Common Heat Treating “Recipes”

A2 Tool Steel

APPLICATIONS: Punches and dies, chuck jaws, cutting tools for woodworking, tooling for plastic injection, dowel pins, hammers, industrial knives, and gage.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature: Ac1: 1460°F (793°C)

Preheating: Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1150-1250°F (621-677°C) and equalize. Then heat to 1300-1400°F (704-760°C).

Austenitizing (High Heat): Heat slowly from the preheat. Furnace or Salt: 1725-1750°F (941-954°C) Soak for 30 minutes for the first inch (25.4 mm) of thickness, plus 15 minutes for each additional inch (25.4 mm).

Quenching: Air, pressurized gas, or interrupted oil to 150-125°F(66-51°C).

Note: Sizes over 3 inches (76.2mm) in cross section may not achieve full hardness by cooling in still air. It is usually necessary to increase the quench cooling rate between 1400 to 900°F (760 to 482°C) by using an air blast, pressurized gas, or an interrupted oil quench. For the oil quench, quench until black, about 900°F (482°C), then cool in still air to 150-125°F(66-51°C).

Tempering: Temper immediately after quenching. Hold at temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum, then air cool to ambient temperature. The typical tempering range is 350 to 500°F (177 to 260°C).

To minimize internal stresses in cross sections greater than 6 inches (152.4 mm) and to improve stability in tools that will be EDM'd after heat treatment, a soaking time of 4 to 6 hours at the tempering temperature is strongly recommended.

Cryogenic Treatment: Some prefer to do cryogenic treatment as an extension of the quench from the austenitizing treatment. Others prefer to cryogenically treat after tempering.

Annealing: Annealing must be performed after hot working and before re-hardening.
Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1550°F (843°C) and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 235 HBW.

D2 Tool Steel

APPLICATIONS: Rolls, punches, dies for blanking, forming, trimming, and thread rolling, shear knives, food-processing knives, and gauges.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature:

Ac1: 1449°F (788°C)	Ac3: 1553°F (845°C)
Ar1: 1418°F (769°C)	Ar3: 1373°F (744°C)

Preheating: To minimize distortion and stresses in large or complex tools use a double preheat. Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1150-1250°F (621-677°C) equalize, then heat to 1400-1450°F (760-788°C). For normal tools, use only the second temperature range as a single preheating treatment.

Austenitizing (High Heat): Heat slowly from the preheat. Furnace or Salt: 1850-1875°F (1010-1024°C).

Quenching: Air or pressurized gas to 150-125ºF (66-51ºC). Sizes up to 4 inches (101.6 mm) in thickness will through harden when air cooled from 1575ºF (857ºC). Sizes up to 6 inches (152.4 mm) in thickness will through harden when air cooled from 1625ºF (885ºC).

Tempering: Temper immediately after quenching. Hold at temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum, then air cool to ambient temperature. The typical tempering range is 350 to 400ºF (177 to 204ºC).

For maximum wear resistance, temper between 300-350°F (149-177°C) for a hardness of 62-64 HRC. For the optimal balance between wear resistance and toughness, temper between 500-550°F (260-288°C). This will produce 58-60 HRC.

For maximum toughness, double temper, 2 hours plus 2 hours, at temperatures above 950°F (510°C). This will produce hardness of less than 58 HRC.

To minimize internal stresses in cross sections greater than 6 inches (152.4 mm) and to improve stability in tools that will be EDM'd after heat treatment, soaking times of 4 to 6 hours at the tempering temperature below 950°F (510°C) are strongly recommended.

Annealing: Annealing must be performed after hot working and before re-hardening. Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1600-1650°F (871-899°C) and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 255 HBW.

S7 Shock-Resisting Tool Steel

APPLICATIONS: Recommended for cold work tools that require resistance to high impact and shock loading, such as shear blades, swaging dies, gripper dies, chisels, and punches.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature:

Ac1: 1460°F (793°C)	Ac3: 1540°F (838°C)
Ar1: 1390°F (754°C)	Ar3: 1310°F (710°C)

Preheating: Heat at a rate not exceeding 400°F per hour (222°C per hour). For complex and large tools, heat to 1150-1250°F (621-677°C) and equalize. Then heat to 1300-1400°F (704-760°C) and equalize. For simple geometries, use only the second preheating temperature range.

Austenitizing (High Heat): Heat slowly from the preheat. Furnace or Salt: 1725°F (941°C). Soak for 30 minutes for the first inch (25.4 mm) of thickness, plus 15 minutes for each additional inch (25.4 mm) of thickness.

Quenching: Air, pressurized gas, or warm oil to 150-125°F (66-51°C). Note: Sizes over 2½ inches (63.5mm) in cross section will not achieve full hardness by cooling in air. It is necessary to increase the quench cooling rate between 1400 to 900°F (760 to 482°C) by using pressurized gas or an interrupted oil quench. For the oil quench, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Hold at temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum, then air cool to ambient temperature. The typical tempering range for cold work tools is 400 to 500°F (204 to 260°C).

To minimize internal stresses in cross sections greater than 6 inches (152.4 mm) and to improve stability in tools that will be EDM'd after heat treatment, a soaking time of 4 to 6 hours at the tempering temperature is strongly recommended.

For hot work tool applications, tempering at a temperature in excess of 900°F (482°C) is recommended, and double tempering is required.

Cryogenic Treatment: *Some prefer to do cryogenic treatment as an extension of the quench from the austenitizing treatment. Others prefer to cryogenically treat after tempering.*

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1550°F (843°C) and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 223 HBW.

S5 Shock-Resisting Tool Steel

APPLICATIONS: Pneumatic tools, shear blades, mandrels, heavy-duty punches, and stamping dies.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature:

Ac1: 1410°F (766°C)

Preheating: Heat at a rate not exceeding 400°F per hour (222°C per hour). For complex and large tools, heat to 1150-1250°F (621-677°C) and equalize. Then heat to 1300-1400°F (704-760°C) and equalize. For simple geometries, use only the second preheating temperature range.

Austenitizing (High Heat): Heat slowly from the preheat. For Oil Quenching: 1600 - 1700°F (871 - 927°C) For Water Quenching: 1550 - 1650°F (842 - 899°C) Soak for 30 minutes for the first inch (25.4 mm) of thickness, plus 15 minutes for each additional inch (25.4 mm) of thickness.

Quenching: Oil or water to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Hold at temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum, then air cool to ambient temperature. To minimize internal stresses in cross sections greater than 6 inches (152.4 mm) and to improve stability in tools that will be EDM'd after heat treatment, a soaking time of 4 to 6 hours at the tempering temperature is strongly recommended.

Cryogenic Treatment: *Some prefer to do cryogenic treatment as an extension of the quench from the austenitizing treatment. Others prefer to cryogenically treat after tempering.*

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1425 - 1475°F (773 - 801°C) and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 229 HBW.

O1 Tool Steel

APPLICATIONS: Where greater dimensional stability in heat treatment or improved wear resistance is required, tool steels with higher alloy contents, such as A2 or D2 should be considered.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature:

Ac1: 1350°F (732°C)	Ac3: 1400°F (760°C)
Ar1: 1295°F (703°C)	Ar3: 1240°F (671°C)

Preheating: Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1200-1300°F (649-704°C) and equalize.

Austenitizing (High Heat): Heat slowly from the preheat to 1475-1500°F (802-816C)

Soak for 30 minutes for the first inch (25.4 mm) of thickness, plus 15 minutes for each additional inch (25.4 mm).

Quenching: Oil quench to a temperature no lower than 150-125°F (66-51°C).

Note: O1 is somewhat prone to quench cracking, especially if there are significant changes in section thickness and sharp internal corners. The oil quenching should be performed so that the heat removal is as uniform as possible in all areas of the part being quenched. Be sure to remove the part from the oil before the temperature drops to ambient temperature. Hot oil at a temperature of 300 to 400°F (149-204°C) is recommended.

Tempering: Temper immediately after quenching. Do not allow the part to cool below 125°F (51°C). The typical tempering range is 350 - 400°F (177 -204°C). Hold at temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum, then air cool to ambient temperature. To minimize internal stresses in cross sections greater than 3 inches (76.2 mm) and to improve stability in parts that will be EDM'd after heat treatment, a soaking time of 4 to 6 hours at the tempering temperature is strongly recommended.

Cryogenic Treatment: *Refrigeration treatments should typically be performed after the temper and must be followed by a second temper.*

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1425 -1450°F (802-816°C) and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 212 HBW.

H13 Tool Steel

APPLICATIONS: Inserts, cores, and cavities for die casting dies, die casting shot sleeves, hot forging dies, extrusion dies, and plastic mold cavities and components that require high toughness and excellent polishability.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature:

Ac1: 1544°F (840°C)	Ac3: 1634°F (890°C)
Ar1: 1475°F (802°C)	Ar3: 1418°F (826°C)

Preheating: To minimize distortion in complex tools use a double preheat. Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1150-1250°F (621-677°C), equalize, then raise to 1500-1600°F (816-871°C) and equalize. For normal tools, use only the second temperature range as a single preheating treatment.

Austenitizing (High Heat): Heat rapidly from the preheat. Furnace or Salt: 1800-1890°F (982-1032°C) For maximum toughness, use 1800°F (982°C) For maximum hardness and resistance to thermal fatigue cracking and wear use 1890 (1032°C). Soak at temperature for 30 to 90 minutes.

Quenching: Air, pressurized gas, or warm oil. Section thicknesses up to and including 5 inches (127 mm) will typically fully through harden when cooled in still air from the austenitizing treatment. Sections greater than 5 inches (127 mm) in thickness will require accelerated cooling by using forced air, pressurized gas, or an interrupted oil quench to obtain maximum hardness, toughness and resistance to thermal fatigue cracking.

For pressurized gas quenching, a minimum quench rate of approximately 50°F per minute (28°C per minute) to below 1000°F (538°C) is required to obtain the optimum properties in the steel.

For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. The typical tempering range is 1000-1150°F (538-621°C). Hold at the tempering temperature for 1 hour per inch (25.4mm) of thickness, but for 2 hours minimum, then air cool to ambient temperature. Double tempering is required. To maximize toughness and tool performance, a third temper is often used as a stress relief after all finish machining, grinding, and EDM work are completed on the tool.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1575-1625°F (857-885°C) and hold at temperature for 1 hour per inch of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 235 HBS.

Premium H13 Hot Work Die Steel

Applications: Premium H13 provides the highest performance in typical applications such as inserts, cores and cavities for die casting dies, die casting shot sleeves, hot forging dies, extrusion dies, and plastic mold cavities and components that require high toughness and excellent polishability.

HEAT TREATING INSTRUCTIONS

CRITICAL TEMPERATURES

Ac1: 1544°F (840°C) Ac3: 1634°F (890°C)

Ar3: 1475°F (802°C) Ar3: 1418°F (826°C)

HARDENING

Preheating: To minimize distortion in complex tools use a double preheat. Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1150-1250°F (621-677°C), then equalize, then raise to 1500-1600°F (816-871°C) and equalize. For normal tools, use only the second temperature range as a single preheating treatment

Austenitizing (High Heat): Heat rapidly from the preheat. Furnace or Salt Bath: 1800-1890°F (982-1032°C). For maximum toughness, use 1800F (982°C). For maximum hardness and resistance to thermal fatigue cracking and wear use 1890°F (1032°C). Soak at temperature for 30 to 90 minutes.

Quenching: Air, pressurized gas or warm oil. Section thicknesses up to and including 5 inches (127mm) will typically fully through harden when cooled in still air from the austenitizing treatment. Sections greater than 5 inches (127mm) in thickness will require accelerated cooling by using forced air, pressurized gas, or an interrupted oil quench to obtain maximum hardness, toughness and resistance to thermal fatigue cracking.

For pressurized gas quenching a minimum quench rate of approximately 50°F per minute (28.5°C per minute) to below 1000°F (538°C) is required to obtain the optimum properties in the steel. For vacuum heat treatment of die casting die components, the heat treatment practices detailed in the latest revision of NADCA 207 are strongly recommended. For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. The typical tempering range is 1000-1150°F (538-621°C). Hold at tempering temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum, then air cool to ambient temperature. Double tempering is required.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1575-1625°F (857-885°C), and hold at temperature for 1 hour per inch of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 235 HBW.

P20 Mold Steel

Applications: Commonly used for plastic injection mold cavities, tooling and for die casting dies for zinc. P20 is typically sold in the pre-hardened condition at a hardness of approximately 300 HBW.

HEAT TREATING INSTRUCTIONS

STRESS RELIEVING

Preheating: Because P20 is sold in a pre-hardened condition, hardening heat treatment is not necessary. After machining and intermittently during service, the steel must be thermally stress relieved by heating to 900ºF (482ºC), equalizing and holding for one hour per inch (25.4mm) of thickness, and cooling in air to ambient temperature.

In those rare circumstances where the steel must be re-hardened, the steel must first be annealed prior to hardening.

HARDENING

Critical Temperature:
Ac1: 1405ºF (763ºC)

Preheating: Heat at a rate not exceeding 400ºF per hour (222ºC per hour) to 1150-1250ºF (621-677ºC) and equalize.

Austenitizing (High Heat): Heat rapidly from the preheat to 1550ºF (843°C). Soak for 30 minutes for first inch (25.4mm) of thickness, plus 15 minutes for each additional inch (25.4mm).

Quenching: Pressurized gas, or interrupted oil to 150-125ºF (66-51ºC).

For oil, quench until black, at about 900°F (482°C), then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching or cryogenic treatment. Hold at the temperature for 1 hour per inch (25.4mm) of thickness, 2 hours minimum, then air cool to ambient temperature. Tempering temperatures and hardness are given in chart above.

Annealing: Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1450°F (788°C) and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50ºF per hour (28ºC per hour) to 1150ºF (621ºC). Continue cooling to ambient temperature in the furnace or in air.

420 MQ Plastic Mold Steel

APPLICATIONS: Plastic mold cavities, plastic extrusion dies, cutlery, surgical and dental instruments, gauges, valves, shafts, cams and ball bearings.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperatures: Ac1: 1475ºF (802ºC) Ac3: 1585ºF (863ºC)

Preheating: To minimize distortion in complex tools use a double preheat. Heat at a rate not exceeding 400º per hour (222º C per hour) to 1150-1250ºF (621- 677ºC), equalize, then raise to 1400-1500ºF (760-816ºC) and equalize. For normal tools, use only the second temperature as a single preheating treatment.

Austenitizing (High Heat): Heat rapidly from the preheat. Furnace or Salt: 1800-1900°F (982-1038°C). For maximum toughness, use 1800ºF (982ºC). For maximum resistance to thermal fatigue, use 1900ºF (1038ºC).

Quenching: Air, pressurized gas, or warm oil. Section thicknesses up to and including 5 inches (127 mm) in thickness. Add an additional 10 minutes of soak time for each additional inch (25.4 mm) of thickness. For pressurized gas, a minimum quench rate of approximately 30ºF per minute (18ºC) per minute to below 1000ºF (538ºC) is required to obtain the optimum properties in the steel. For oil, quench until black, about 900ºF (482ºC), then cool in still air to 150-125ºF (66-51ºC).

Tempering: Temper immediately after quenching. The typical tempering range of 700ºF (371ºC) will result in a hardness of approximately 51 to 53 HRC. However, tempering temperatures in the range of 400 to 775ºF (204-413ºC) may be used. Hold at the tempering temperature for 1 hour per inch (25.4 mm) of thickness, but for no less than 4 hours, then air cool to ambient temperature. Double tempering is required. To maximize toughness, a third temper is recommended.

Annealing: Annealing must be performed after hot working and before re-hardening. Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1525-1625°F (830-885°C) and hold at temperature for 1 hour per inch of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 40°F per hour (22°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 235 HBW.

M2 High Speed Steel

APPLICATIONS: Twist drills, taps, milling cutters, reamers, broaches, saws, and knives.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature:

Ac1: 1530°F (832°C)	Ac3: 1610°F (877°C)
Ar1: 1430°F (777°C)	Ar3: 1380°F (749°C)

Preheating: To minimize distortion and stresses in large or complex tools use a double preheat. Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1100°F (593°C) equalize, then heat to 1450-1550°F (788-843°C). For normal tools, use only the second temperature range as a single preheating treatment.

Austenitizing (High Heat): Heat rapidly from the preheat.
For Cutting Tools:
Furnace: 2200-2250°F (1204-1232°C)
Salt: 2175-2225°F (1191-1218°C)
To maximize toughness, use the lowest temperature.
To maximize hot hardness, use the highest temperature.
For punches, dies, and tools that require maximum toughness without hot hardness:
Furnace: 2075-2175°F (1175-1191°C)
Salt: 2050-2150°F (1121-1177°C)

Quenching: Pressurized gas, warm oil, or salt. For pressurized gas, a rapid quench rate to below 1000°F (538°C) is critical to obtain the desired properties. For oil, quench until black, about 900°F (482°C), then cool in still air to 150 -125°F (66-51°C). For salt maintained at 1000-1100°F (538-593°C), equalize, then cool in still air to 150 -125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical tempering range is 1025-1050°F (552-566°C). Hold at temperature for 2 hours, then air cool to ambient temperature. Double tempering is required. For large cross sections, and especially for blanks from which tools will be cut by wire EDM, triple tempering is strongly recommended.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1525-1550°F (829-843°C) and hold at temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be 248 HBW or lower.

M42 Super High-Speed Steel

APPLICATIONS: Twist drills, taps, milling cutters, reamers, broaches, saws, knives, and thread rolling dies.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature:

Ac1: 1560°F (849°C)

Preheating: Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1500-1600°F (816-871°C), and equalize.

Austenitizing (High Heat): Heat rapidly from the preheat.
Furnace: 2150-2175°F (1177-1191°C)
Salt: 2125-2150°F (1163-1177°C)

To maximize toughness, use the lowest temperature.
To maximize hot hardness, use the highest temperature.

Quenching: Pressurized gas, warm oil, or salt. For pressurized gas, a rapid quench rate to below 1000°F
(538°C) is critical to obtain the desired properties.
For oil, quench until black, about 900°F (482°C), then cool in still air to 150 -125°F (66-51°C).
For salt maintained at 1000-1100°F (538-593°C), equalize, then cool in still air to 150 -125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical tempering range is 950-1050°F (510-566°C). Hold at temperature for 2 hours, then air cool to ambient temperature. Triple tempering is required.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1500-1575°F (843-857°C), and hold for 1 hour per inch (25.4 mm) of thickness, minimum of 2 hours. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be 269 HBW or lower.

Forging: Preheat to 1200-1400°F (649-760°C) and equalize. Then heat rapidly to 2000-2100°F (1093-1149°C) and equalize prior to forging. Reheat if work piece temperature falls below 1800°F (982°C). After forging, cool slowly to ambient temperature in the furnace or buried in insulating material, then anneal as described above.

A6 Tool Steel

APPLICATIONS: Blanking and forming dies, trim dies, bending and forming tools, mandrels, chuck jaws, tooling for plastic injection molding, dowel pins, shear knives, and gauges.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature: Ac1: 1340ºF (727ºC)

Preheating: Heat at a rate not exceeding 400ºF per hour (222ºC per hour) to 1200-1300ºF (649-704ºC) and equalize.

Austenitizing (High Heat): Heat slowly from the preheat. Furnace or Salt: 1525-1625ºF (829-885ºC) Soak for 30 minutes for the first inch (25.4 mm) of thickness, plus 15 minutes for each additional inch (25.4 mm).

Quenching: Air or pressurized gas to 150-125ºF (66- 51ºC). Sizes up to 4 inches (101.6 mm) in thickness will through harden when air cooled from 1575ºF (857ºC). Sizes up to 6 inches (152.4 mm) in thickness will through harden when air cooled from 1625ºF (885ºC).

Tempering: Temper immediately after quenching. Hold at temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum, then air cool to ambient temperature. The typical tempering range is 350 to 400ºF (177 to 204ºC).

To minimize internal stresses in cross sections greater than 6 inches (152.4 mm) and to improve stability in tools that will be EDM'd after heat treatment, a soaking time of 4 to 6 hours at the tempering temperature is strongly recommended.

Cryogenic Treatment: *Some prefer to do cryogenic treatment as an extension of the quench from the austenitizing treatment. Others prefer to cryogenically treat after tempering.*

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400ºF per hour (222ºC per hour) to 1370ºF (743ºC), and hold at temperature for 1 hour per inch (25.4 mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 20ºF per hour (11ºC per hour) to 950ºF (510ºC). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 248 HBW.

A7 Wear-Resistant Tool Steel

APPLICATIONS: Brick mold liners, sand slinger liners, shot blasting equipment liners, extrusion tools for ceramics, powder compaction tooling, and machine tool ways.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature: Ac1: 1340ºF (727ºC)

Preheating: Heat at a rate not exceeding 400ºF per hour (222ºC per hour) to 1200-1300ºF (649-704ºC) and equalize.

Austenitizing (High Heat): Heat rapidly from the preheat. Furnace or Salt: 1700-1800°F (927-982°C). For maximum toughness, use 1700°F (927°C). For maximum wear resistance use 1800°F (982°C).

Soak at temperature for 15 minutes per inch (25.4 mm) of thickness; 30 minutes minimum.

Quenching: Air or pressurized gas. For air cooling, cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical tempering temperature is 300°F (149°C) for maximum wear resistance. Hold at temperature for four hours then air cool to ambient temperature.

For maximum toughness, double temper, 2 hours plus 2 hours, at temperatures above 900°F (482°C).

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1500-1550°F (816-843°C), and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 293 HBW.

Graph-Air® (A10) Cold Work Tool Steel

APPLICATIONS: Thread gauges, master gages, cams, bushings, sleeves, meat granulator plates, arbors, forming rolls, shear blades, punches, dies, bar feed guides and other machine tool parts.

HEAT TREATING INSTRUCTIONS

HARDENING

Preheating: Preheating is not required, but for tools with complex geometries, may be beneficial for dimensional stability. Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1200-1250°F (649-677°C) and equalize.

Austenitizing (High Heat): Heat slowly from the preheat to 1450-1550°F (788-843°C).

Up to 2 in. (51mm) thickness: use 1450°F (788°C)
2 in. (51mm) to 4 in. (101.6mm) thickness: use 1475°F (802°C).
Over 4 in. (101.6mm) thickness: use 1500°F (816°C)

Quenching: Pressurized gas, warm oil, or salt. For pressurized gas, a rapid quench rate to below 1000°F (538°C) is critical to obtain the desired properties. For oil, quench until black, about 900°F (482°C), then cool in still air to 150 -125°F (66-51°C). For salt maintained at 1000-1100°F (538-593°C), equalize, then cool in still air to 150 -125°F (66-51°C).

Tempering: Temper immediately after quenching. The typical tempering range is 300 - 500°F (149 - 260°C). Hold at temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum, then air cool to ambient temperature. The actual hardness obtained is dependent upon the section size of the part being quenched and tempered

To minimize internal stresses in cross sections greater than 3 inches (76.2 mm) and to improve stability in parts that will be EDM'd after heat treatment, a soaking time of 4 to 6 hours at the tempering temperature is strongly recommended.

Cryogenic Treatment: Refrigeration treatments should typically be performed after the temper and must be followed by a second temper.

Annealing: Annealing must be performed after hot working. Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1450°F (788°C) and hold at temperature for 2 hours. Cool at 20°F (11°C) per hour to 900°F (482°C) then air cool to ambient temperature. Reheat to 1150°F (621°C), hold for 6 hours, then air cool to ambient temperature. The resultant hardness should be a maximum of 269 HBW.

SOFTENING FOR REWORKING

To anneal for reworking after a tool has been hardened, an abbreviated treatment may be used. Heat to 1450°F (788°C), hold for 2 hours. Cool to 1260°F (682°C) at any convenient rate, then cool at 20°F (11°C) per hour from 1260 (682°C) to 1000°F (538°C). Hold at 1000°F (538°C) for 3 hours, then air cool to ambient temperature.

O6 Cold Work Tool Steel

APPLICATIONS: Thread gauges, master gages, cams, bushings, sleeves, meat granulator plates, arbors, forming rolls, shear blades, punches, dies, bar feed guides and other machine tool parts.

HEAT TREATING INSTRUCTIONS

HARDENING

Preheating: Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1200-1250°F (649-677°C) and equalize.

Austenitizing (High Heat): Heat slowly from the preheat to 1450-1550°F (788-843°C).
Less than ½ inch (12.7mm) thickness: use 1450°F (788°C)
½ to 2 inches (12.7 to 51mm) thickness: use 1475°F (802°C)
Over 2 inches (51mm) thickness: use 1500°F (816°C)

Quenching: Oil or pressurized gas.

For oil, quench to 150 - 125°F (66 - 51°C)

For pressurized gas, the quench rate to below 1000°F (538°C) should be a minimum of 400°F 222°C) per minute and is critical for obtaining the desired properties.

Tempering: Temper immediately after quenching. The typical tempering range is 300 - 400°F (149 - 204°C). Hold at temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum, then air cool to ambient temperature. The actual hardness obtained is dependent upon the section size of the part being quenched and tempered. To minimize internal stresses in cross sections greater than 3 inches (76.2 mm) and to improve stability in parts that will be EDM'd after heat treatment, a soaking time of 4 to 6 hours at the tempering temperature is strongly recommended.

Cryogenic Treatment: Refrigeration treatments should typically be performed after the temper and must be followed by a second temper.

Annealing: Annealing must be performed after hot working and before re hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1450°F (816°C) and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness, 2 hours minimum. Then cool at 10°F (5.5°C) per hour to 1300°F (704°C). Then cool at 25°F (14°C) per hour from 1300°F (704°C) to 1000°F (538°C). Then cool in air to ambient temperature. The resultant hardness should be a maximum of 229 HBW.

D3 Tool Steel

APPLICATIONS: Forming rolls, drawing dies, forming, powder compaction tooling, and lamination dies.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature:

Ac1: 1440°F (782°C)	Ac3: 1530°F (832°C)
Ar1: 1410°F (766°C)	Ar3: 1370°F (743°C)

Preheating: To minimize distortion and stresses in large or complex tools use a double preheat. Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1200-1250°F (649-677°C) equalize, then heat to 1400-1450°F (760-788°C). For normal tools, use only the first temperature range as a single preheating treatment.

Austenitizing (High Heat): Heat slowly from the preheat to 1700-1750°F (927-954°C)

Quenching: For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C).

For pressurized gas, the furnace should have a minimum quench pressure of 4 bars. A quench rate of approximately 400°F (222°C) per minute to below 1000°F (538°C) is critical to obtain the desired properties.

Tempering: Temper immediately after quenching. Hold at temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum, then air cool to ambient temperature.

For maximum wear resistance, temper between 300-350°F (149-177°C) for a hardness of 62-63 HRC. For the optimal balance between wear resistance and toughness, temper between 450-500°F (232-260°C). This will produce 58-60 HRC.

To minimize internal stresses in cross sections greater than 6 inches (152.4 mm) and to improve stability in tools that will be EDM'd after heat treatment, soaking times of 4 to 6 hours at the tempering temperature are strongly recommended.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1600-1650°F (871-899°C) and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 255 HBW.

Cryogenic Treatment: Refrigeration treatments should typically be performed after the first temper, and must be followed by a second temper

D7 Tool Steel

APPLICATIONS: Brick mold liners, briquetting dies, shot blasting equipment liners, tools for ceramic extrusion and molding, powder compaction tooling, deep drawing dies, flattening rolls, and machine tool ways.

HEAT TREATING INSTRUCTIONS

HARDENING

Preheating: 1400-1500°F (760-816°C)

Austenitizing (High Heat): Heat rapidly from the preheat. Furnace or Salt: 1850-2000°F (1010-1093°C) For maximum toughness, use 1850-1900°F (1010-1038°C). For maximum wear resistance use 1950-2000°F (1038-1093°C).

Soak at temperature for 15 minutes per inch (25.4 mm) of thickness; 30 minutes minimum. A minimal dimensional change will occur if an austenitizing temperature of 1900°F (1038°C) is used.

Quenching: Air, warm oil, or pressurized gas. For air cooling, cool in still air to 150-125°F (66-51°C). Sections 10 inches (254 mm) thick or more must be quenched at a faster rate, using one of the methods below, to attain maximum hardness.

For pressurized gas, a minimum quench rate of 300°F per minute (167°C per minute) to below 1000°F (538°C) is critical to obtain the desired properties. For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C). For salt maintained at 1000-1100°F (538-593°C), equalize in the salt, then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. The typical tempering temperature is 300°F (149°C) for maximum wear resistance. Hold at temperature for four hours then air cool to ambient temperature. For maximum toughness, double temper, 2 hours plus 2 hours, at temperatures above 950°F (510°C).

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1600-1650°F (871-899°C),

and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 262 HBW.

L6 Tool Steel

APPLICATIONS: Punches and dies, cold forming tools, and coining dies.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature: Ac1: 1325°F (719°C)

Preheating: Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1150-1250°F (621-677°C) and equalize.

Austenitizing (High Heat): Heat slowly from the preheat.
Furnace or Salt: 1450-1500°F (788-816C)
Soak for 30 minutes for the first inch (25.4 mm) of thickness, plus 15 minutes for each additional inch (25.4 mm).

Quenching: Oil to 150-125°F (66-51°C).

Note: *Sizes under 3 inches (76.2mm) in cross section will achieve moderate hardness by cooling in a blast of air or pressurized gas.*

Tempering: Temper immediately after quenching. Hold at temperature for 1 hour per inch (25.4 mm) of thickness, 4 hours minimum, then air cool to ambient temperature.

To minimize internal stresses in cross sections greater than 6 inches (152.4 mm) and to improve stability in tools that will be EDM'd after heat treatment, a soaking time of 8 to 10 hours at the tempering temperature is strongly recommended.

Cryogenic Treatment: *Some prefer to do cryogenic treatment as an extension of the quench from the austenitizing treatment. Others prefer to cryogenically treat after tempering.*

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1400°F (760°C) and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 235 HBW.

For improved machinability, hold at 1400°F (760°C) for1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace cool from 1400°F (760°C) to 1250°F (677°C), hold for 8 hours, then air cool to ambient temperature. The resultant hardness should be a maximum of 192 HBW.

Lescowear™ Cold Work Tool Steel

APPLICATIONS: Punches, blanking dies, thread roll dies, coining dies, drawing dies, upsetting dies, and rolls.

HEAT TREATING INSTRUCTIONS

HARDENING

Preheating: To minimize distortion and stresses in large or complex tools use a double preheat. Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1150-1250°F (621-677°C) equalize, then heat to 1500-1550°F (816-843°C). For normal tools, use only the second temperature range as a single preheating treatment.

Austenitizing (High Heat): Heat rapidly from the preheat. Furnace or Salt: 1900-2000°F (1038-1093°C)

Equalize and soak at the austenitizing temperature for 30 minutes for pieces up to 1 inch (25.4 mm) in thickness, plus 15 minutes for each additional inch (25.4 mm) of thickness.

For maximum toughness, austenitize at the low end of the recommended range. For maximum wear resistance, austenitize at the upper end of the recommended range.

Quenching: Cool in still to 150-125°F(66-51°C).

Tempering: Temper immediately after quenching. Hold at temperature for 1 hour per inch (25.4 mm) of thickness, 2 hours minimum, then air cool to ambient temperature. Typical tempering temperatures are 950 to 1100°F (510 to 593°C).

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1550-1650°F (843-899°C) and hold at temperature for 1 hour per inch (25.4mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 25°F per hour (11°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 241 HBW.

CPM 1V Powder Metal Tool Steel

APPLICATIONS: CMP 1V should be considered for service in blanking dies, sizing dies, shear blades, cold and hot forging punches, forging dies, gear rolling dies, and many other applications where a combination of strength and toughness is required. CPM 1V should also be considered for severe applications where only steels such as S7, A9, and the high-alloy hot work steels have been suitable.

HEAT TREATING INSTRUCTIONS

HARDENING

Preheating: 1500-1550°F (816-845°C), equalize.
Austenitizing (High Heat): Heat rapidly from the preheat.
Furnace: 1950-2025°F (1066-1107°C)
Salt Bath: 1925-2000°F (1052-1093°C)

Quenching: Pressurized gas, warm oil, or air.

For pressurized gas, a quench rate of approximately 400°F (222°C) per minute to below 1000°F (538°C) is critical to obtain the desired properties.

For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical temperature range is 950-1100°F (510-593°C). Do not temper below 950°F (510°C). Hold at temperature for 2 hours then air cool to ambient temperature. Double tempering is required. Triple tempering is recommended if tools will be wire EDM'd from a solid block after heat treatment.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1575-1600°F (854-871°C) and hold at temperature for 1 hour per inch of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 255 HRW.

CPM 3V Powder Metal Tool Steel

APPLICATIONS: CPM 3V should be considered for service in blanking & sizing dies, shear blades, cold and hot forging punches, powder compaction tooling and many other applications where a combination of strength, wear resistance and toughness is required.

HEAT TREATING INSTRUCTIONS

HARDENING

Preheating: 1500-1550°F (816-845°C), equalize.

Austenitizing (High Heat): Heat rapidly from the preheat.

For Maximum Wear Resistance: Furnace or Salt Bath: 2000-2050°F (1093-1121°C)
Soak for 20 minutes minimum at temperature.

For Balanced Wear & Toughness:
Furnace or Salt Bath: 1950°F (1066°C)
Soak for 20 minutes minimum at temperature

For Maximum Toughness:
Furnace or Salt Bath: 1875-1900°F (1024-1038°C)
Soak for 45 minutes minimum at temperature

Quenching: Air, pressurized gas, warm oil, or salt. For pressurized gas, the furnace should have a minimum quench pressure of 4 bars. For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C), then cool in still air to 150-125°F (66-51°C). For salt maintained at 1000-1100°F (538-593°C), equalize in the salt, then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical temperature range is 1000-1100°F (524-593°C). Do not temper below 950°F (510°C). Hold at temperature for 1 hour per inch of thickness, 2 hours minimum, then air cool to ambient temperature. Double tempering is required. Triple tempering is recommended when austenitized at 2000°F (1093°C) or above and when tooling will be wire EDM'd from a solid block after heat treatment.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1600-1650°F (871-899°C) and hold at temperature for 1 hour per inch of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be approximately 241 HBW.

CPM 4V Powder Metal Tool Steel

Applications: CPM 4V should be considered for applications where a higher attainable hardness and additional abrasion resistance is required than can be offered by CPM 3V.

HEAT TREATING INSTRUCTIONS

HARDENING

Preheating: 1500-1550°F (816-845°C), equalize.

Austenitizing (High Heat): Heat rapidly from the preheat.

For Maximum Wear Resistance:

- Furnace or Salt Bath: 2100°F (1149°C)
- Soak for 15 minutes at temperature

For Balanced Wear & Toughness:

- Furnace or Salt Bath: 1875-1950°F (1024-1065°C)
- Soak for 30 minutes at temperature

For Maximum Toughness:

- Furnace or Salt Bath: 1800°F (982°C)
- Soak for 30 minutes at temperature

Quenching: Air, pressurized gas, warm oil, or salt.

For pressurized gas, the furnace should have a minimum quench pressure of 4 bars.

For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C).

For salt maintained at 1000-1100°F (538-593°C), equalize in the salt, then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical temperature range is 1000-1100°F (524-593°C). Do not temper below 950°F (510°C). Hold at temperature for 1 hour per inch of thickness, 2 hours minimum, then air cool to ambient temperature. Double tempering is required.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1600-1650°F (871-899°C) and hold at temperature for 1 hour per inch of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be approximately 241 HBW.

CPM 9V Powder Metal Tool Steel

APPLICATIONS: CPM 9V is widely used for plastic injection feed screws, non-return valves, shear blades, and forging dies.

HEAT TREATING INSTRUCTIONS

Critical Temperature: Ac1: 1590°F (866°C)

HARDENING

Preheating: 1500-1550°F (816-845°C), equalize.

Austenitizing (High Heat): Heat rapidly from the preheat, typically by transferring to a second furnace.

For Higher Wear Resistance:
Furnace or Salt Bath: 2050°F (1121°C)
Soak for 25 minutes minimum at temperature

For Balance of Wear Resistance and Toughness:
Furnace or Salt Bath: 1950-2000°F (1066-1093°C)
Soak for 25 minutes minimum at temperature

For Maximum Toughness and minimum distortion in cooling:
Furnace: 1900°F (1038°C)
Salt Bath: 1875°F (1025°C)
Soak for 45 minutes minimum at temperature

Quenching: Air, pressurized gas, warm oil, or salt. Warm oil or salt bath quenching will give maximum hardening response. For pressurized gas, the furnace should have a minimum quench pressure of 4 bars. The quench rate to below 1000°F (538°C) is critical to obtain the desired properties.

For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C). For salt maintained at 1000-1100°F (538-593°C), equalize in the salt, then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical temperature range is 1000-1100°F (538-593°C). Do not temper below 1000°F (538°C). Hold at temperature for 2 hours then air cool to ambient temperature. Double tempering is required. Triple tempering is required when austenitized above 2050°F (1121°C).

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1600-1650°F (871-899°C) and hold at temperature for 1 hour per inch of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 30°F per hour (17°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 277 HBW.

CPM 10V Powder Metal Tool Steel

APPLICATIONS: Suitable for use in cold work tooling applications requiring maximum wear resistance such as thread roll dies, punches, blanking dies, shears, nozzles, screw tips, barrel liners and powder compaction tooling.

HEAT TREATING INSTRUCTIONS

Critical Temperature: Ac1: 1540°F (838°C)

HARDENING

Preheating: 1500-1550°F (816-845°C), equalize.

Austenitizing (High Heat): Heat rapidly from the preheat, typically by transferring to a second furnace.

For Optimum Wear Resistance:
Soak for 5 to 15 minutes
Furnace or Salt Bath: 2150 (1177°C)

For Balance of Wear Resistance and Toughness:
Soak for 15 to 30 minutes.
Furnace or Salt Bath: 2050°F (1121°C)

For Maximum Toughness and minimum distortion in cooling:
Soak for 30 to 60 minutes.
Furnace: 1975°F (1080°C)
Salt Bath: 1950°F (1066°C)

Quenching: Air, pressurized gas, warm oil, or salt. Sections less than 3” thick may be air cooled to maximum hardness. Sections 3” thick or more must be quenched at a faster rate, using one of the methods below, to attain maximum hardness. For pressurized gas, the furnace should have a minimum quench pressure of 4 bars. The quench rate to below 1000°F (538°C) is critical to obtain the desired properties. For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C). For salt maintained at 1000-1100°F (538-593°C), equalize in the salt, then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical temperature range is 1000-1100°F (538-593°C). Do not temper below 1000°F (538°C). Hold at temperature for 2 hours then air cool to ambient temperature. Double tempering is required. Triple tempering is required when austenitized at 2100°F (1149°C) or higher.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1600 - 1650°F (871 - 899°C) and hold at temperature for 1 hour per inch of maximum thickness: 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 30°F per hour (17°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 277 HBW.

CPM 15V Powder Metal Tool Steel

APPLICATIONS: Intended for applications requiring exceptional wear resistance such as dies or core rods.

HEAT TREATING INSTRUCTIONS

Critical Temperature: Ac1: 1540°F (838°C)

HARDENING

Preheating: 1500-1550°F (816-845°C), equalize. A second pre-heat stage at 1850-1900°F (1010-1040°C) is suggested for vacuum or atmosphere hardening.

Austenitizing (High Heat): Heat rapidly from the preheat, typically by transferring to a second furnace.

Furnace or Salt Bath: 1950-2150°F (1065-1175°C)

Soak for 10-30 minutes at temperature.

Quenching: Air, pressurized gas, warm oil, or salt. Sections less than 3” thick may be air cooled to maximum hardness. Sections 3” thick or more must be quenched at a faster rate, using one of the methods below, to attain maximum hardness.

For pressurized gas, the furnace should have a minimum quench pressure of 4 bars. The quench rate to below 1000°F (538°C) is critical to obtain the desired properties.

For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C).

For salt maintained at 1000-1100°F (538-593°C), equalize in the salt, then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical temperature range is 1000-1100°F (538-593°C). Do not temper below 1000°F (538°C). Hold at temperature for 2 hours then air cool to ambient temperature. Double tempering is required. Triple tempering is required when austenitized at 2100°F (1149°C) or higher.
Size Change: +0.04/0.05%

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1600°F (871°C) and hold at temperature for 1 hour per inch of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at the rate not exceeding 30°F per hour (17°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 277 HBW.

CPM Rex M4 HC Powder Metal High Speed Steel

APPLICATIONS: Intended for applications requiring exceptional wear resistance such as dies or core rods.

HEAT TREATING INSTRUCTIONS

Critical Temperature: Ac1: 1545°F (840°C)

HARDENING

Preheating: 1500-1550°F (816-845°C), equalize. A second preheat at 1850-1900°F (1010-1040°C) is recommended for vacuum hardening.

Austenitizing (High Heat): Heat rapidly from the preheat.

For Cutting Tools:
Soak for 5 to 15 minutes.
Furnace: 2150-2200°F (1177-1204°C)
Salt Bath: 2125-2175°F (1163-1191°C)

For Cold Work Tooling:
Soak for 20 to 45 minutes.
Furnace: 1875-2125°F (1023-1163°C)
Salt Bath: 1850-2100°F (1010-1149°C)

Quenching: Pressurized gas, warm oil, or salt. For pressurized gas, the furnace should have a minimum quench pressure of 4 bars. A quench rate of approximately 400°F (222°C) per minute to below 1000°F (538°C) is critical to obtain the desired properties.

For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C).
For salt maintained at 1000-1100°F (538-593°C), equalize in the salt, then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical temperature range is 1000-1100°F (538-593°C). Do not temper below 1000°F (538°C). Hold at temperature for 2 hours then air cool to ambient temperature. Double tempering is required. Triple tempering is required when austenitized at 2100°F (1149°C) or higher.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1575-1600°F (857-871°C) and hold at temperature for 1 hour per inch of maximum thickness; 2 hours minimum.

Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C).

Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 255 HBW.

CPM Rex T15 Powder Metal High Speed Steel

APPLICATIONS: Typical tooling applications in which CPM Rex T15 excels include high-performance broaches, form tools, milling cutters, end mills, taps, and reamers. CPM Rex T15 is the high-speed steel of choice for any cutting application on strong or abrasive materials that generate high cutting tool temperatures.

HEAT TREATING INSTRUCTIONS

Critical Temperature:

Ac1: 1520°F (827°C)	Ac3: 1570°F (854°C)
Ar1: 1445°F (785°C)	Ar3: 1410°F (766°C)

HARDENING

Preheating: 1500-1550°F (816-845°C), equalize. A second preheat at 1850-1900°F (1010-1040°C) is recommended for vacuum hardening.

Austenitizing (High Heat): Heat rapidly from the preheat.
Furnace: 2150-2260°F (1177-1238°C)
Salt Bath: 2150-2250°F (1177-1221°C)

The use of a lower austenitizing temperature will maximize impact toughness. The use of a higher austenitizing temperature will maximize hot hardness and wear resistance.

Quenching: Pressurized gas, warm oil, or salt.

For pressurized gas, the furnace should have a minimum quench pressure of 4 bars. A quench rate of approximately 400°F (222°C) per minute to below 1000°F (538°C) is critical to obtain the desired properties.

For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C), equalize in the salt, then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical temperature range is 1000-1100°F (538-593°C). Do not temper below 1000°F (538°C). Hold at temperature for 2 hours then air cool to ambient temperature. Triple tempering is required.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1575-1600°F (857-871°C) and hold at temperature for 1 hour per inch (25.4 mm) of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 30°F per hour (15°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 277 HBW.

CPM Rex 76 Powder Metal High Speed Steel

APPLICATIONS: Form tools, broaches, milling cutters, hobs, and special cutting tools where high hot hardness is required.

HEAT TREATING INSTRUCTIONS

HARDENING

Critical Temperature: Ac1: 1535°F (835°C)

Preheating: 1500-1550°F (816-845°C), equalize.
A second preheat at 1850-1900°F (1010-1040°C) is recommended for vacuum hardening.

Austenitizing (High Heat): Heat rapidly from the preheat. Soak for 3 to 10 minutes, depending upon the temperature.
Furnace: 2125-2200°F (1163-1204°C)
Salt Bath: 2100-2190°F (1149-1199°C)

Quenching: Pressurized gas, warm oil, or salt.

For pressurized gas, the furnace should have a minimum quench pressure of 4 bars. A quench rate of approximately 400°F (222°C) per minute to below 1000°F (538°C) is critical to obtain the desired properties.

For oil, quench until black, about 900°F (482°C), then cool in still air to 150-125°F (66-51°C).

For salt maintained at 1000-1100°F (538-593°C), equalize in the salt, then cool in still air to 150-125°F (66-51°C).

Tempering: Temper immediately after quenching. Typical temperature range is 1000-1100°F (538-593°C). Do not temper below 1000°F (538°C). Hold at temperature for 2 hours then air cool to ambient temperature. Triple tempering is required. Quadruple tempering is required when austenitized at 2175°F (1190°C) or higher.

Annealing: Annealing must be performed after hot working and before re-hardening.

Heat at a rate not exceeding 400°F per hour (222°C per hour) to 1575-1600°F (857-871°C), and hold at temperature for 1 hour per inch of maximum thickness; 2 hours minimum. Then cool slowly with the furnace at a rate not exceeding 50°F per hour (28°C per hour) to 1000°F (538°C). Continue cooling to ambient temperature in the furnace or in air. The resultant hardness should be a maximum of 311 HBS.