cold-work in flattening or straightening is recognized in mechanical property limits.

Source: *Aluminum Standards and Data* (Arlington County, VA, USA: Aluminum Association Inc., 2000).

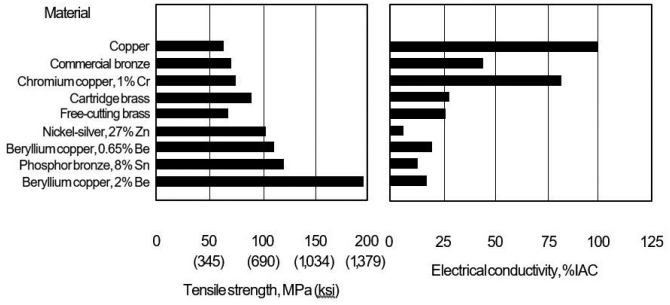
MELTING TEMPERATURES OF COMMON ALLOYS

UNS	Common Name	Melting Temperature ˚C	Melting Temperature ˚F
A24430	Cast Al B443.0	570–630	1,065–1,170
A91100	Al 1100	640–660	1,190–1,215
A95052	Al 5052	610–650	1,125–1,200
C11000	ETP Copper	1,083	1,980
C23000	Red Brass	990–1,025	1,810–1,880
C28000	Muntz Metal	900–905	1,650–1,660
C44300	Admiralty Brass, As	900–935	1,650–1,720
C61400	Aluminum Bronze D	1,045–1,060	1,910–1,940
C70600	90-10 Copper-Nickel	1,100–1,150	2,010–2,100
C71500	70-30 Copper-Nickel	1,170–1,240	2,140–2,260
C83600	Ounce Metal	854–1,010	1,510–1,840
F10006	Gray Cast Iron	1,150–1,200	2,100–2,200
G10200	Carbon Steel	1,520	2,760
J94224	HK Cast SS	1,400	2,550
L13002	Tin	232	450
L51120	Chemical Lead	326	618
L55030	50/50 Solder	183–216	361–421
M11311	Mg AZ31B	605–632	1,120–1,170
M13310	Mg HK31A	589–651	1,092–1,204
N02200	Nickel 200	1,435–1,445	2,615–2,635
N04400	400 Alloy	1,300–1,350	2,370–2,460
N06600	600 Alloy	1,350–1,410	2,470–2,575
N10276	C-276 Alloy	1,320–1,370	2,420–2,500
N10665	B-2 Alloy	1,300–1,370	2,375–2,500
P00020	Gold	1,063	1,945
P03980	Palladium	1,552	2,826
P04995	Platinum	1,769	3,217
P07015	Silver	961	1,761
R03600	Molybdenum	2,610	4,730
R04210	Niobium (Columbium)	2,470	4,470
R05200	Tantalum	2,996	5,425
R07005	Tungsten	3,410	6,170
R50250	Titanium, Gr 1	1,705	3,100
R56400	Titanium, Gr 5	1,600–1,660	2,920–3,020
R60702	Zr 702	1,860	3,380
S30400	304 SS	1,400–1,450	2,550–2,650
S31000	310 SS	1,400–1,450	2,500–2,650
S41000	410 SS	1,480–1,530	2,700–2,790
S44600	446 SS	1,430–1,510	2,600–2,750
S50200	5Cr-0.5Mo	1,480–1,540	2,700–2,800
Z13001	Steel Zinc	420	787

COEFFICIENTS OF THERMAL EXPANSION OF COMMON ALLOYS

UNS	Common Name	in./in./˚F×10^{-6}	mm/mm/˚C×10^{-6}	Range-˚C
A24430	Cast Al B443.0	12.3	22.	20–100
A91100	Al 1100	13.1	24.	20–100
A95052	Al 5052	13.2	24.	20–100
C11000	ETP Copper	9.4	16.9	20–100
C23000	Red Brass	10.4	18.7	20–300
C28000	Muntz Metal	11.6	21.	20–300
C44300	Admiralty Brass, As	11.2	20.	20–300
C61400	Aluminum Bronze D	9.0	16.2	20–300
C70600	90-10 Copper-Nickel	9.5	17.1	20–300
C71500	70-30 Copper-Nickel	9.0	16.2	20–300
C83600	Ounce Metal	10.2	18.4	0–100
F10006	Gray Cast Iron	6.7	12.1	0–100
G10200	Carbon Steel	6.7	12.1	0–100
J94224	HK Cast SS	9.4	16.9	20–540
L13002	Tin	12.8	23.	0–100
L51120	Chemical Lead	16.4	30.	0–100
L55030	50/50 Solder	13.1	24.	0–100
M11311	Mg AZ31B	14.5	26.	20–100
M13310	Mg HK31A	14.5	26.	20–100
N02200	Nickel 200	7.4	13.3	20–90
N04400	400 Alloy	7.7	13.9	20–90
N06600	600 Alloy	7.4	13.3	20–90
N10276	C-276 Alloy	6.3	11.3	20–90
N10665	B-2 Alloy	5.6	10.1	20–90
R03600	Molybdenum	2.7	4.9	20–100
R05200	Tantalum	3.6	6.5	20–100
R50250	Titanium, Gr 1	4.8	8.6	0–100
R56400	Titanium, Gr 5	4.9	8.8	0–100
R60702	Zr 702	2.9	5.2	0–100
S30400	304 SS	9.6	17.3	0–100
S31000	310 SS	8.0	14.4	0–100
S41000	410 SS	6.1	11.0	0–100
S44600	446 SS	5.8	10.4	0–100
S50200	5Cr-0.5Mo Steel	7.3	13.1	20–540
Z13001	Zinc	18.	32.	0–100

STRENGTH AND ELECTRICAL CONDUCTIVITY RELATIONSHIP FOR COPPER AND COPPER ALLOYS



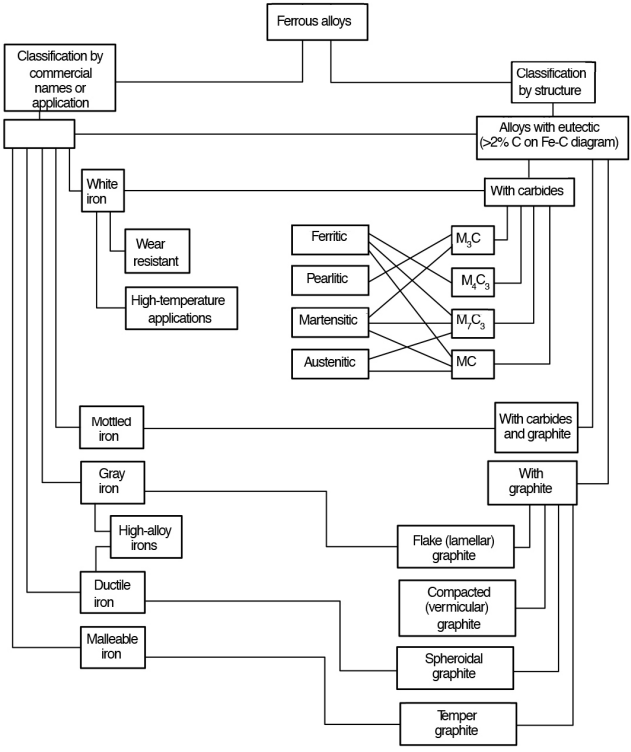
Source: GEM 2001, "Guide to Engineering Materials: Advanced Materials and Processes" (Materials Park, OH, USA: ASM International, 2000), p. 124. Reprinted with permission from ASM International.

CLASSIFICATION OF COPPER ALLOYS

Generic Name	UNS No.	Composition
Wrought Alloys		
Coppers	C10100–C15760	> 99% Cu
High-copper alloys	C16200–C19600	> 96% Cu
Brasses	C20500–C28580	Cu-Zn
Leaded brasses	C31200–C38590	Cu-Zn-Pb
Tin brasses	C40400–C49080	Cu-Zn-Sn-Pb
Phosphor bronzes	C50100–C52400	Cu-Sn-P
Leaded phosphor bronzes	C53200–C54800	Cu-Sn-Pb-P
Copper-phosphorus and copper-silver-phosphorus alloys	C55180–C55284	Cu-P-Ag
Aluminum bronzes	C60600–C64400	Cu-Al-Ni-Fe-Si-Sn
Silicon bronzes	C64700–C66100	Cu-Si-Sn
Other copper-zinc alloys	C66400–C69900	–
Copper-nickels	C70000–C79900	Cu-Ni-Fe
Nickel silvers	C73200–C79900	Cu-Ni-Zn
Cast Alloys		
Coppers	C80100–C81100	»99% Cu
High-copper alloys	C81300–C82800	»94% Cu
Red and leaded red brasses	C83300–C85800	Cu-Zn-Sn-Pb (75–89% Cu)
Yellow and leaded yellow brasses	C85200–C85800	Cu-Zn-Sn-Pb (57–74% Cu)
Manganese bronzes and leaded manganese bronzes	C86100–C86800	Cu-Zn-Mn-Fe-Pb
Silicon bronzes, silicon brasses	C87300–C87900	Cu-Zn-Si
Tin bronzes and leaded tin bronzes	C90200–C94500	Cu-Sn-Zn-Pb
Nickel-tin bronzes	C94700–C94900	Cu-Ni-Sn-Zn-Pb
Aluminum bronzes	C95200–C95810	Cu-Al-Fe-Ni
Copper-nickels	C96200–C96800	Cu-Ni-Fe
Nickel silvers	C97300–C97800	Cu-Ni-Zn-Pb-Sn
Leaded coppers	C98200–C98800	Cu-Pb
Special alloys	C99300–C99750	–

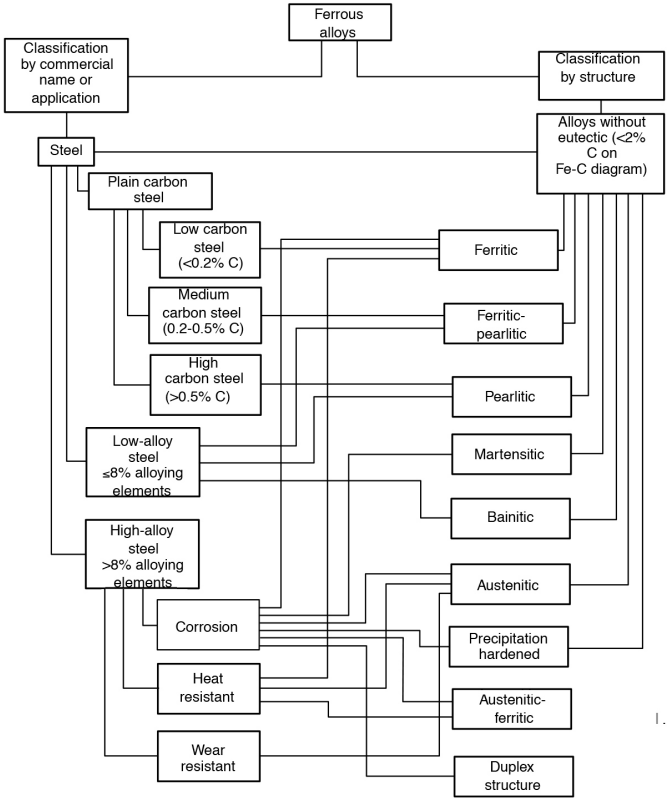
Source: GEM 2001, "Guide to Engineering Materials: Advanced Materials and Processes" (Materials Park, OH, USA: ASM International, 2000), p. 119. Reprinted with permission from ASM International.

CLASSIFICATION OF FERROUS CASTING ALLOYS



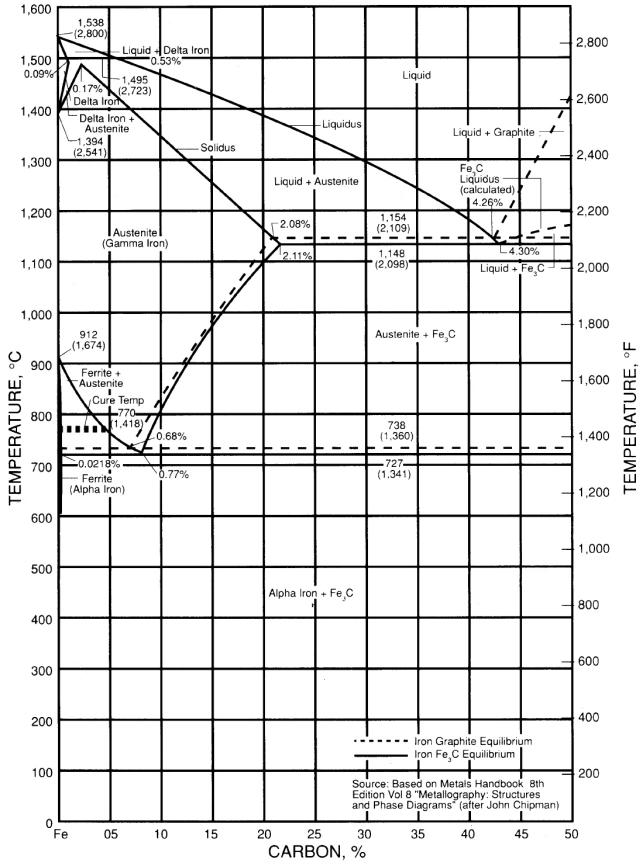
Source: GEM 2001, "Guide to Engineering Materials: Advanced Materials and Processes" (Materials Park, OH, USA: ASM International, 2000), p. 45. Reprinted with permission from ASM International.

CLASSIFICATION OF STEELS



Source: GEM 2001, "Guide to Engineering Materials: Advanced Materials and Processes" (Materials Park, OH, USA: ASM International, 2000), p. 51. Reprinted with permission from ASM International.

IRON-CARBON EQUILIBRIUM DIAGRAM



Source: *Metals Progress Databook* (Materials Park, OH, USA: ASM International, 1980), p. 109. Reprinted with permission from ASM International.

CRITICAL TRANSFORMATION TEMPERATURES FOR STEELS

Definitions

Transformation temperature range is that range of temperature within which austenite forms during heating and transforms during cooling. Transformation temperature is the temperature at which a change in phase occurs. The following symbols have been used:

Ac_1 The temperature at which austenite begins to form during heating.

Ac_3 The temperature at which the transformation of ferrite to austenite is completed during heating.

Ar_1 The temperature at which transformation of austenite to ferrite or to ferrite plus cementite is completed during cooling.

Ar_3 The temperature at which austenite begins to transform to ferrite during cooling.

	Thermal Critical Range							
	On Heating				On Cooling			
	Ac_1		Ac_3		Ar_3		Ar_1	
Type of Steel	˚F	˚C	˚F	˚C	˚F	˚C	˚F	˚C
Low Carbon	1,330	723	1,605	874	1,540	838	1,240	671
Medium Carbon	1,350	732	1,540	838	1,470	799	1,340	727
Carbon - 1/2 Mo	1,340	727	1,570	854	1,480	804	1,225	663
1 Cr 1/2 Mo	1,420	771	1,635	891	1,550	843	1,420	771
2 1/4 Cr 1 Mo	1,480	804	1,600	871	1,510	821	1,330	721
5 Cr 1/2 Mo	1,506	819	1,620	882	1,445	785	1,325	719
7 Cr 1/2 Mo	1,520	827	1,620	882	1,450	788	1,340	727
9 Cr 1 Mo	1,490	810	1,580	860	1,420	771	1,320	716
12 Cr - Type 410	1,435	780	1,545	841	1,310	710	1,130	609

Critical ranges were determined with a heating rate of 250˚F per hour and a cooling rate of 50 ˚F per hour.

TEMPER AND RADIATION COLOR OF CARBON STEEL

°F	Approx. °C	Temper Color
380–400	200	Pale yellow
420–440	220	Straw yellow
460–480	240	Yellowish brown
500–540	270	Bluish purple
540–560	285	Violet
560–580	300	Pale blue
600–640	325	Blue
		Radiation Color
1,000	540	Black
1,100	590	Faint dark red
1,200	650	Cherry red (dark)
1,300	700	Cherry red (med.)
1,400	760	Red
1,500	815	Light red
1,600	870	Reddish orange
1,700	930	Orange
1,800	980	Changes
1,900	1,040	to
2,000	1,090	Pale orange lemon
2,100	1,150	Lemon
2,200	1,205	Light lemon
2,300	1,260	Yellow
2,400	1,315	Light yellow
2,500	1,370	Yellowish gray: “while”

ANNEALING TEMPERATURES FOR AUSTENITIC STAINLESS STEELS AND RELATED ALLOYS

Solution annealing consists of heating to temperature and cooling rapidly. Temperatures are from indicated ASTM standards. Consult alloy producers for details.

UNS	Name	ASTM	Form	°F	°C
J93370	CD-4MCu	A743	Casting	1,900 min	1,040 min
J95150	CN-7M	A743	Casting	2,050 min	1,120 min
N08020	20Cb-3	B464	Pipe	1,800–1,850	980–1,010
N08024	20Mo-4	B464	Pipe	1,925–1,975	1,050–1,080
N08026	20Mo-6	B464	Pipe	2,050–2,200	1,120–1,205
N08028	Sanicro 28	B668	Tube	1,975–2,085	1,080–1,140
N08366	AL-6X	B675	Pipe	2,200 min	1,205 min
N08367	AL-6XN	B675	Pipe	2,150 min	1,175 min
N08700	JS700	B599	Plate	2,000 min	1,090 min
N08904	904L Alloy	B677	Pipe, Tube	1,950–2,100	1,065–1,150
N08925	25-6Mo	B677	Pipe, Tube	1,950–2,100	1,065–1,150
S20910	22-13-5	A312	Pipe	1,900 min	1,040 min
S24000	18-3 Mn	A312	Pipe	1,900 min	1,040 min
S30400	304 SS	A312	Pipe	1,900 min	1,040 min
S30403	304L SS	A312	Pipe	1,900 min	1,040 min
S30409	304H SS	A312	Pipe	1,900 min	1,040 min
S30451	304N SS	A312	Pipe	1,900 min	1,040 min
S30453	304LN SS	A312	Pipe	1,900 min	1,040 min
S30815	253MA	A312	Pipe	1,900 min	1,040 min
S30900	309 SS	A312	Pipe	1,900 min	1,040 min
S31000	310 SS	A312	Pipe	1,900 min	1,040 min
S31254	254 SMO	A312	Pipe	2,100 min	1,150 min
S31600	316 SS	A312	Pipe	1,900 min	1,040 min
S31603	316L SS	A312	Pipe	1,900 min	1,040 min
S31609	316H SS	A312	Pipe	1,900 min	1,040 min
S31651	316N SS	A312	Pipe	1,900 min	1,040 min

UNS	Name	ASTM	Form	°F	°C
S31653	316LN SS	A312	Pipe	1,900 min	1,040 min
S31700	317 SS	A312	Pipe	1,900 min	1,040 min
S31703	317L SS	A312	Pipe	1,900 min	1,040 min
S31725	317LM SS	A312	Pipe	1,900 min	1,040 min
S31726	317L4 SS	A312	Pipe	1,900 min	1,040 min
S32100	321 SS*	A312	Pipe	1,900 min	1,040 min
S32109	321H SS*	A312	Pipe	CW 2,000 min HR 1,925 min	CW 1,095 min HR 1,050 min
S34700	347 SS*	A312	Pipe	1,900 min	1,040 min
S34709	347H SS*	A312	Pipe	CW 2,000 min HR 1,925 min	CW 1,095 min HR 1,050 min
S34800	348 SS*	A312	Pipe	1,900 min	1,040 min
S38100	18-18-2	A312	Pipe	1,900 min	1,040 min
S31200	44LN	A790	Pipe	1,920–2,010	1,050–1,100
S31260	DP-3	A790	Pipe	1,870–2,010	1,020–1,100
S31500	3RE60	A790	Pipe	1,800–1,900	980–1,040
S31803	2205 Alloy	A790	Pipe	1,870–2,010	1,020–1,100
S32304	SAF 2304	A790	Pipe	1,800–1,900	930–1,040
S32550	Ferralium 255	A790	Pipe	1,900 min	1,040 min
S32950	7 Mo Plus	A790	Pipe	1,820–1,880	990–1,025

*A stabilization heat treatment after solution anneal improves resistance to intergranular corrosion.

ANNEALING TREATMENTS FOR FERRITIC STAINLESS STEELS

UNS	Common Name	Treatment Temperature ˚C	Treatment Temperature ˚F
Conventional ferritic grades			
S40500	405	650–815	1,200–1,500
S40900	409	870–900	1,600–1,650
S43000	430	705–790	1,300–1,450
S43020	430F	705–790	1,300–1,450
S43400	434	705–790	1,300–1,450
S44600	446	760–830	1,400–1,525
Low-interstitial ferritic grades			
S43035	439	870–925	1,600–1,700
S44400	444	955–1,010	1,750–1,850
S44626	26-1	760–955	1,400–1,750
S44660	Ti SC-1	1,010–1,065	1,850–1,950
S44735	29-4C	1,010–1,065	1,850–1,950
S44800	29-4.2	1,010–1,065	1,850–1,950
S44635	26-4.4	1,010–1,065	1,850–1,950

Note: Postweld heat treating of low-interstitial ferritic stainless steels is generally unnecessary and frequently undesirable. Any annealing of these grades should be followed by water quenching or very rapid cooling.

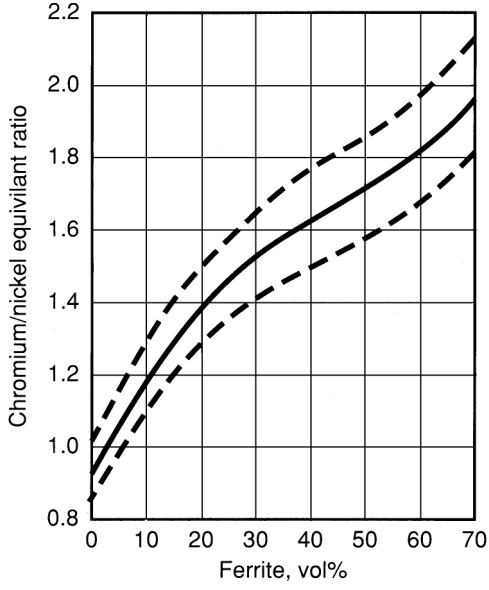
Source: H.E. Boyer, T.L. Gall, eds., *Metals Handbook,* Desk Edition (Materials Park, OH, USA: ASM International, 1985), pp. 28–61. Reprinted with permission, copyright ASM International.

ANNEALING TEMPERATURES AND PROCEDURES FOR MARTENSITIC STAINLESS STEELS

	Process (subcritical) Annealing[a]		Full Annealing[b][c]		Isothermal Annealing[c]	
UNS	˚C	Hardness	˚C	Hardness	Procedure[d]	Hardness
S40300, S41000	650–760	82–92 HRB	830–885	75–85 HRB	Heat to 830 to 885 ˚C; hold 6 H at 705 ˚C	85 HRB
S41400	650–730	99 HRB-24 HRC	Not recommended		Not recommended	
S41600, S41623	650–760	86–92 HRB	830–885	75–85 HRB	Heat to 830 to 885 ˚C; hold 2 h at 720 ˚C	85 HRB
S42000	675–760	94–97 HRB	830–885	86–95 HRB	Heat to 830 to 885 ˚C; hold 2 h at 705 ˚C	95 HRB
S43100	620–705	99 HRB-30 HRC	Not recommended		Not recommended	
S44002	675–760	90 HRB-22 HRC	845–900	94–98 HRB	Heat to 845 to 98 HRB 900 ˚C; hold 4 h at 690 ˚C	
S44003	675–760	98 HRB-23 HRC	845–900	95 HRB-20 HRC	Same as S44002	20 HRC
S44004	675–760	98 HRB-23 HRC	845–900	98 HRB-25 HRC	Same as S44002	25 HRC

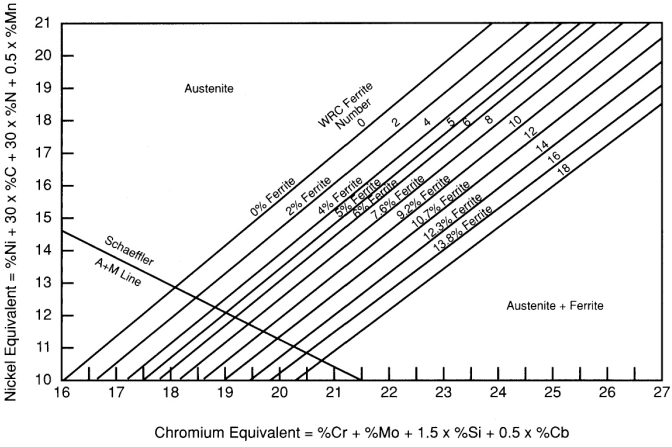
[a] Air cool from temperature; maximum softness is obtained by heating to temperature at high end of range. [b] Soak thoroughly at temperature within range indicated; furnace cool at 790 ˚C; continue cooling at 15 to 25 ˚C/h to 595 ˚C; air cool to room temperature; [c] Recommended for applications in which full advantage may be taken of the rapid cooling to the transformation temperature and from it to room temperature; [d] Preheating to a temperature within the process annealing range is recommended for thin-gage parts, heavy sections, previously hardened parts, parts with extreme variations in section or with sharp re-entrant angles, and parts that have been straightened or heavily ground or machined to avoid cracking and minimize distortion, particularly for S42000, S43100, S44002, S44003, and S44004.

SCHOEFER DIAGRAM FOR ESTIMATING THE AVERAGE FERRITE CONTENT IN AUSTENITIC IRON-CHROMIUM-NICKEL ALLOY CASTINGS



Source: L.J. Korb, *Metals Handbook*, 9th ed., vol. 13 (Materials Park, OH, USA: ASM International, 1987), p. 577. Reprinted with permission from ASM International.

DELTA FERRITE CONTENT OF STAINLESS STEEL WELD METALS



Note: The actual nitrogen content is preferred. If this is not available, the following applicable nitrogen value shall be used; GMAW welds–0.08% (except self-shielding flux cored electrode GMAW welds–0.12%); welds of other process–0.06%.

Source: ASME Pressure Vessel Code, Section III, Fig. NB-2433.1–1, 1977. Reprinted from ASME B31.3–1990, and 1977 BPVC, Section III-NB, with permission from The American Society of Mechanical Engineers. All rights reserved.

OVERVIEW OF JOINING PROCESSES

																	Brazing							
		S	S	G	F	G	P	E	E	R	F	O	D	F	E	L	T	F	I	R	D	I	D	S
		M	A	M	C	T	A	S	G	W	W	F	F	R	B	B	B	B	B	B	B	R	F	
		A	W	A	A	A	W	W	W			W	W	W	W	W						B	B	
Material	**Thickness**	**W**		**W**	**W**	**W**																		
Carbon Steel	S	X	X	X		X				X	X	X			X	X	X	X	X	X	X	X	X	X
	I	X	X	X	X	X				X	X	X		X	X	X	X	X	X	X	X		X	X
	M	X	X	X	X					X	X	X		X	X	X	X	X	X				X	
	T	X	X	X	X			X	X		X	X		X	X			X					X	
Low Alloy Steel	S	X	X	X		X				X	X	X	X		X	X	X	X	X	X	X	X	X	X
	I	X	X	X	X	X				X	X		X	X	X	X	X	X	X				X	X
	M	X	X	X	X						X		X	X	X	X	X	X	X				X	
	T	X	X	X	X			X		X	X		X	X	X		X						X	
Stainless Steel	S	X	X	X		X	X			X	X	X	X		X	X	X	X	X	X	X	X	X	X
	I	X	X	X	X	X	X			X	X		X	X	X	X	X	X	X				X	X
	M	X	X	X	X		X				X		X	X	X	X	X	X	X				X	
	T	X	X	X	X			X			X		X	X	X			X					X	
Cast Iron	I	X										X					X	X	X				X	X
	M	X	X	X	X							X					X	X	X				X	X
	T	X	X	X	X							X						X					X	
Nickel and Alloys	S	X		X		X	X			X	X	X			X	X	X	X	X	X	X	X	X	X
	I	X	X	X		X	X			X	X			X	X	X	X	X	X				X	X
	M	X	X	X			X				X			X	X	X	X	X					X	
	T	X		X				X			X			X	X			X					X	

																		Brazing							
		S	S	G	F	G	P	E	E	R	F	O	D	F	E	L	T	F	I	R	D	I	D	S
		M	A	M	C	T	A	S	G	W	W	F	F	R	B	B	B	B	B	B	B	R	F	
		A	W	A	A	A	W	W	W			W	W	W	W	W						B	B	
Material	**Thickness**	**W**		**W**	**W**	**W**																		
Aluminum and Alloys	S	X		X		X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	I	X		X		X				X	X		X	X	X	X	X	X			X		X	X
	M	X		X		X					X			X	X		X	X			X		X	
	T	X		X				X	X		X				X			X					X	
Titanium and Alloys	S			X		X	X			X	X		X		X	X		X	X			X	X	
	I			X		X	X				X		X	X	X	X		X					X	
	M			X		X	X				X		X	X	X	X		X					X	
	T			X							X		X		X		X	X					X	
Copper and Alloys	S			X		X	X				X				X		X	X	X	X			X	X
	I			X			X				X			X	X		X	X		X			X	X
	M			X							X			X	X		X	X					X	
	T			X							X				X			X					X	
Magnesium and Alloys	S			X		X				X					X	X	X	X			X		X	
	I			X		X				X	X			X	X	X	X	X			X		X	
	M			X							X			X	X	X		X					X	
	T			X							X				X									
Refractory Alloys	S			X		X	X			X	X				X		X	X	X	X		X	X	
	I			X			X				X				X		X	X					X	
	M									X	X													
	T																							

This table presented as a general survey only. In selecting processes to be used with specific alloys, the reader should refer to other appropriate sources of information.

OVERVIEW OF JOINING PROCESSES

Legend

Process Code		Thickness
SMAW - Shielded Metal Arc Welding-	FRW-Friction Welding	S-Sheet up to 3 mm (1/8 in.)
SAW-Submerged Arc Welding	EBW-Electron Beam Welding	I-Intermediate 3 to 6 mm (1/8 to 3/4 in.)
GMAW-Gas Metal Arc Welding	LBW-Laser Beam Welding	M-Medium 6 to 19 mm (1/4 to 3/4 in.)
FCAW-Flux Cored Arc Welding	Brazing	T-Thick 19 mm (3/4 in.) and up
GTAW-Gas Tungsten Arc Welding	TB-Torch Brazing	
PAW-Plasma Arc Welding	FB-Fumace Brazing	
ESW-Electroslag Welding	IB-Induction Brazing	
EGW-Electrogas Welding	RB-Resistance Brazing	X-Commercial Process
RW-Resistance Welding	DB-Dip Brazing	
FW-Flash Welding	IRB-Infrared Brazing	
OFW-Oxyfuel Gas Welding	DFB-Diffusion Brazing	
DFW-Diffusion Welding	S-Soldering	

Source: R.L. O'Brien, *Welding Handbook*, 8th ed., vol. 1, (Miami, FL, USA: American Welding Society, 1987), p. 3. Reprinted with permission from American Welding Society.

PREHEAT TEMPERATURES FOR WELDING CARBON AND ALLOY STEELS

Base Metal P-No.[1]	Weld Metal Analysis A-No.[2]	Base Metal Group	Nominal Wall Thickness in.	Nominal Wall Thickness mm	Min. Specified Tensile Strength, Base Metal ksi	Min. Specified Tensile Strength, Base Metal MPa	Min. Temp Required ˚F	Min. Temp Required ˚C	Min. Temp Recommended ˚F	Min. Temp Recommended ˚C
1	1	Carbon steel	<1	<25.4	≤71	≤490	...	...	50	10
			≥1	≥25.4	All	All	...	...	175	79
			All	All		>71	...	...	175	79
3	2, 11	Alloy steels, Cr < 1/2%	<1.2	<12.7	≤71	≤490	...	...	50	10
			≥1/2	≥12.7	All	All	...	...	175	79
			All	All	>71	>490	...	...	175	79
4	3	Alloy steels 1/2% < Cr ≤ 2%	All	All	All	All	300	149	...	...
5	4, 5	Alloy steels, 2 1/4% ≤ Cr ≤ 10%	All	All	All	All	350	177	...	...
6	6	High alloy steels martensitic	All	All	All	All	...	...	300[3]	149[3]
7	7	High alloy steels ferritic	All	All	All	All	...	...	50	10
8	8, 9	High alloy steel austenitic	All	All	All	All	...	...	50	10
9A, 9B	10	Nicke Alloy steels	All	All	All	All	...	...	200	93

Base Metal P-No.[1]	Weld Metal Analysis A-No.[2]	Base Metal Group	Nominal Wall Thickness in.	Nominal Wall Thickness mm	Min. Specified Tensile Strength, Base Metal ksi	Min. Specified Tensile Strength, Base Metal MPa	Min. Temp Required ˚F	Min. Temp Required ˚C	Min. Temp Recommended ˚F	Min. Temp Recommended ˚C
10	...	Cr-Cu steel	All	All	All	All	300–400	149–204	...	...
10A	...	Mn-V steel	All	All	All	All	...	...	175	79
10E	...	27Cr steel	All	All	All	All	300[4]	149[4]	...	...
11A SG 1	...	8Ni. 9Ni steel	All	All	All	All	...	...	50	10
11A SG 2	...	5Ni steel	All	All	All	All	50	10	...	...
21–52	...	...	All	All	All	All	...	...	50	10

Notes:

[1] P-Number from BPV Code, Section IX, Table QW-422, Special P-Numbers (SP-1, SP-2, SP-3, SP-4, and SP-5) require special consideration. The required thermal treatment for Special P-Numbers shall be established by the engineering design and demonstrated by the welding procedure qualification.

[2] A-Number from BPV Code, Section IX, Table QW-442.

[3] Maximum interpass temperature 315˚C (600˚F).

[4] Maintain interpass temperature between 177˚C–232˚C (350˚F–450˚F).

Source: ASME B31.3 "Process Piping" (New York, NY, USA: ASME, 1990), Table 330.1 and 1977 BPVC, Section III-NB. Used with permission from The American Society of Mechanical Engineers. All rights reserved.

POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND ALLOY STEELS

Base Metal P-Number[1]	Weld Metal Analysis A-Number[2]	Base Metal Group	Nominal Wall Thickness		Min. Specified Tensile Strength, Base Metal		Metal Temperature Range		Holding TIme		Brinell Hardness[4] Max.
			in.	mm	ksi	MPa	˚F	˚C	hr./in. Nominal Walt[3]	Min. Time, hr.	
1	1	Carbon steel	≤3/4	≤19	AllAll	All All	None	None	···	···	···
			>3.4	>19	≤71	≤490	1,100–1,200	593–649	1	1	···
3	2, 11	Alloy steels	≤3/4	≤19			None	None	···	···	···
		Cr≤ 1/2%	>3/4	>19	All	All	1,100–1,325	593–718	1	1	225
			All	All	>71	>490	1,100–1,325	593–718	1	1	225
4	3	Alloysteels	≤1/2	≤12.7	≤71	≤490	None	None	···	···	···
		1/2%≤Cr≤2%	>1/2	>12.7	All	All	1,300–1,375	704–746	1	2	225
			All	All	>71	>490	1,300–1,375	704–746	1	2	225
5	4, 5	Alloy steels									
		2 1/4% ≤Cr≤10% ≤3% Cr & ≤0.15% C &	≤1/2	≤12.7	All	All	None	None	···	···	···
		≥3% Cr or >0.15% C or	>1/2	>12.7	All	All	1,300–1,400	704–760	1	2	241

Base Metal P-Number[1]	Weld Metal Analysis A-Number[2]	Base Metal Group	Nominal Wall Thickness		Min. Specified Tensile Strength, Base Metal		Metal Temperature Range		Holding TIme		Brinell Hardness[4] Max.
			in.	mm	ksi	MPa	˚F	˚C	hr./in. Nominal Walt[3]	Min. Time, hr.	
6	6	High alloy steels martensitic	All	All	All	All	1350–1,450	732–788	1	2	241
		A 240 Gr. 429	All	All	All	All	1,150–1,225	621–663	1	2	241
7	7	High alloy steels ferritic	All	All	All	All	None	None	···	···	···
8	8, 9	High alloy steels austenitic	All	All	All	All	None	None	···	···	···
9A, 9B	10	Nickel alloy steels	≤3/4	≤19	All	All	None	None	···	···	···
	···		> 3/4	> 19	All	All	1,100–1,175	593–635	1/2	1	···
10	···	Cr-Cu steel	All	All	All	All	1,400–1,500[5]	760–816[5]	1/2	1/2	···
10A	···	Mn-V steel	≤3/4	≤19	≤71	≤490	None	None	···	···	···
			> 3/4	> 19	All	All	1,100–1,300	593–704	1	1	225
			All	All	> 71	> 490	1,100–1,300	593–704	1	1	225
10E	···	27Cr steel	All	All	All	All	1,225–1,300[6]	663–704[6]	1	1	···

Base Metal P-Number[1]	Weld Metal Analysis A-Number[2]	Base Metal Group	Nominal Wall Thickness		Min. Specified Tensile Strength, Base Metal		Metal Temperature Range		Holding TIme		Brinell Hardness[4] Max.
			in.	mm	ksi	MPa	˚F	˚C	hr./in. Nominal Walt[3]	Min. Time, hr.	
10H	···	Cr-Ni-Mo steel	All	All	All	All	See Note[7]		1/2	1/2	···
11A SG 1	···	8Ni, 9Ni steel	≤2	≤51	All	All	None	None	···	···	···
			>2	>51	All	All	1,025–1,085[8]	552–585[8]	1	1	···
11A SG 2	···	5Ni steel	>2	>51	All	All	1,025–1,085[8]	552–585[8]	1	1	···

Notes:

(1) P-Number from BPV Code, Section IX, Table QW-422. Special P-Numbers (SP-1, SP-2, SP-3, SP-4, and SP-5) require special consideration. The required thermal treatment for Special P-Numbers shall be established by the engineering design and demonstrated by the welding procedure qualification.
(2) A-Number from BPV Code, Section IX, Table QW-442.
(3) For SI equivalent, h/mm, divide hr./in. by 25.
(4) See 331.1.7.
(5) Cool as rapidly as possible after the hold period.
(6) Cooling rate to 650˚C (1,200˚F) shall be less than 55 ˚C(100˚F)/h; thereafter, the cooling rate shall be fast enough to prevent embrittlement.
(7) Postweld heat treatment is neither required nor prohibited, but any heat treatment applied shall be performed at 982˚C–1,038˚C (1,800˚F–1,900˚F) followed by rapid cooling.
(8) Cooling rate shall be >167˚C (300˚F)/hr. to 316˚C (600˚F).

Source: ASME B31.3 "Process Piping" (New York, NY, USA: ASME, 1990), Table 330.1 and 1977 BPVC, Section III-NB. Used with permission from The American Society of Mechanical Engineers. All rights reserved.

FILLER METALS SUITABLE FOR WELDING JOINTS BETWEEN DISSIMILAR AUSTENITIC STAINLESS STEELS

Suitable filler metals (listed in no preferred order, prefix ER omitted) Base metal B (type of steel being welded to base metal listed in the firstcolumn)

Base Metal A	Base Metal B 304L	306	309	309S	310	310S	316, 316 H	316	317	321, 321 H	347, 347 H 348, 348 H
304, 304H, 305	308L	308L	308, 309	306, 309	306, 309, 310	306, 309, 310	308, 316	308, 316	308, 316, 317	308	308
304L		308L	308, 309	306, 309	306, 309, 310	306, 309, 310	308, 316	308L, 316L	308, 316, 317	308L, 347	308L, 347
308			308, 309	306, 309	306, 309, 310	306, 309, 310	308, 316	308, 316	308, 316, 317	308	308, 347
309				309	309, 310	309, 310	309, 316	309, 316	309, 316	309, 347	309 347
309S					309, 310	309S, 310S	309, 316	309L, 316L	309, 316	309, 347	309 347
310							310, 316	310, 316	310, 317	308, 310	308, 310
310S							316	316	317	308, 310	308, 310
316, 316H								316	316, 317	308, 316	308, 316, 347
316L									317	316L	316L, 347
317										308, 317	308, 317, 347
321, 321H											308L, 347

Source: E.F. Nippes, ed., *Metals Handbook,* 9th ed., vol. 6 (Materials Park, OH, USA: ASM International, 1983), p. 335. Reprinted with permission from ASM International.

ELECTRODES AND FILLER METALS FOR DISSIMILAR JOINTS BETWEEN NICKEL ALLOYS AND OTHER METALS

		Carbon and Low Alloy Steels		300 Series Stainless Steels		Copper	
UNS	Common Name	Electrode	Filler Metal	Electrode	Filler Metal	Electrode	Filler Metal
N02200	Nickel 200	Weld A	82	Weld A	82	190	60
N04400	400 Alloy	190	61	Weld A	82	190	60
N05500	K-500 Alloy	190	61	Weld A	82	190	60
N06002	X Alloy	X	X	X	X		
N06022	C-22 Alloy	C-22	C-22	C-22	C-22		
N06030	G-30 Alloy	C-22	C-22	C-22	C-22		
N06455	C-4 Alloy	C-22	C-22	C-22	C-22		
N06600	600 Alloy	Weld A	82	Weld A	82	141	61
N06625	625 Alloy	Weld A	82	Weld A	82	141	61
N06985	G-3 Alloy	C-22	C-22	C-22	C-22		
N07718	718 Alloy	Weld A	82	Weld A	82	141	61
N07750	X-750 Alloy	Weld A	82	Weld A	82	141	61
N08020	20Cb-3	C-22	C-22	C-22	C-22		
N08366	AL-6X	C-22	C-22	C-22	C-22		
N08800	800 Alloy	Weld A	82	Weld A	82	141	61
N08825	825 Alloy	112	625	112	625	141	61
N08904	904L Alloy	C-22	C-22	C-22	C-22		
N10276	C-276 Alloy	C-276	C-276	C-276	C-276		
N10665	B-2 Alloy	B-2	B-2	B-2	B-2		

Designations for Nickel-Base Electrodes and Filler Metals:

Common	UNS	AWS
60	N04060	A5.14 (ERNiCu-7)
61	N02061	A5.14 (ERNi-1)
82	N06082	A5.14 (ERNiCr-3)
141	W82141	A5.11 (ENi-1)
190	W84190	A5.11 (ENiCu-7)
Weld A	W86133	A5.11 (ENiCrFe-2)

Source: This partial listing is adapted from Inco Alloys International "Joining" and Haynes International "Welding Filler Material Information."