TOOL STEEL

COLD WORK
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AISI A2 DCF

An air-hardening tool steel containing five percent chromium. Replaces the oil hardening (O1 type) when safer hardening, less distortion and increased wear-resistance are required. Provides an intermediate grade between the oil hardening and the high carbon, high chromium (D2) types.

TYPICAL APPLICATIONS

Large Blanking Dies, Thread Roller Dies, Long Punches, Rolls, Master Hubs, Trimming Dies, Forming Dies, Precision Tools, Gauges, Coining Dies, Extrusion Dies, Mandrels, Shear Blades and Slitters.

TYPICAL ANALYSIS	TYPE A2 (UNS T30102)
Carbon (C)	.95/1.05
Manganese (Mn)	1.00 max
Silicon (Si)	.50 max
Tungsten (W)	
Molybdenum (Mo)	.90/1.40
Chromium (Cr)	4.75/5.50
Vanadium (V)	.15/.50
*Nickel (Ni)	.30 max
FORGING (a)	
Start forging at	1850-2000°F (1010-1093°C)
Do not forge below	1650°F (899°C)
NORMALIZING (b)	Do not normalize
ANNEALING (c)	
Temperature	1550-1600°F (843-871°C)
Rate of cooling, max. per hour	40°F (22°C)
Typical annealed hardness, Brinell	201-235
HARDENING	
Rate of heating	Slowly
Preheat temperature	1450 °F (788°C)
Hardening temperature	1700-1800°F (927-962°C)
Time at temperature, minutes	20-45 (j)
Quenching medium	A (l)
TEMPERING	
Tempering temperature	350-1000°F (177-538°C)
Approx. tempered hardness, Rockwell C	57-62
WEAR RESISTANCE	High
TOUGHNESS	Medium
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Medium to High
DEPTH OF HARDENING	Deep
MACHINABILITY	Medium
GRINDABILITY	Medium
DISTORTION IN HEAT TREATING	Lowest
SAFETY IN HARDENING	Highest
RESISTANCE TO DECARBURIZATION	Medium

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI A6

A6 is an air-hardening, non-deforming tool steel that combines the deep hardening characteristics of air-hardening steels with the simplicity of low temperature heat treatment possible in many of the oil-hardening grades.

TYPICAL APPLICATIONS

Blanking Dies, Precision Tools, Forming Dies, Coining Dies, Master Hubs, Shear Blades, Plastic Molds, Spindles, Mandrels, Heavy Duty Punches.

TYPICAL ANALYSIS	TYPE A6 (UNS T30106)
Carbon (C)	.65/.75
Manganese (Mn)	1.80/2.50
Silicon (Si)	.50 max
Tungsten (W)	
Molybdenum (Mo)	.90/1.40
Chromium (Cr)	.90/1.20
Vanadium (V)	
Cobalt (Co)	
*Nickel (Ni)	.30 max
FORGING (a)	
Start forging at	1900-2050°F (1038-1213°C)
Do not forge below	1600°F (871°C)
NORMALIZING (b)	Do not normalize
ANNEALING (c)	
Temperature	1350-1375°F (732-746°C)
Rate of cooling, max. per hour	25°F (14°C)
Typical annealed hardness, Brinell	217-248
HARDENING	
Rate of heating	Slowly
Preheat temperature	1200°F (649°C)
Hardening temperature	1525-1600°F (829-871°C)
Time at temperature, minutes	20-45 (j)
Quenching medium	A (l)
TEMPERING	
Tempering temperature	300-800°F (149-427°C)
Approx. tempered hardness, Rockwell C	54-60
WEAR RESISTANCE	Low to Medium
TOUGHNESS	Medium to High
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Medium
DEPTH OF HARDENING	Deep
MACHINABILITY	Low to Medium
GRINDABILITY	Medium
DISTORTION IN HEAT TREATING	Lowest
SAFETY IN HARDENING	Highest
RESISTANCE TO DECARBURIZATION	Medium to High

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W..

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI D2

D2 is an air-hardening, high carbon, high chromium tool steel with extremely high wear resisting properties. It is a very deep hardening steel and will be practically free from size change after proper treatment. The high percentage of chromium gives it mild corrosion-resisting properties in the hardened condition.

TYPICAL APPLICATIONS

Blanking Dies, Forming Dies, Coining Dies, Slitting Cutters, Heading Tools, Long Punches, Forming Rolls, Edging Rolls, Master Tools, Beading Rolls, Intricate Punches, Extrusion Dies, Drawing Dies, Lamination Dies, Thread Rolling Dies, Shear Blades, Burnishing Tools, Gauges, Knurls, Wear Parts.

TYPICAL ANALYSIS	TYPE D2 (UNS T30402)
Carbon (C)	1.40/1.60
Manganese (Mn)	.60 max
Silicon (Si)	.60 max
Tungsten (W)	
Molybdenum (Mo)	.70/1.20
Chromium (Cr)	11.00/13.00
Vanadium (V)	1.10 max
Cobalt (Co)	1.00 max
*Nickel (Ni)	.30 max
FORGING (a)	
Start forging at	1850-2000°F (1010-1093°C)
Do not forge below	1700°F (927°C)
NORMALIZING (b)	Do not normalize
ANNEALING (c)	
Temperature	1600-1650°F (871-899°C)
Rate of cooling, max. per hour	40°F (22°C)
Typical annealed hardness, Brinell	217-255
HARDENING	
Rate of heating	Very Slowly
Preheat temperature	1500°F (816°C)
Hardening temperature	1800-1875°F (982-1024°C)
Time at temperature, minutes	15-45 (j)
Quenching medium	A (l)
TEMPERING	
Tempering temperature	400-1000°F (204-538°C)
Approx. tempered hardness, Rockwell C	54-61
WEAR RESISTANCE	High to Very High
TOUGHNESS	Low
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Medium to High
DEPTH OF HARDENING	Deep
MACHINABILITY	Low
GRINDABILITY	Low
DISTORTION IN HEAT TREATING	Lowest
SAFETY IN HARDENING	Highest
RESISTANCE TO DECARBURIZATION	Medium

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

DC53

DC53 is a general purpose, cold work die and mold steel whose strength and toughness approach those of high-speed steels.

TYPICAL APPLICATIONS

Forming Dies, Thread Rolling Dies, Cold Forging Dies, Gauges, Plastic Molds, Stepped Punch and Press Punching Dies.

TYPICAL ANALYSIS	TYPE DC53
Carbon (C)	.95
Molybdenum (Mo)	2.00
Chromium (Cr)	8.00
Vanadium (V)	.25
Cobalt (Co)	
*Nickel (Ni)	
FORGING (a)	
Start forging at	1100°C
Do not forge below	900°C
NORMALIZING (b)	
ANNEALING (c)	
Temperature	830°C - 880°C
Rate of cooling, max. per hour	40°F (22°C)
Typical annealed hardness, Brinell	255°
HARDENING	
Rate of heating	Slowly
Preheat temperature	800°C - 850°C)
Hardening temperature	1020° C - 1040°C
Time at temperature, minutes	15 - 45
Quenching medium	Air, Gas
TEMPERING	
Tempering temperature	520-550°C
Approx. tempered hardness, Rockwell C	64-58
WEAR RESISTANCE	High to Very High
TOUGHNESS	High
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	High
DEPTH OF HARDENING	Through Harden
MACHINABILITY	High
GRINDABILITY	High
DISTORTION IN HEAT TREATING	Low
SAFETY IN HARDENING	High
RESISTANCE TO DECARBURIZATION	High

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI O1

O1 is an oil-hardening, non-deforming tool steel which can be hardened at relatively low temperatures. Tools and dies made from O1 will have good wearing qualities since the tungsten and higher chromium content gives improved wear resistance over the straight manganese grades.

TYPICAL APPLICATIONS

Blanking Dies, Bushings, Forming Dies, Master Tools, Forming Rolls, Gauges, Trim Dies.

TYPICAL ANALYSIS	TYPE O1 (UNS T31501)
Carbon (C)	.85/1.00
Manganese (Mn)	1.00/1.40
Silicon (Si)	.50 max
Tungsten (W)	.40/.60
Molybdenum (Mo)	
Chromium (Cr)	.40/.60
Vanadium (V)	.30 max
Cobalt (Co)	
*Nickel (Ni)	.30 max
FORGING (a)	
Start forging at	1800-1950°F (982-1066°C)
Do not forge below	1550°F (843°C)
NORMALIZING (b)	1600°F (871 °C)
ANNEALING (c)	
Temperature	1400-1450°F (760-788°C)
Rate of cooling, max. per hour	40°F (22°C)
Typical annealed hardness, Brinell	183-212
HARDENING	
Rate of heating	Slowly
Preheat temperature	1200°F (649°C)
Hardening temperature	1450-1500°F (788-816°C)
Time at temperature, minutes	10-30
Quenching medium	0 (l)
TEMPERING	
Tempering temperature	350-500°F (177-260°C)
Approx. tempered hardness, Rockwell C	57-62
WEAR RESISTANCE	Medium
TOUGHNESS	Medium
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Low
DEPTH OF HARDENING	Medium
MACHINABILITY	High
GRINDABILITY	High
DISTORTION IN HEAT TREATING	Low
SAFETY IN HARDENING	Medium to High
RESISTANCE TO DECARBURIZATION	High

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI O6

O6 is an oil-hardening cold work steel which has outstanding machinability resulting from small particles of graphitic carbon uniformly distributed throughout the steel. These particles increase resistance to wear and galling in service. For an oil-hardening steel, 06 holds size well during heat treating.

TYPICAL APPLICATIONS

Blanking Dies, Piercing Dies, Drawing Dies, Pneumatic Hammers, Forming Dies, Spinning Tools, Punches, Stamps, Gauges, Wear Plates, Cams, Rotary Slitting Cutters.

TYPICAL ANALYSIS	TYPE O6 (UNS T31506)
Carbon (C)	1.25/1.55
Manganese (Mn)	.30/1.10
Silicon (Si)	.55/1.50
Tungsten (W)	
Molybdenum (Mo)	.20/.30
Chromium (Cr)	.30 max
*Nickel (Ni)	.30 max
FORGING (a)	
Start forging at	1800-1950°F (982-1066°C)
Do not forge below	1500°F (816°C)
NORMALIZING (b)	1600°F (871 °C)
ANNEALING (c)	
Temperature	1400-1450°F (766-788°C)
Rate of cooling, max. per hour	20°F (11°C)
Typical annealed hardness, Brinell	183-217
HARDENING	
Rate of heating	Slowly
Preheat Temperature	
Hardening temperature	1450-1500°F (788-816°C)
Time at temperature, minutes	10-30
Quenching medium	0 (I)
TEMPERING	
Tempering temperature	350-600°F (177-316°C)
Approx. tempered hardness, Rockwell C	58-63
WEAR RESISTANCE	Medium
TOUGHNESS	Medium
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Low
DEPTH OF HARDENING	Medium
MACHINABILITY	Highest
GRINDABILITY	High
DISTORTION IN HEAT TREATING	Low
SAFETY IN HARDENING	Medium to High
RESISTANCE TO DECARBURIZATION	High

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI L6

L6 is a tough, oil-hardening tool steel possessing a fine-grained structure and desirable shock resistance. L6 is also associated with high strength and good non-deforming characteristics.

TYPICAL APPLICATIONS

Forming Rolls, Spindles, Punches, Trim Dies, Blanking Dies, Embossing Dies, Forming Dies, and Shear Blades.

TYPICAL ANALYSIS	TYPE L6 (UNS T61206)
Carbon (C)	.65/.75
Manganese (Mn)	.25/.80
Silicon (Si)	.50 max
Molybdenum (Mo)	.50 max
Chromium (Cr)	.60/1.20
Vanadium (V)	.30 max
*Nickel (Ni)	1.25/2.00
FORGING (a)	
Start forging at	1800-2000°F (982-1093°C)
Do not forge below	1550°F (843°C)
NORMALIZING (b)	1600°F (871 °C)
ANNEALING (c)	
Temperature	1400-1450°F (760-788°C)
Rate of cooling, max. per hour	40°F (22°C)
Typical annealed hardness, Brinell	183-255
HARDENING	
Rate of heating	Slowly
Hardening temperature	1450-1550°F (788-843°C)
Time at temperature, minutes	10-30 (j)
Quenching medium	0 (l)
TEMPERING	
Tempering temperature	350-1000°F (177-538°C)
Approx. tempered hardness, Rockwell C	45-62
WEAR RESISTANCE	Medium
TOUGHNESS	Very High
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Low
DEPTH OF HARDENING	Medium
MACHINABILITY	Medium
GRINDABILITY	High
DISTORTION IN HEAT TREATING	Low
SAFETY IN HARDENING	Medium
RESISTANCE TO DECARBURIZATION	High

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI S5

S5 is an oil-hardening silicon-manganese steel of medium carbon content especially adapted for punches, shear blades, chisels, and other shock resisting applications. S5 is therefore applicable where the properties of silicon-manganese steels are desired in combination with well-known advantages of oil-hardening steels. A reduced tendency to distort or crack in heat treatment is accordingly combined with high toughness in S5.

TYPICAL ANALYSIS	TYPE S5 (UNS T41905)
Carbon (C)	.50/.65
Manganese (Mn)	.60/1.00
Silicon (Si)	1.75/2.25
Tungsten (W)	
Molybdenum (Mo)	.20/1.35
Chromium (Cr)	.35 max
Vanadium (V)	.35 max
Cobalt (Co)	
FORGING (a)	
Start forging at	1850-2050°F (1010-1121°C)
Do not forge below	1600°F (871°C)
NORMALIZING (b)	Do not normalize
ANNEALING (c)	
Temperature	1425-1475°F (774-802°C)
Rate of cooling, max. per hour	25°F (14°C)
Typical annealed hardness, Brinell	192-229
HARDENING	
Rate of heating	Slowly
Preheat Temperature	1400°F (760°C)
Hardening temperature	1600-1700°F (871-927°C)
Time at temperature, minutes	5-20
Quenching medium	0 (l)
TEMPERING	
Tempering temperature	350-800°F (177-427°C)
Approx. tempered hardness, Rockwell C	50-60
WEAR RESISTANCE	Low to Medium
TOUGHNESS	Highest
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Low
DEPTH OF HARDENING	Medium
MACHINABILITY	Medium to High
GRINDABILITY	Medium to High
DISTORTION IN HEAT TREATING	Medium
SAFETY IN HARDENING	High
RESISTANCE TO DECARBURIZATION	Low

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI S7

AISI S7 is a general purpose air-hardening tool steel with high impact and shock resistance. It has good resistance to softening at moderately high temperatures. This combination of properties makes it suitable for many hot work and cold work applications. Excellent combination of high strength and toughness. Useful in moderate hot work as well as cold work work tooling. Added size stability when air hardened.

TYPICAL APPLICATIONS

Bull Riveters, Concrete Breakers (Moll Points), Riveting Dies, Powder Metal Dies, Notching Dies, Dowels, Drills, Drill Plates, Hubs, Plastic Mold Dies, Cold Forming Dies, Blanking Dies, Bending Dies, and Master Hobs.

TYPICAL ANALYSIS	TYPE S7 (UNS T41907)
Carbon (C)	.45/.55
Manganese (Mn)	.20/.80
Silicon (Si)	.20/1.00
Tungsten (W)	
Molybdenum (Mo)	1.30/1.80
Chromium (Cr)	3.00/3.50
Vanadium (V)	.30 max
Cobalt (Co)	
FORGING (a)	
Start forging at	1950-2050°F (1066-1121°C)
Do not forge below	1700°F (927°C)
NORMALIZING (b)	Do not normalize
ANNEALING (C)	
Temperature	1500-1550°F (816-843°C)
Rate of cooling, max. per hour	25°F (14°C)
Typical annealed hardness, Brinell	187-223
HARDENING	
Rate of heating	Slowly
Preheat Temperature	1200-1300°F (649-704°C)
Hardening temperature	1700-1750°F (927-954°C)
Time at temperature, minutes	15-45 (j)
Quenching medium	A or O (l)
TEMPERING	
Tempering temperature	400-1150°F
(Do not temper below 400ºF)	(204-621°C)
Approx. tempered hardness, Rockwell C	45-57
WEAR RESISTANCE	Low to Medium
TOUGHNESS	Very High
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	High
DEPTH OF HARDENING	Medium to Deep
MACHINABILITY	Medium to High
GRINDABILITY	Medium to High
DISTORTION IN HEAT TREATING	A: Lowest /O: Low
SAFETY IN HARDENING	A: Highest /O: High
RESISTANCE TO DECARBURIZATION	Medium

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI S7 ESR

S7 ESR tool steel is specifically designed for use in molds and other applications where a highly polished or a very smooth finish is required. The ESR (Electro Slag Remelt) process removes most of the non-metallic inclusions in the steel. S7 ESR double melt's relatively low carbon level, fortified chemistry, ultra-clean, uniform, and homogeneous internal structure make it superior to the other conventionally manufactured shock-resisting tool steels. The following charts show microcleanliness ratings of ESR tool steels by ASTM E45, Method D:

Typical Microcleanliness	**A**	**B**	**C**	**D**
Thin	<0.5	<0.5	<0.5	1.0
Heavy	<0.5	<0.5	<0.5	1.0
Maximum Rated Microcleanliness	**A**	**B**	**C**	**D**
Thin	1.5	1.5	2.0	1.5
Heavy	1.0	1.0	1.0	1.0

The quality control of the S7 ESR process assures the exceptional cleanliness throughout by removing most harmful inclusions in the material (such as, oxides, nitrides and sulfides). The ESR steel produced will reflect a mirror like surface condition, subsequently reducing friction giving you easier ejection of parts, the elimination of minute scratches, and other stress-raisers that could lead to premature die failures.

The higher quality steel produced by special melt practices imparts a most important characteristic—freedom of inclusions and other imperfections. Other advantages include: cleanliness, stability, improved mechanical properties, structures relatively free from segregation resulting in less cracking, and quality assurance by ultrasonic testing of all ESR material produced.

TYPICAL ANALYSIS	TYPE S7 ESR
Carbon (C)	.50
Manganese (Mn)	.60
Silicon (Si)	.65
Molybdenum (Mo)	1.40
Chromium (Cr)	3.25

ANNEALING (C)

When properly annealed, this steel has a machinability rating of 95 as compared to a 1% carbon steel rated at 100.

TEMPERING

Tempering	Rockwell C
As Quenched	60
400°F	58
500°F	56
600°F	55
700°F	54
800°F	53
900°F	52
1000°F	51
1100°F	47
1200°F	38

1" specimen, 3 long were air-hardened from 1725°F.
Material may become brittle when tempered at less than 400°F.

HARDENING - For hardening information refer to p. 14-10.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI P20

PREHARDENED

P20 is a chrome-moly tool steel made specifically to fill the requirements for the machined cavities and forces used in zinc die casting and plastic molding. It is delivered fully quenched and tempered to approximately Brinell 300. Other hardness levels may be obtained through additional heat treatment. P20 composition and structure provide excellent machining and polishing characteristics.

TYPICAL ANALYSIS	TYPE P20 (UNS T51620)
Carbon (C)	0.35
Manganese (Mn)	0.80
Silicon (Si)	0.50
Tungsten (W)	
Molybdenum (Mo)	0.45
Chromium (Cr)	1.70
Vanadium (V)	
Cobalt (Co)	
Nickel (Ni)	
FORGING (a) Start forging at Do not forge below	 2000°F (1093°C) 1700°F (927°C)
NORMALIZING (b)	Do not normalize
ANNEALING (c) Temperature Rate of cooling, max. per hour Typical annealed hardness, Brinell	 1450-1500°F (788-816°C) 30°F per hour to 1000°F 207 max.
HARDENING Rate of heating Preheat temperature Hardening temperature Time at temperature, minutes Quenching medium	 Slowly None 1500-1600°F (816-871°C) 60 min. per inch of thick. O (l)
TEMPERING Tempering temperature Approx. tempered hardness, Rockwell C	 300-1200°F (149-649°C) 26-54
WEAR RESISTANCE	Low to Medium
TOUGHNESS	Very High
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	High
DEPTH OF HARDENING	Medium to Deep
MACHINABILITY	Medium
GRINDABILITY	Medium
DISTORTION IN HEAT TREATING	Low
SAFETY IN HARDENING	High
RESISTANCE TO DECARBURIZATION	High

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI T420 STAINLESS ESR

AISI T420 ESR is an air or oil hardening mold steel having superior internal steel cleanliness combined with good resistance to corrosion. It is suitable for mold applications and is capable of providing an excellent polished surface. A special re-melting process called Electro Slag Refining or ESR provides a 420 type steel with the very low inclusion content required by mold makers who polish mold surfaces.

TYPICAL ANALYSIS	TYPE T420 (UNS S42000)
Carbon (C)	Over 0.15
Manganese (Mn)	1.00 max
Silicon (Si)	1.00 max
Tungsten (W)	.03 max
Molybdenum (Mo)	.03 max
Chromium (Cr)	12.00/14.00
Vanadium (V)	
Cobalt (Co)	
*Nickel (Ni)	
FORGING (a) Start forging at Do not forge below	
NORMALIZING (b)	
ANNEALING (c) Temperature Rate of cooling, max. per hour Typical annealed hardness, Brinell	 1600-1650°F (871-899°C) 192-241
HARDENING Rate of heating Preheat temperature Hardening temperature Time at temperature, minutes Quenching medium	 1350-1450°F (735-788°C) 1850-1950°F (1110-1066°C) A (l)
TEMPERING Tempering temperature Approx. tempered hardness, Rockwell C	 450-750°F (232-399°C) 49-53
WEAR RESISTANCE	Low
TOUGHNESS	Medium
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Good
DEPTH OF HARDENING	Medium
MACHINABILITY	Medium
GRINDABILITY	Good
DISTORTION IN HEAT TREATING	Low
SAFETY IN HARDENING	High
RESISTANCE TO DECARBURIZATION	Medium

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI W2

W2 is a shallow hardening tool steel. Due to its vanadium content, the grain is superior in toughness and resistance to fatigue compared to straight carbon tool steels thereby making it desirable for many types of impact tools.

TYPICAL ANALYSIS	TYPE W2 (UNS T27302)
Carbon (C)	.85/1.50
Manganese (Mn)	.10/.40
Silicon (Si)	.10/.40
Tungsten (W)	.15 max
Molybdenum (Mo)	.10 max
Chromium (Cr)	.15 max
Vanadium (V)	.15/.35
Cobalt (Co)	
*Nickel (Ni)	.20 max
FORGING (a)	
Start forging at	1800-1950°F (982-1066°C)
Do not forge below	1500°F (816°C)
NORMALIZING (b)	1450-1700°F (d)
ANNEALING (c)	
Temperature	1360-1450°F(d) (738-788°C)
Rate of cooling, max. per hour	40°F (22°C)
Typical annealed hardness, Brinell	156-201
HARDENING	
Rate of heating	Slowly
Preheat temperature	(g)
Hardening temperature	1400-1550°F (e) (760-843°C)
Time at temperature, minutes	10-30
Quenching medium	B or W (I)
TEMPERING	
Tempering temperature	350-650°F (177-343°C)
Approx. tempered hardness, Rockwell C	50-64
WEAR RESISTANCE	Low to Medium
TOUGHNESS	High (I)
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Low
DEPTH OF HARDENING	Shallow
MACHINABILITY	Highest
GRINDABILITY	Highest
DISTORTION IN HEAT TREATING	High
SAFETY IN HARDENING	Low to Medium
RESISTANCE TO DECARBURIZATION	Highest

• Refer to pp. 14-26 thru 14-27 for notes (a) to (o) incl., explanation of letter 0, A, S, B and W.

* Unless otherwise specified, nickel plus copper equal 0.75% max. for all tool steel types.

AISI H13

H13 is a 5% chromium hot work tool steel designed for applications that require extreme toughness combined with good red-hardness. H13 will allow an extra margin of safety in tools subject to heavy hammer blows, and those containing deep recesses or sharp corners. Although H13 was designed as a hot work steel, it has solved many cold work applications where extra toughness could be gained with some sacrifice of wear resistance.

TYPICAL APPLICATIONS

Aluminum Extrusion Dies, Die Casting Dies, Heavy Duty Compression Tools, Forming Punches, Hot Forging Dies, Shear Blades, Plastic Mold Dies, and Bolt Dies.

TYPICAL ANALYSIS	TYPE H13 (UNST20813)
Carbon (C)	.32/.45
Manganese (Mn)	.20/.50
Silicon (Si)	.80/1.20
Tungsten (W)	
Molybdenum (Mo)	1.10/1.75
Chromium (Cr)	4.75/5.50
Vanadium (V)	.80/1.20
Cobalt (Co)	
*Nickel (Ni)	.30 max
FORGING (a)	
Start forging at	1950-2100°F (1066-1149°C)
Do not forge below	1650°F (899°C)
NORMALIZING (b)	Do not normalize
ANNEALING (c)	
Temperature	1550-1650°F (843-899°C)
Rate of cooling, max. per hour	40°F (22°C)
Typical annealed hardness, Brinell	192-229
HARDENING	
Rate of heating	Moderately from preheat
Preheat temperature	1500°F (816°C)
Hardening temperature	1825-1900°F (996-1038°C)
Time at temperature, minutes	15-40 (j)
Quenching medium	A (l)
TEMPERING	
Tempering temperature	1000-1200°F (k) (538-649°C)
Approx. tempered hardness, Rockwell C	38-53
WEAR RESISTANCE	Medium
TOUGHNESS	Very High
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	High
DEPTH OF HARDENING	Deep
MACHINABILITY	Medium to High
GRINDABILITY	Medium to High
DISTORTION IN HEAT TREATING	Very Low
SAFETY IN HARDENING	Highest
RESISTANCE TO DECARBURIZATION	Medium to High

VISCOUNT 44®

PREHARDENED AISI TYPE H13 TYPICAL ANALYSIS

Viscount 44® is fully heat treated H13 hot work steel with carefully controlled and evenly dispersed sulphide additives. It is the same analysis type as Latrobe's popular VDC, but the free-machining sulphides improve the machinability to the point where die work at a hardness of Rockwell C 42-46 is practical. It is thus possible to bypass the risk of heat treatment involved in tool building.

Prehardening gives Viscount 44® a tremendous advantage when used for hot work dies because of the constant danger of size change or distortion during heat treatment. The product also eliminates costly finishing operations after heat treatment.

Using prehardened Viscount 44® for extrusion tools makes it possible to produce dies, backers, bolsters, dummy blocks, etc. in a few hours, allowing extremely short delivery schedules to be met. In addition, the use of prehardened Viscount 44® for extrusion dies ensures clean metal at the bearing surfaces free from any possible decarburization, carburization, scale, sub-scale or other deleterious conditions sometimes encountered when finished dies are heat treated.

Field tests show that Viscount 44®'s performance in aluminum, magnesium, and zinc die casting dies is at best the equivalent of regular H13. Particular examples have shown that over 100,000 shots can be obtained in large dies and over 200,000 shots in smaller dies.

Field reports also indicate excellent performance with Viscount 44® on forging dies, plastic molds, extrusion tools, and other hot work tools.

TYPICAL ANALYSIS	VISCOUNT 44®
Carbon (C)	.40
Manganese (Mn)	.80
Silicon (Si)	1.00
Tungsten (W)	
Molybdenum (Mo)	1.35
Chromium (Cr)	5.25
Vanadium (V)	1.00
Cobalt (Co)	
TEMPERING Approx. tempered hardness, Rockwell C	42-46
WEAR RESISTANCE	Medium
TOUGHNESS	Very High
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	High
DEPTH OF HARDENING	
MACHINABILITY	Low
GRINDABILITY	Medium
DISTORTION IN HEAT TREATING	
SAFETY IN HARDENING	
RESISTANCE TO DECARBURIZATION	

DRM1

HOT and WARM FORGING DIE STEEL

DRM1 tool steel features high hardness and high tough Matrix type high speed tool steel vastly surpasses hot work die steels. DRM1 improves hot and warm die life by its higher toughness than conventional grade.

TYPICAL APPLICATIONS

Used for hot and warm forging dies and punches.

TYPICAL ANALYSIS	TYPE DRM1
Carbon (C)	.60
Manganese (Mn)	.50
Silicon (Si)	.20
Tungsten (W)	3.00
Molybdenum (Mo)	1.00
Chromium (Cr)	4.20
Vanadium (V)	1.50
Cobalt (Co)	2.00
ANNEALING (c) Temperature Slow cooling Typical annealed hardness, Brinell	 1472-1616°F (800-880°C) ≤235HB
HARDENING Rate of heating Preheat temperature Hardening temperature Time at temperature, minutes Quenching	 Moderately from preheat 1742°F (950°C) 2012-2084°F (1100-1140°C) 20-30 per inch of thickness for material under 4" 10-20 per inch of thickness for material 4" and over OQ-Oil Quenching, GC-Gas Quenching in vacuum furnace, Salt Bath, Similar to conventional high speed steels
TEMPERING Tempering temperature Approx. tempered hardness, Rockwell C	Minimal Double Temper AC-Air Cooling, 1022-1148°F (550-620°C) 56-58 HRC
WEAR RESISTANCE	Good
TOUGHNESS	Very High
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	High
MACHINABILITY	Better and faster than conventional high speed steels
GRINDABILITY	Better and faster than conventional high speed steels

DRM2

WARM and COLD FORGING DIE STEEL

DRM2 is a matrix type high speed tool steel available for warm and cold forging tools where critical performance is required. DRM2 prolongs service life due to its higher hardness and toughness than those of conventional grades.

TYPICAL APPLICATIONS

Used for warm and cold forging dies and punches.

TYPICAL ANALYSIS	TYPE DRM2
Carbon (C)	.70
Tungsten (W)	1.00
Molybdenum (Mo)	2.40
Chromium (Cr)	5.50
Vanadium (V)	1.00
ANNEALING (c)	
Temperature	1472-1616°F (800-880°C)
Slow cooling	
Typical annealed hardness, Brinell	≤235HB
HARDENING	
Rate of heating	Moderately from preheat
Preheat temperature	1742°F (950°C)
Hardening temperature	1922-2012°F (1050-1100°C)
Time at temperature, minutes	20-30 per inch of thickness for material under 4" 10-20 per inch of thickness for material 4" and over
Quenching	OQ-Oil Quenching, GC-Gas Quenching in vacuum furnace, Salt Bath, Similar to conventional high speed steels
TEMPERING	Minimal Double Temper AC-Air Cooling,
Tempering temperature	1022-1148°F (550-620°C)
Approx. tempered hardness, Rockwell C	58-62 HRC
WEAR RESISTANCE	Good
TOUGHNESS	High
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	High
MACHINABILITY	Better and faster than conventional high speed steels
GRINDABILITY	Better and faster than conventional high speed steels

DRM3

COLD FORGING DIE STEEL

Conventional grade MH88 has been improved to DRM3. High hardness and tough DRM3 with excellent hardenability is suitable for high precision cold working tools.

TYPICAL APPLICATIONS

Used for hot and warm forging dies and punches.

TYPICAL ANALYSIS	TYPE DRM3
Carbon (C)	.80
Manganese (Mn)	.35
Silicon (Si)	.70
Tungsten (W)	.95
Molybdenum (Mo)	4.35
Chromium (Cr)	5.50
Vanadium (V)	1.20
ANNEALING (c) Temperature Slow cooling Typical annealed hardness, Brinell	 1472-1616°F (800-880°C) ≤235HB
HARDENING Rate of heating Preheat Temperature Hardening temperature Time at temperature, minutes Quenching	 Moderately from preheat 1742°F (950°C) 2012-2084°F (1100-1140°C) 30-90 OQ-Oil Quenching, GC-Gas Quenching in vacuum furnace, Salt Bath, Similar to conventional high speed steels
TEMPERING Tempering temperature Approx. tempered hardness, Rockwell C	Minimal Double Temper AC-Air Cooling, 1022-1148°F (550-620°C) 62-66 HRC
WEAR RESISTANCE	Very High
TOUGHNESS	Good
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	High
MACHINABILITY	Better and faster than conventional high speed steels
GRINDABILITY	Better and faster than conventional high speed steels

AISI M2

M2 is a tungsten-molybdenum high-speed steel and is a popular grade for general purpose cutting and non-cutting applications. It has a wider heat-treating range than most of the molybdenum high-speed steels, coupled with a resistance to decarburization that is characteristic of tungsten types. M2 offers an excellent combination of red hardness, toughness, and wear resistance. M2 is available in a wide variety of shapes and sizes. As with all Alro Specialty Metal products, M2 is subjected to a variety of rigid quality control tests and inspection to ensure quality, uniformity, and reliability.

TYPICAL APPLICATIONS

Broaches, Boring Tools, Chasers, Cold Forming Rolls, Cold Heading Inserts, Drills, End Mills, Form Tools, Hobs, Lathe and Planer Tools, Punches, Milling Cutters, Taps, Reamers, and Saws.

TYPICAL ANALYSIS	TYPE M2 (UNS T11302)
Carbon (C)	.78/.88
Manganese (Mn)	.15/.88
Silicon (Si)	.20/.45
Tungsten (W)	5.50/6.75
Molybdenum (Mo)	4.50/5.50
Chromium (Cr)	3.75/4.50
Vanadium (V)	1.75/2.20
Nickel (Ni)	.30 max
FORGING (a) Start forging at Do not forge below	 1900-2100°F (1038-1149°C) 1700°F (927°C)
NORMALIZING (b)	Do not normalize
ANNEALING (c) Temperature Rate of cooling, max. per hour Typical annealed hardness, Brinell	 1600-1650°F (871-899°C) 40°F (22°C) 212-241
HARDENING Rate of heating Preheat Temperature Hardening temperature Time at temperature, minutes Quenching medium	 Rapidly from preheat 1350-1550°F (732-843°C) 2175-2250°F (h) (1191-1232°C) 2-5 O, A, or S (I)
TEMPERING Tempering temperature Approx. tempered hardness, Rockwell C	 1000-1100°F (538-593°C) 60-65
WEAR RESISTANCE	Very High
TOUGHNESS	Low
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Very High
DEPTH OF HARDENING	Deep
MACHINABILITY	Medium
GRINDABILITY	Low
DISTORTION IN HEAT TREATING	A or S: Low/O: Medium
SAFETY IN HARDENING	Medium
RESISTANCE TO DECARBURIZATION	High

AISI M3

M3 was developed after extensive studies of the effect of increased carbon and vanadium contents on the intermediate molybdenum-tungsten high-speed steels. The analysis was tried and proven on practically all high-speed steel applications. M3 offers the unusual combination of extremely high-edge strength at high hardness levels. With few exceptions, best life is accomplished with a minimum hardness of 65.5 Rockwell C. Experience indicates that the chemical balance achieved in M3 results in optimum combination of cutting ability, abrasion resistance, edge strength, red hardness, and long service life. M3 is more readily machined and offers less grinding resistance than higher vanadium types.

TYPICAL APPLICATIONS

Drills, Taps, End Mills, Reamers, Counterbores, Broaches, Hobs, Form Tools, Lathe and Planer Tools, Checking Tools, Milling Cutters, Slitting Saws, Punches, Drawing Dies, and Wood Working Knives.

TYPICAL ANALYSIS	TYPE M3 (UNS T11313)
Carbon (C)	1.00-1.10
Manganese (Mn)	.15-.40
Silicon (Si)	.20-.45
Tungsten (W)	5.00-6.75
Molybdenum (Mo)	4.75-6.50
Chromium (Cr)	3.75-4.50
Vanadium (V)	2.25-2.75
Nickel (Ni)	.30 max
FORGING (a)	
Start forging at	1900-2100°F (1038-1149°C)
Do not forge below	1700°F (927°C)
NORMALIZING (b)	Do not normalize
ANNEALING (c)	
Temperature	1600-1650°F (871-899°C)
Rate of cooling, max. per hour	40°F (22°C)
Typical annealed hardness, Brinell	223-255
HARDENING	
Rate of heating	Rapidly from preheat
Preheat Temperature	1350-1550°F (732-843°C)
Hardening temperature	2200-2250°F (h) (1191-1232°C)
Time at temperature, minutes	2-5
Quenching medium	O, A, or S (l)
TEMPERING	
Tempering temperature	1000-1100°F (538-593°C)
Approx. tempered hardness, Rockwell C	61-66
WEAR RESISTANCE	Highest
TOUGHNESS	Low
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Very High
DEPTH OF HARDENING	Deep
MACHINABILITY	Medium
GRINDABILITY	Very Low
DISTORTION IN HEAT TREATING	A or S: Low/O: Medium
SAFETY IN HARDENING	Medium
RESISTANCE TO DECARBURIZATION	High

AISI M4 (PM)

M4 PM, a member of the molybdenum-tungsten family of high-speed steels, is a special purpose grade which utilizes its higher carbon and vanadium contents to develop excellent abrasion resistance. Produced conventionally, M4 is difficult to machine in the annealed condition and grind in the hardened condition. M4 PM is produced by the powder metallurgy process and allows an addition of .06/.08 sulfur which provides a uniform dispersion of small sulfides throughout the structure and enhances machinability. Coupled with finer carbides and structural uniformity, better grindability is also achieved. These factors, along with increased toughness, are ideally suited for heavy-duty cold-work applications.

TYPICAL APPLICATIONS

Blades, Broaches, Chasers, Die Inserts, Form Tools, Lathe and Planer Tools, Milling Cutters, Punches, Reamers, Slitter Knives, Spade Drills, and Taps.

TYPICAL ANALYSIS	TYPE M4 PM (UNS T11304)
Carbon (C)	1.30
Manganese (Mn)	.30
Silicon (Si)	.40
Tungsten (W)	5.50
Molybdenum (Mo)	4.50
Chromium (Cr)	4.50
Vanadium (V)	4.00
Sulphur (S)	.07
FORGING (a) Start forging at Do not forge below	
ANNEALING (c) Temperature Rate of cooling, max. per hour Typical annealed hardness, Brinell	 1550-1600°F (843-871°C)
HARDENING Rate of heating Preheat Temperature Hardening temperature Time at temperature, minutes Quenching medium	 1450-1550°F (788-843°C) 2150-2250°F (h) (1176-1232°C) 10-30 O (l)
TEMPERING Tempering temperature Approx. tempered hardness, Rockwell C	 1000-1100°F (538-593°C) 62-66
WEAR RESISTANCE	Highest
TOUGHNESS	Low
RESISTANCE TO SOFTENING EFFECT OF ELEVATED TEMPERATURE	Very High
DEPTH OF HARDENING	Deep
MACHINABILITY	Medium
GRINDABILITY	High
DISTORTION IN HEAT TREATING	Low
SAFETY IN HARDENING	Medium
RESISTANCE TO DECARBURIZATION	Medium

AISI M42

M42 is a molybdenum-cobalt high-speed steel capable of being hardened to 70 Rockwell C. The carbon content is higher than in most high-speed steels, and with this balanced composition, contributes to wear resistance and hot hardness as well as the high hardness capability. M42 exhibits good grindability and relatively good toughness at high hardness levels. M42 is being used for the machining of heat treated materials (high hardness) and high temperature alloys.

TYPICAL APPLICATIONS

Broaches, Circular and Dovetail Form Tools, Drills, End Mills, Lathe Tools, Milling Cutters, Punches, Reamers, Slitting Saws, and Twist Drills.

TYPICAL ANALYSIS	TYPE M4 (UNS T11342)
Carbon (C)	1.05-1.15
Manganese (Mn)	.15-.40
Silicon (Si)	.15-.65
Tungsten (W)	1.15-1.85
Molybdenum (Mo)	9.00-10.00
Chromium (Cr)	3.50-4.25
Vanadium (V)	.95-1.35
Cobalt (Co)	7.75-8.75
Nickel (Ni)	.30 max
FORGING (a)	
Start forging at	1900-2100°F (1038-1149°C)
Do not forge below	1700°F (927°C)
ANNEALING (c)	
Temperature	1600-1650°F (871-899°C)
Rate of cooling, max. per hour	40°F (22°C)
Typical annealed hardness, Brinell	235-269
HARDENING	
Rate of heating	Rapidly from preheat
Preheat Temperature	1350-1550°F (733-843°C)
Hardening temperature	2125-2175°F (h)(o) (1163-1191°C)
Time at temperature, minutes	2-5
Quenching medium	O, A, or S (l)
TEMPERING	
Tempering temperature	950-1100°F (510-593°C)
Approx. tempered hardness, Rockwell C	65-70
WEAR RESISTANCE	Very High to Highest
TOUGHNESS	Low
RESISTANCE TO SOFTENING EFFECT OF	
ELEVATED TEMPERATURE	Highest
DEPTH OF HARDENING	Deep
MACHINABILITY	Medium
GRINDABILITY	Low
DISTORTION IN HEAT TREATING	A or S: Low/O: Medium
SAFETY IN HARDENING	Low to Medium
RESISTANCE TO DECARBURIZATION	Low

AISI T15 (PM)

T15 PM is a tungsten high-speed steel designed for use in machining operations requiring heavy cuts, high speeds and feeds. Its primary use is in applications requiring the machining of high-hardness heat-treated materials such as high temperature alloys. The high carbon, vanadium, and cobalt contents contribute to good wear resistance, hot hardness and good hardness capabilities. T15 PM is produced by the powder metallurgy process which has resulted in improved quality from the standpoint of structural uniformity, response to heat treatment and grindability. These factors, along with increased toughness, are increased usage in the industry because of its recognized superior cutting ability.

TYPICAL APPLICATIONS

Broaches, Chasers, Form Tools, Heavy Duty Cutting Tools, High Production Blades, Milling Cutters, Reamers, and Taps.

TYPICAL ANALYSIS	TYPE T15 PM (UNS T12015)
Carbon (C)	1.55
Manganese (Mn)	.30
Silicon (Si)	.30
Tungsten (W)	12.25
Molybdenum (Mo)	
Chromium (Cr)	4.00
Vanadium (V)	5.00
Cobalt (Co)	5.00
FORGING (a) Start forging at Do not forge below	
ANNEALING (c) Temperature Rate of cooling, max. per hour Typical annealed hardness, Brinell	 1600-1650°F (871-899°C)
HARDENING Rate of heating Preheat Temperature Hardening temperature Time at temperature, minutes Quenching medium	 1450-1500°F (788-816°C) 2175-2225°F (h)(o) (1190-1218°C)
TEMPERING Tempering temperature Approx. tempered hardness, Rockwell C	 1000-1100°F (538-593°C) 66-68
WEAR RESISTANCE	Highest
TOUGHNESS	Low
RESISTANCE TO SOFTENING EFFECT OF	
ELEVATED TEMPERATURE	Very High
DEPTH OF HARDENING	Deep
MACHINABILITY	Medium
GRINDABILITY	High
DISTORTION IN HEAT TREATING	Medium
SAFETY IN HARDENING	Medium
RESISTANCE TO DECARBURIZATION	Medium

Super Square

Precision milled Super Square offers better utilization of skilled labor, machine time and overall productivity

Super Square Benefits:

- 2, 4, 6 side precision milled
- Available in all metal grades
- Flat, square and parallel
- Milled to customer tolerances
- Fast delivery to meet customer needs

Materials	2 Side	4 Side	6 Side
Tool Steel	●	●	●
Cast Iron	●	●	●
Stainless Steel	●	●	●
Aluminum	●	●	●
Alloys	●	●	●
Carbon	●	●	●
Copper	●	●	●
Brass	●	●	●
Bronze	●	●	●

HEAT TREATING NOTES

(a) The temperature at which to start heat treating is given as a range, the higher side of which should be used for large sections and heavy or rapid reductions, and the lower side for smaller sections and lighter reduction. As the alloy content of steel increases, the time of soaking at forging temperature increases proportionately. Likewise, as the alloy content increases, it becomes necessary to cool slowly from the maximum heating temperature. With very high alloy steels, such as high-speed steels and air- hardening steels, this slow cooling is imperative in order to prevent cracking and to leave the steel in semi-soft condition. Either furnace cooling or burying in an insulating medium, such as lime, mica, or silocel is satisfactory.

(b) The length of time the steel is held after being uniformly heated through at the normalizing temperature varies from about 15 minutes for a small section to about one hour for large sizes. Cooling from the normalizing temperature is done in still air. The purpose of normalizing after forging is to refine the grain structure and to produce a uniform structure throughout the forging. Normalizing should not be confused with low temperature [about 1200°F (649°C)] annealing used for the relief of residual stresses resulting from heavy machining, bending, and forming.

(c) The annealing temperature is given as a range, the upper limit of which should be used for large sections and the lower limit for smaller sections. The length of time the steel is held after being uniformly heated through at the annealing temperature varies from about one hour for light sections and small furnace charges of carbon or low alloy tool steel to about four hours for heavy sections and large furnace charges of high alloy steel.

(d) Normalizing, annealing, and hardening temperatures of carbon tool steels are given as ranges as they vary with carbon content. The following temperatures are suggested:

Normalizing
0.60 to 0.75% C: 1500°F (816°C)
0.75 to 0.90% C: 1450°F (788°C)
0.90 to 1.10% C: 1600°F (871°C)
1.10 to 1.40% C: 1600 to 1700°F (871 to 927°C)

Annealing
0.60 to 0.90% C: 1360 to 1400°F (738 to 760°C)
0.90 to 1.40% C: 1400 to 1450°F (760 to 788°C)

(e) Varies with carbon content as follows:

0.60-0.80% C: 1450-1550°F (788 to 843°C)
0.85-1.05% C: 1425-1550°F (774 to 843°C)
1.10-1.40% C: 1400-1525°F (760 to 829°C)

(f) Toughness decreases with increasing carbon content and depth of hardening.

(g) For large tools and tools having intricate sections, preheating at 1050-1200°F (566-649°C) is recommended.

(h) When high temperature heating is carried out in a salt bath, the range of temperatures should be about 25°F (14°C) lower than that shown.

(j) Times shown apply to open furnace heat treatment. For pack hardening a common rule is to heat for 1/2 hour per inch (25.4 mm) of cross section of the pack.

(k) Double tempering suggested for not less than one hour at temperature each temper.

Continued on next page ▶

HEAT TREATING NOTES

(l) O: Oil quench
A: Air Cool
S: Salt bath quench
B: Brine quench
W: Water quench

(m) Triple tempering suggested for not less than one hour at temperature each temper.

(n) When high carbon material is involved, lowering of the hardening temperature an additional 25°F (14°C) is suggested. This is in addition to the 25°F (14°C) reduction involving salt bath hardening.

(o) Available in two silicon contents, nominally 0.33% and 0.55%. When 0.55% silicon is used, the maximum suggested hardening temperature is 2150°F (1177°C).

TOOL WRAP

Tool Wrap is a revolutionary new approach to the heat treatment process. Here's how it works: wrap your parts in our special Tool Wrap as you would a package or a sandwich because Tool Wrap can be wrinkled, folded or cut with scissors (.002 thick T321 Stainless). Then place in your furnace and air cool as usual with the Tool Wrap on the material. Try Tool Wrap on all air hardening grades and hot work steels.

Consider the following advantages of Tool Wrap:

- ✓ No costly atmosphere or special controls needed.
- ✓ No time consuming Ni chrome box packing.
- ✓ Scale free heat treating.
- ✓ Hardened parts remain scale free, minimizing grinding.

GRADE AVAILABILITY

Grade	Thickness	Maximum Temperature
321 Stainless	.002"	2000°F (1093°C)
309 Stainless	.002"	2240°F (1093°C)

Tool Wrap edges are extremely sharp, gloves should always be worn when working with Tool Wrap.

TOOL STEEL FLATS AND SQUARES DCF

Size (inches)		Pounds (per ft)
3/8 x	1/2	0.751
	3/4	1.083
	1	1.440
	1-1/4	1.785
	1-3/8	1.931
	1-1/2	2.129
	1-3/4	2.446
	2	2.818
	2-1/4	3.101
	2-1/2	3.507
	2-3/4	3.801
	3	4.196
	3-1/2	4.885
	3-3/4	5.173
	4	5.574
	4-1/2	6.263
	5	6.877
	6	8.327
	6-1/2	8.901
	7	9.581
	8	11.086
	9	12.465
	10	13.661
	12	16.419
1/2 x	1/2	0.986
	5/8	1.212
	3/4	1.438
	7/8	1.664
	1	1.890
	1-1/8	2.116
	1-1/4	2.342
	1-3/8	2.568
	1-1/2	2.794
	1-3/4	3.247
	1-7/8	3.473
	2	3.699
	2-1/4	4.151
	2-1/2	4.603
	2-3/4	5.055
	3	5.508
	3-1/4	5.960
	3-1/2	6.412
	4	7.316
	4-1/2	8.221
	5	9.125
	5-1/2	10.029

Size (inches)		Pounds (per ft)
1/2 x	6	10.934
	6-1/2	11.838
	7	12.743
	8	14.551
	9	16.360
	10	18.169
	12	21.786
	14	25.404
	16	29.021
5/8 x	5/8	1.500
	3/4	1.780
	7/8	2.060
	1	2.340
	1-1/8	2.620
	1-1/4	2.900
	1-3/8	3.180
	1-1/2	3.460
	1-3/4	4.020
	2	4.580
	2-1/4	5.139
	2-1/2	5.699
	2-3/4	6.259
	3	6.819
	3-1/4	7.379
	3-1/2	7.939
	4	9.058
	4-1/2	10.178
	5	11.298
	5-1/2	12.417
	6	13.537
	6-1/2	14.657
	7	15.776
	8	18.016
	9	20.255
	10	22.495
	12	26.973
3/4 x	3/4	2.123
	7/8	2.456
	1	2.790
	1-1/8	3.124
	1-1/4	3.458
	1-3/8	3.791
	1-1/2	4.125
	1-3/4	4.793
	2	5.460

Size (inches)		Pounds (per ft)
3/4 x	2-1/4	6.128
	2-1/2	6.795
	2-3/4	7.463
	3	8.130
	3-1/4	8.798
	3-1/2	9.465
	4	10.800
	4-1/2	12.135
	5	13.470
	5-1/2	14.805
	6	16.140
	6-1/2	17.475
	7	18.810
	8	21.480
	9	24.150
	10	26.820
	12	32.161
	14	37.501
	16	42.841
	20	53.521
7/8 x	7/8	2.853
	1	3.240
	1-1/8	3.628
	1-1/4	4.015
	1-3/8	4.403
	1-1/2	4.791
	1-3/4	5.566
	2	6.341
	2-1/4	7.116
	2-1/2	7.891
	2-3/4	8.666
	3	9.442
	3-1/4	10.217
	3-1/2	10.992
	4	12.542
	4-1/2	14.093
	5	15.643
	5-1/2	17.193
	6	18.744
	7	21.844
	8	24.945
	9	28.046
	10	31.146
	12	37.348

DCF Thickness and Width Oversize Ranges :

Width (based on thickness)	
Through 4" thick	.035 to .077 oversize
Over 4" thick.....	.062 to .124 oversize

Thickness	
Through 4" thick	.015 - .035 oversize
Over 4" thick	.062 - .124 oversize

Actual weight may vary because of oversize tolerance.
Sizes not listed above can be cut from plate.
For Powdered Metal add 3% for weight

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TOOL STEEL FLATS AND SQUARES DCF

Size (inches)		Pounds (per ft)
1 x	1	3.690
	1-1/4	4.573
	1-3/8	5.014
	1-1/2	5.456
	1-3/4	6.339
	2	7.222
	2-1/4	8.104
	2-1/2	8.987
	2-3/4	9.870
	3	10.753
	3-1/2	12.519
	4	14.284
	4-1/2	16.050
	5	17.816
	5-1/2	19.581
	6	21.347
	6-1/2	23.113
	7	24.878
	8	28.410
	9	31.941
	10	35.472
	12	42.535
	14	49.598
	16	56.660
1-1/8 x	1-1/8	4.636
	1-1/4	5.131
	1-1/2	6.121
	1-3/4	7.112
	2	8.102
	2-1/4	9.093
	2-1/2	10.083
	2-3/4	11.074
	3	12.064
1-1/8 x	3-1/2	14.045
	4	16.026
	4-1/2	18.007
	5	19.988
	5-1/2	21.969
	6	23.950
	8	31.874
	10	39.798
	12	47.722
1-1/4 x	1-1/4	5.688
	1-1/2	6.787
	1-3/4	7.885
1-1/4 x	2	8.983
	2-1/4	10.081
	2-1/2	11.179
	2-3/4	12.277
	3	13.376
	3-1/2	15.572
	4	17.768
	4-1/2	19.965
	5	22.161
	5-1/2	24.357
	6	26.553
	7	30.946
	8	35.339
	9	39.731
	10	44.124
	12	52.909
	16	70.480
	20	88.050
	24	105.621
1-3/8 x	1-3/8	6.849
	1-1/2	7.452
	1-3/4	8.658
	2	9.864
	2-1/4	11.069
	2-1/2	12.275
	2-3/4	13.481
	3	14.687
	3-1/2	17.099
	4	19.510
	4-1/2	21.922
	5	24.333
	5-1/2	26.745
	6	29.157
1-3/8 x	8	38.803
	9	43.627
	10	47.814
	12	57.334
1-1/2x	1-1/2	8.127
	1-3/4	9.431
	2	10.744
	2-1/4	12.058
	2-1/2	13.371
	2-3/4	14.685
	3	15.998
	3-1/2	18.625
1-1/2x	4	21.252
	4-1/2	23.879
	5	26.506
	5-1/2	29.133
	6	31.760
	7	37.014
	8	42.268
	9	47.522
	10	52.776
	12	63.284
	16	84.299
	20	105.315
	24	126.331
1-3/4x	1-3/4	10.977
	2	12.506
	2-1/4	14.034
	2-1/2	15.563
	2-3/4	17.092
	3	18.621
	3-1/2	21.678
	4	24.736
	4-1/2	27.794
	5	30.851
	5-1/2	33.909
	6	36.967
	7	43.082
	8	49.197
	9	55.312
	10	61.427
	12	73.658
2 x	2	14.267
	2-1/4	16.011
	2-1/2	17.755
	2-3/4	19.499
	3	21.244
	3-1/2	24.732
	4	28.220
	4-1/2	31.708
	5	35.197
	5-1/2	38.685
	6	42.173
	7	49.150
	8	56.126
	9	63.103
	10	70.079

DCF Thickness and Width Oversize Ranges :

Width (based on thickness)	Thickness
Through 4" thick ..... .035 to .077 oversize	Through 4" thick ..... .015 - .035 oversize
Over 4" thick..... .062 to .124 oversize	Over 4" thick ..... .062 - .124 oversize

Actual weight may vary because of oversize tolerance.
Sizes not listed above can be cut from plate.
For Powdered Metal add 3% for weight

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TOOL STEEL FLATS AND SQUARES DCF

Size (inches)		Pounds (per ft)
2 x	12	84.032
	16	111.938
	20	139.845
	24	167.751
2-1/4x	2-1/4	17.988
	2-1/2	19.947
	2-3/4	21.907
	3	23.866
	3-1/2	27.785
	4	31.704
	4-1/2	35.623
	5	39.542
	5-1/2	43.461
	6	47.380
	7	55.218
	8	63.055
	9	70.893
	10	78.731
	12	94.407
2-1/2x	2-1/2	22.139
	2-3/4	24.314
	3	26.489
	3-1/2	30.838
	4	35.188
	4-1/2	39.538
	5	43.887
	5-1/2	48.237
	6	52.586
	7	61.285
	8	69.985
	9	78.684
	10	87.383
	12	104.781
	16	137.746
	20	172.086
	24	206.426
2-3/4x	2-3/4	26.721
	3	29.112
	3-1/2	33.892
	4	38.672
	4-1/2	43.452
	5	48.232
	5-1/2	53.013
	6	57.793
2-3/4 x	7	66.469
	8	75.904
	9	85.339
	10	94.774
	12	113.644
	16	151.384
	20	189.124
	24	227.147
3 x	3	31.734
	3-1/2	36.945
	4	42.156
	4-1/2	47.367
	5	52.578
	5-1/2	57.788
	6	62.999
	7	73.421
	8	83.843
	9	94.265
	10	104.686
	12	125.530
	16	165.022
	20	206.162
3-1/2x	3-1/2	43.052
	4	49.124
	4-1/2	55.196
	5	61.268
	5-1/2	67.340
	6	73.412
	7	85.557
	8	97.701
	9	109.845
	10	121.990
	12	146.278
	16	192.299
	20	240.239
4 x	4	56.092
	4-1/2	63.025
	5	69.959
	5-1/2	76.892
	6	83.826
	7	97.693
	8	111.559
	9	125.426
	10	139.293
4 x	12	162.027
	16	219.575
	20	274.315
4-1/2 x	4-1/2	71.618
	5	79.413
	6	95.003
	8	126.182
	10	154.542
5 x	5	88.188
	5-1/2	96.844
	6	105.500
	7	122.812
	8	140.124
	10	174.749
	12	209.373
5-1/2x	5-1/2	106.480
	6	115.998
	8	154.067
	10	192.137
6 x	6	126.495
	7	147.252
	8	168.010
	10	209.524
	12	251.039

* 10" THICK PLATE IS AVAILABLE IN SOME GRADES. PLEASE INQUIRE.

DCF Thickness and Width Oversize Ranges :

Width (based on thickness)	
Through 4" thick	.035 to .077 oversize
Over 4" thick.....	.062 to .124 oversize

Thickness	
Through 4" thick	.015 - .035 oversize
Over 4" thick	.062 - .124 oversize

Actual weight may vary because of oversize tolerance.
Sizes not listed above can be cut from plate.
For Powdered Metal add 3% for weight

TOOL STEEL ROUNDS

DCF

Diameter (inches)	Pounds (per ft)	Diameter (inches)	Pounds (per ft)	Diameter (inches)	Pounds (per ft)
1/4	.182	2-3/4	20.817	8-1/2	204.154
5/16	.285	2-7/8	22.725	8-3/4	211.460
3/8	.404	3	25.778	9	228.202
7/16	.545	3-1/8	27.896	9-1/2	253.589
1/2	.727	3-1/4	30.099	10	280.423
9/16	.912	3-1/2	34.754	10-1/2	308.492
5/8	1.117	3-3/4	39.745	11	337.900
11/16	1.344	4	45.070	11-1/2	368.646
3/4	1.591	4-1/4	51.079	12	400.928
7/8	2.157	4-1/2	57.094	12-1/2	434.359
1	2.799	4-3/4	63.443	13	469.130
1-1/8	3.525	5	70.126	13-1/2	505.238
1-1/4	4.335	5-1/4	77.145	14	543.372
1-3/8	5.225	5-1/2	84.498	14-1/2	582.182
1-1/2	6.206	5-3/4	92.185	15	622.331
1-5/8	7.408	6	100.207	16	706.644
1-3/4	8.564	6-1/4	109.830	17	796.311
1-7/8	9.803	6-1/2	118.571	18	891.333
2	11.125	6-3/4	127.646	19	991.709
2-1/8	12.531	7	137.057	20	1097.440
2-1/4	14.021	7-1/4	149.891	22	1324.964
2-3/8	15.595	7-1/2	160.074	24	1573.907
2-1/2	17.252	7-3/4	170.592	26	1844.266
2-5/8	18.993	8	181.445	28	2136.044

*For Powdered Metal add 3% for weight.

*DC53 rounds under 6-1/2" are hot rolled and oversized to finish at their nominal size. 6-1/2" and over are rough turned and oversized to finish at their nominal size.

*M2 rounds are available in on-size diameters and oversize diameters. M2 rounds are available in 3/8" to 6" diameters.

Alro's in-house services can have a tremendous affect on your turnaround time. If your need is for one piece or thousands of pieces Alro can accommodate to your satisfaction.

DE-CARB FREE THICKNESS AND WIDTH OVERSIZE RANGES

Flats and Squares

Size (inches)	Width - Based on Thickness (inches)	Thickness (inches)
Through 4" thick	.035 - .077 oversize	.015 - .035 oversize
Over 4" thick	.062 - .124 oversize	.062 - .093 oversize

Rounds - Typical Machining Allowances

	Nominal Size (inches)	Oversize Tolerance (inches)
Rough Turned Tolerances:	1/2 to 3 Over 3 thru 6	+0.015 to +0.035 +0.062 to +0.186
(All rounds 3" diameter and over are supplied with a Rough Turned tolerance)	Over 6 thru 7 Over 7 thru 18 Over 18	+0.093 to +0.250 +0.090 to +0.375 +0.125 to +0.5625

MACHINING AND DECARBURIZATION ALLOWANCES

When ordering hot rolled bar stock, allowances must be made for machining in order to remove all decarburized surface. Decarburization is caused by heating for forging or rolling, and annealing. To obtain a uniform surface hardness and keep warpage to a minimum on finished tools, it is necessary to remove all the decarburization from all surfaces before hardening.

The minimum allowances for machining and the maximum decarburization limits for rounds, hexagons, octagons, and flats are given in the following tables.

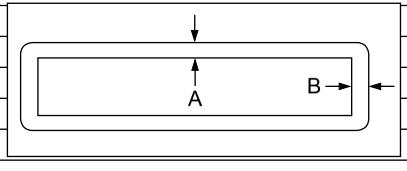
Minimum Allowances Per Side for Machining Prior to Heat Treatment for Hot Rolled Rounds

Ordered Size (inches)	Hot Rolled	Forged	Rounds Rough Turned
Up to 1/2, incl.	.016	—	—
Over 1/2 to 1, incl.	.031	—	—
Over 1 to 2, incl.	.048	.072	—
Over 2 to 3, incl.	.063	.094	.020
Over 3 to 4, incl.	.088	.120	.024
Over 4 to 5, incl.	.112	.145	.032
Over 5 to 6, incl.	.150	.170	.040
Over 6 to 8, incl.	.200	.200	.048
Over 8	—	.200	.072

HOT ROLLED MACHINING AND DECARBURIZATION ALLOWANCES

Maximum Decarburization Limits — 80% of allowances per side for machining
Minimum Allowances Per Side for Machining Prior to Heat Treatment for Hot-Rolled Square and Flat Bars

Specified Thickness (inches)		Specified Width, In. 0 to 1/2 Incl.	Over 1/2 to 1 Incl.	Over 1 to 2 Incl.	Over 2 to 3 Incl.	Over 3 to 4 Incl.	Over 4 to 5 Incl.	Over 5 to 6 Incl.	Over 6 to 7 Incl.	Over 7 to 8 Incl.	Over 8 to 9 Incl.	Over 9 to 10 Incl.
0 to 1/2, incl.	A	.025	.025	.030	.035	.040	.045	.050	.055	.060	.060	.060
	B	.025	.036	.044	.056	.068	.092	.104	.120	.136	.144	.152
Over 1/2 to 1, incl.	A		.045	.045	.050	.055	.060	.070	.070	.075	.075	.075
	B		.045	.052	.064	.080	.104	.120	.136	.160	.160	.160
Over 1 to 2, incl.	A			.065	.065	.070	.070	.075	.075	.090	.095	.100
	B			.065	.075	.084	.112	.124	.144	.168	.180	.180
Over 2 to 3, incl.	A				.085	.085	.085	.085	.090	.100	.100	.100
	B					.102	.120	.136	.160	.180	.190	.190
Over 3 to 4, incl.	A					.115	.115	.115	.115	.125	.125	.125
	B					.115	.127	.140	.180	.190	.190	.190
Over 4 to 5, incl.	A						.150	.150	.150	.150	.150	.150
	B						.150	.165	.180	.190	.190	.190
Over 5 to 6, incl.	A							.190	.190	.190	.190	.190
	B							.190	.190	.190	.190	.190
Over 6	A								.250	.250	.250	.250
	B								.250	.250	.250	.250



Minimum Allowances Per Side for Machining of Forged Squares and Flat Bars

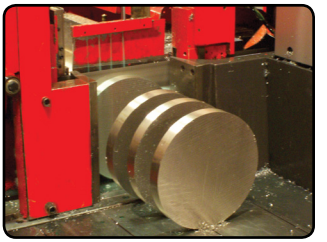
Specified Thickness (inches)		Specified Width, In. 0 to 1/2 Incl.	Over 1/2 to 1 Incl.	Over 1 to 2 Incl.	Over 2 to 3 Incl.	Over 3 to 4 Incl.	Over 4 to 5 Incl.	Over 5 to 6 Incl.	Over 6 to 7 Incl.	Over 7 to 8 Incl.	Over 8 to 9 Incl.	Over 9 to 10 Incl.
0 to 1/2, incl.	A	.030	.030	.035	.040	.045	.055	.065	.070	.075		
	B	.030	.048	.064	.080	.100	.120	.144	.168	.200		
Over 1/2 to 1, incl.	A		.060	.060	.065	.065	.075	.080	.085	.090	.100	.110
	B		.060	.072	.084	.100	.120	.144	.168	.200	.200	.200
Over 1 to 2, incl.	A			.090	.090	.090	.100	.110	.115	.125	.140	.150
	B			.090	.100	.108	.124	.148	.172	.200	.200	.200
Over 2 to 3, incl.	A				.120	.120	.125	.130	.135	.150	.160	.175
	B				.120	.130	.140	.148	.172	.200	.200	.200
Over 3 to 4, incl.	A					.150	.150	.160	.180	.190	.210	.225
	B					.150	.150	.160	.180	.190	.210	.225
Over 4 to 5, incl.	A						.180	.180	.190	.210	.225	.250
	B						.180	.180	.190	.210	.225	.250
Over 5 to 6, incl.	A							.210	.225	.225	.250	.250
	B							.210	.225	.225	.250	.250
Over 6	A								.250	.250	.250	.250
	B								.250	.250	.250	.250

Alro Steel

Metals • Industrial Supplies • Plastics

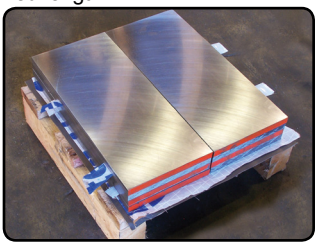
Tool Steel Processing Capabilities

Making a trim cut on Tool Steel Plate to create bar stock.



Production cutting to your specified length.

Creating DCF bars at our plate processing facility in Charlotte MI.



Tool Steel, ground top and bottom to customer specifications.

Alro's Production/Precision Sawing

Cutting Capacities

	Non Ferrous Cold Saws	Carbon Steel Cold Saws	Precision Cut Band Saws
	• Aluminum • Brass • Copper • Plastic	• Alloys • Stainless Steel • Tool Steel • Carbon Steel	• Alloys • Stainless Steel • Tool Steel • Carbon Steel
Rounds	.375" to 3.5"	.375" to 7"	up to 28"
Squares	.250" to 3.5"	.250" to 6.25"	up to 20"
Rd. Pipe/Tube	.375" to 3.5"	.375" to 7"	up to 20"
Sq. Pipe/Tube	.375" to 3.5"	.375" to 6.25"	up to 20"
Cut Length	.250" to 24"	.187" to 48"	.187" to 36"
Length Tolerance	+ or - .004"	+ or - .004"	+ or - .010"

This is a guideline only. Tolerance may vary depending on material.

Visit the Alro Web Site

alro.com