HARDENING AND TEMPERING OF TOOL STEELS

AISI type	Rate of heating	Hardening: Preheat temperature °C	Hardening: Preheat temperature °F	Hardening: Hardening temperature °C	Hardening: Hardening temperature °F	Time at temperature, min	Quenching medium[a]	Tempering temperature °C	Tempering temperature °F
Molybdenum high-speed steels									
M1, M7, M10	Rapidly from preheat	730–845	1350–1550	1175–1220	2150–2225[b]	2–5	O, A, or S	540–595[c]	1000–1100[c]
M2	Rapidly from preheat	730–845	1350–1550	1190–1230	2175–2250[b]	2–5	O, A, or S	540–595[c]	1000–1100[c]
M3, M4, M30, M33, M34	Rapidly from preheat	730–845	1350–1550	1205–1230[b]	2200–2250[b]	2–5	O, A, or S	540–595[c]	1000–1100[c]
M6	Rapidly from preheat	790	1450	1175–1205[b]	2150–2200[b]	2–5	O, A, or S	540–595[c]	1000–1100[c]
M36	Rapidly from preheat	730–845	1350–1550	1220–1245[b]	2225–2275[b]	2–5	O, A, or S	540–595[c]	1000–1100[c]
M41	Rapidly from preheat	730–845	1350–1550	1190–1215[b]	2175–2220[b]	2–5	O, A, or S	540–595[d]	1000–1100[d]
M42	Rapidly from preheat	730–845	1350–1550	1190–1210[b]	2175–2210[b]	2–5	O, A, or S	510–595[d]	950–1100[d]
M43	Rapidly from preheat	730–845	1350–1550	1190–1215[b]	2175–2220[b]	2–5	O, A, or S	510–595[d]	950–1100[d]
M44	Rapidly from preheat	730–845	1350–1550	1200–1225[b]	2190–2240[b]	2–5	O, A, or S	540–625[d]	1000–1160[d]
M46	Rapidly from preheat	730–845	1350–1550	1190–1220[b]	2175–2225[b]	2–5	O, A, or S	525–565[d]	975–1050[d]
M47	Rapidly from preheat	730–845	1350–1550	1180–1205[b]	2150–2200[b]	2–5	O, A, or S	525–595[d]	975–1100[d]
Tungsten high-speed steels									
T1, T2, T4, T8	Rapidly from preheat	815–870	1500–1600	1260–1300[b]	2300–2375[b]	2–5	O, A, or S	540–595[c]	1000–1100[c]
T5, T6	Rapidly from preheat	815–870	1500–1600	1275–1300[b]	2325–2375[b]	2–5	O, A, or S	540–595[c]	1000–1100[c]
T15	Rapidly from preheat	815–870	1500–1600	1205–1260[b]	2200–2300[b]	2–5	O, A, or S	540–650[d]	1000–1200[d]
Chromium hot-work steels									
H10	Moderately from preheat	815	1500	1010–1040	1850–1900	15–40[e]	A	540–650	1000–1200
H11, H12	Moderately from preheat	815	1500	995–1025	1825–1875	15–40[e]	A	540–650	1000–1200
H13	Moderately from preheat	815	1500	995–1040	1825–1900	15–40[e]	A	540–650	1000–1200
H14	Moderately from preheat	815	1500	1010–1065	850–1950	15–40[e]	A	540–650	1000–1200
H19	Moderately from preheat	815	1500	1095–1205	2000–2200	2–5	A or O	540–705	1000–1300
Molybdenum hot-work steels									
H41, H43	Rapidly from preheat	730–845	1350–1550	1095–1190	2000–2175	2–5	O, A, or S	565–650	1050–1200
H42	Rapidly from preheat	730–845	1350–1550	1120–1220	2050–2225	2–5	O, A, or S	565–650	1050–1200
Tungsten hot-work steels									
H21, H22	Rapidly from preheat	815	1500	1095–1205	2000–2200	2–5	A or O	595–675	1100–1250
H23	Rapidly from preheat	845	1550	1205–1260	2200–2300	2–5	O	650–815	1200–1500
H24	Rapidly from preheat	815	1500	1095–1230	2000–2250	2–5	O	565–650	1050–1200
H25	Rapidly from preheat	815	1500	1150–1260	2100–2300	2–5	A or O	565–675	1050–1250
H26	Rapidly from preheat	870	1600	1175–1260	2150–2300	2–5	O, A, or S	565–675	1050–1250
Medium-alloy air-hardening cold-work steels									
A2	Slowly	790	1450	925–980	1700–1800	20–45	A	175–540	350–1000
A3	Slowly	790	1450	955–980	1750–1800	25–60	A	175–540	350–1000
A4	Slowly	675	1250	815–870	1500–1600	20–45	A	175–425	350–800
A6	Slowly	650	1200	830–870	1525–1600	20–45	A	150–425	300–800
A7	Very slowly	815	1500	955–980	1750–1800	30–60	A	150–540	300–1000
A8	Slowly	790	1450	980–1010	1800–1850	20–45	A	175–595	350–1100
A9	Slowly	790	1450	980–1025	1800–1875	20–45	A	510–620	950–1150
A10	Slowly	650	1200	790–815	1450–1500	30–60	A	175–425	350–800
Oil-hardening cold-work steels									
O1	Slowly	650	1200	790–815	1450–1500	10–30	O	175–260	350–500
O2	Slowly	650	1200	760–800	1400–1475	5–20	O	175–260	350–500
O6	Slowly	—	—	790–815	1450–1500	10–30	O	175–315	350–600
O7	Slowly	650	1200	790–830	W:1450–1525 O:1550–1625	10–30	O or W	175–290	350–550

AISI type	Rate of heating	Hardening: Preheat temperature °C	Hardening: Preheat temperature °F	Hardening: Hardening temperature °C	Hardening: Hardening temperature °F	Time at temperature, min	Quenching medium[a]	Tempering temperature °C	Tempering temperature °F
Shock-resisting steels									
S1	Slowly	—	—	900–955	1650–1750	15–45	O	205–650	400–1200
S2	Slowly	650[f]	1200[f]	845–900	1550–1650	5–20	B or W	175–425	350–800
S5	Slowly	760	1400	870–925	1600–1700	5–20	O	175–425	350–800
S7	Slowly	650–705	1200–1300	925–955	1700–1750	15–45	A or O	205–620	400–1150
Mold steels									
P2	—	900–925[g]	1650–1700[g]	830–845[h]	1525–1550[h]	15	O	175–260	350–500
P3	—	900–925[g]	1650–1700[g]	800–830[h]	1475–1525[h]	15	O	175–260	350–500
P4	—	970–995[g]	1775–1825[g]	970–995[h]	1775–1825[h]	15	A	175–480	350–900
P5	—	900–925[g]	1650–1700[g]	845–870[h]	1550–1600[h]	15	O or W	175–260	350–500
P6	—	900–925[g]	1650–1700[g]	790–815[h]	1450–1500[h]	15	A or O	175–230	350–450
P20	—	870–900[h]	1600–1650[h]	815–870	1500–1600	15	O	480–595[i]	900–1100[i]
P21[j]	Slowly	Do not preheat		705–730	1300–1350	60–180	A or O	510–550	950–1025
Low-alloy special-purpose steels									
L2	Slowly	—	—	W:790–845 O:845–925	W:1450–1550 O:1550–1700	10–30	O or W	175–540	350–1000
L3	Slowly	—	—	W:775–815 O:815–870	W:1425–1500 O:1500–1600	10–30	O or W	175–315	350–600
L6	Slowly	—	—	790–845	1450–1550	10–30	O	175–540	350–1000
Carbon-tungsten special-purpose steels									
F1, F2	Slowly	650	1200	790–870	1450–1600	15	W or B	175–260	350–500
Water-hardening steels									
W1, W2, W3	Slowly	565–650[k]	1050–1200[k]	760–815	1400–1550	10–30	B or W	175–345	350–650
High-carbon, high-chromium cold-work steels									
D1, D5	Very slowly	815	1500	980–1025	1800–1875	15–45	A	205–540	400–1000
D3	Very slowly	815	1500	925–980	1700–1800	15–45	O	205–540	400–1000
D4	Very slowly	815	1500	970–1010	1775–1850	15–45	A	205–540	400–1000
D7	Very slowly	815	1500	1010–1065	1850–1950	30–60	A	150–540	300–1000

(a) O, oil quench; A, air cool; S, salt bath quench; W, water quench; B, brine quench. (b) When the high-temperature heating is carried out in a salt bath, the range of temperatures should be about 15°C (25°F) lower than given in this line. (c) Double tempering recommended for not less than 1 h at temperature each time. (d) Triple tempering recommended for not less than 1 h at temperature each time. (e) Times apply to open-furnace heat treatment. For pack hardening, a common rule is to heat 1.2 min/mm (30 min/in.) of cross section of the pack. (f) Preferable for large tools to minimize decarburization. (g) Carburizing temperature. (h) After carburizing. (i) Carburized case hardness. (j) P21 is a precipitation-hardening steel having a thermal treatment that involves solution treating and aging rather than hardening and tempering. (k) Recommended for large tools and tools with intricate sections.

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