SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE INFORMATION REPORT

SAE J437a | REV. APR70

Issued 1949-01
Revised 1970-04

Superseding J437a MAY69

Submitted for recognition as an American National Standard

SELECTION AND HEAT TREATMENT OF TOOL AND DIE STEELS

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

1. ***Scope***—The information in this report covers data relating to SAE J438, Tool and Die Steels, and is intended as a guide to the selection of the steel best suited for the intended purpose and to provide recommended heat treatments and other data pertinent to their use.

Specific requirements as to physical properties are not included because the majority of tool and die steels are either worked or given special heat treatments by the purchaser. The purchaser may or may not elect to use the accompanying data for specification purposes.

2. *References*

2.1 Applicable Publication—The following publication forms a part of the specification to the extent specified herein. Unless otherwise indicated the lastest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J438—Tool and Die Steels

2.1.2 ASM PUBLICATION—ATTN: MSC/Book Order, ASM International, PO Box 473, Novelty, OH 44072-9901.

ASM Handbook—1948 Edition, pp. 658-659

3. *The Selection of Tool and Die Steels*[1]

Simplification of the problems connected with the selection of tool steels has long been an aim of both producers and consumers. This article is restricted to a discussion of the general principles involved in selection and will include a tabulation of the metallurgical characteristics of the principal tool steel types as an aid in selection. A correlation of these metallurgical characteristics with the requirements of the tool in operation should form the basis of a sound approach to the selection of a steel for any application. Table 1.

1. Condensed from the ASM Handbook, 1948 edition, pp. 658–659, with the permission of the American Society for Metals.

TABLE 1—COMPARISON OF TOOL STEELS ON BASIS OF PROPERTIES AFFECTING SELECTION

SAE Steel Designation	Nondeforming Properties	Safety in Hardening	Depth of Hardening (1)	Toughness	Resistance to Softening Effect of Heat	Wear Resistance	Machinability
Water Hardening Tool Steels							
W108	Poor	Fair	Shallow	Good(2)	Poor	Fair	Best
W109	Poor	Fair	Shallow	Good(2)	Poor	Fair	Best
W110	Poor	Fair	Shallow	Good(2)	Poor	Good	Best
W112	Poor	Fair	Shallow	Good(2)	Poor	Good	Best
W209	Poor	Fair	Shallow	Good	Poor	Fair	Best
W210	Poor	Fair	Shallow	Good	Poor	Good	Best
W310	Poor	Fair	Shallow	Good	Poor	Good	Best
Shock Resisting Tool Steels							
S1—Chromium-Tungsten	Fair	Good	Medium	Good	Fair	Fair	Fair
S2—Silicon-Molybdenum	W Poor(3) O Fair(3)	W Poor(3) O Good(3)	Medium	Best	Fair	Fair	Good
S5—Silicon-Manganese	W Poor(3) O Fair(3)	W Poor(3) O Good(3)	Medium	Best	Fair	Fair	Fair
Cold Work Tool Steels							
Oil Hardening Types							
O1—Low Manganese	Good	Good	Medium	Fair	Poor	Good	Good
O2—High Manganese	Good	Good	Medium	Fair	Poor	Good	Good
O6—Molybdenum Graphitic	Fair	Good	Medium	Fair	Poor	Good	Best
Medium Alloy Air Hardening Types							
A2—5% Chromium Air Hard	Best	Best	Deep	Fair	Fair	Good	Fair
High Carbon-High Chromium Types							
D2—High Carbon-High Chromium (Air)	Best	Best	Deep	Fair	Fair	Best	Poor
D3—High Carbon-High Chromium (Oil)	Good	Good	Deep	Poor	Fair	Best	Poor
D5—High Carbon-High Chromium-Cobalt	Best	Best	Deep	Fair	Fair	Best	Poor
D7—High Carbon-High Chromium-High Vanadium	Best	Best	Deep	Poor	Fair	Best	Poor
Hot Work Tool Steels							
Chromium Base Types							
H11—Chromium-Molybdenum-V	Good	Good	Deep	Good	Good	Fair	Fair
H12—Chromium-Molybdenum-Tungsten	Good	Good	Deep	Good	Good	Fair	Fair
H13—Chromium-Molybdenum-VV	Good	Good	Deep	Good	Good	Fair	Fair
Tungsten Base Types							
H21—Tungsten	Good	Good	Deep	Good	Good	Fair	Fair
High Speed Tool Steels							
Tungsten Base Types							
T1—Tungsten 18-4-1	Good	Good	Deep	Poor	Good	Good	Fair
T2—Tungsten 18-4-2	Good	Good	Deep	Poor	Good	Good	Fair
T4—Cobalt-Tungsten 18-4-1-5	Good	Fair	Deep	Poor	Best	Good	Fair
T5—Cobalt-Tungsten 18-4-2-8	Good	Fair	Deep	Poor	Best	Good	Fair
T8—Cobalt-Tungsten 14-4-2-5	Good	Fair	Deep	Poor	Best	Good	Fair
Molybdenum Base Types							
M1—Molybdenum 8-2-1	Good	Fair	Deep	Poor	Good	Good	Fair
M2—Molybdenum-Tungsten 6-6-2	Good	Fair	Deep	Poor	Good	Good	Fair
M3—Molybdenum-Tungsten 6-6-3	Good	Fair	Deep	Poor	Good	Best	Fair
M4—Molybdenum-Tungsten 6-6-4	Good	Fair	Deep	Poor	Good	Best	Fair
Special Purpose Tool Steels							
Low Alloy Types							
L6—Nickel-Chromium	Fair	Good	Medium	Fair	Poor	Fair	Fair
L7—Chromium	Fair	Good	Medium	Fair	Poor	Good	Fair

1. These are intended to emphasize major differences between the groups of steels and do not account for the minor differences in depths of hardening that exist between steels of the same group. This is particularly true of the Water Hardening W Steels which are frequently furnished with varying degrees of hardenability as listed in Table 1.
2. Toughness decreases somewhat with increasing depth of hardening.
3. W as shown here indicates water quench. O as shown here indicates oil quench.

Practical experience indicates that in the majority of instances the choice is not limited to a single type of tool steel or even to a particular family of tool steels for a workable solution to an individual tooling problem. Because it is desirable to select the steel that will give the most economical overall performance, the tool life obtained with each steel under consideration should be judged by weighing such factors as expected productivity, ease of fabrication, and cost.

The majority of tool steel applications can be divided into a small number of groups or types of operations: cutting, shearing, forming, drawing, extrusion, rolling, and battering. Cutting tools include drills, taps, broaches, hobs, lathe tools, and the like. Shearing tools include shears, blanking and trimming dies, punches, and such. Forming tools include draw, forging, cold heading, and die casting dies. Battering tools include chisels and all forms of tools involving heavy shock. Many of these classifications can be further divided into cold and hot working tools.

For each of these groups, certain metallurgical characteristics are of utmost importance. Most cutting tools require high hardness, high resistance to the softening effect of heat, and high wear resistance. Shearing tools require high wear resistance combined with fair toughness, and these characteristics must be properly balanced depending on the tool design, thickness of stock being sheared, and temperature of the shearing operation. Forming tools must possess high wear resistance or high toughness and high strength, and many require maximum resistance to heat softening. In battering tools high toughness is most important.

Hardness, strength, toughness, wear resistance, and resistance to heat softening are, therefore, prime selective factors for tool steel applications. Many other properties must be seriously considered in individual applications; these include permissible distortion in hardening, permissible surface decarburization, hardenability or depth of hardness desired, resistance to heat checking, machinability and grindability, as well as heat treating requirements, including temperatures, atmospheres, and equipment.

Table 1 lists those properties which merit special consideration when selecting steels for any application, from the list shown. For compositions of these steels, Table 1 of SAE J438.

Table 2 is presented as an aid in the relative evaluation of those properties which must be considered for the proper heat treatment of the steels.

4. ***Relation of Design to Heat Treatment*****—**The design bears, in many ways, upon the serviceability of the tool or machine part, and unsatisfactory performance may frequently be traced directly to faulty design. This discussion is concerned only with design as it affects the heat treating operation and, through the heat treatment, the serviceability of the finished part. It is the purpose of this discussion to bring about a better mutual understanding between the designer and the steel treater so that faulty design which may cause cracking or distorting during heat treating can be avoided.

The fundamental principles of good design from a heat treatment standpoint are quite simple. Heat treated steel has a certain strength depending upon the analysis of the steel, the quality of the metal, and the heat treatment which it has received. When subjected to a combination of forces its ultimate strength, the steel cracks or fails. There are 2 types of force combining to break steel, which are:

a. The internal stress set up during fabrication and heat treatment of the tool.
b. The external force of service.

Sometimes the internal stresses alone exceed the strength of the metal, and the parts crack in hardening. Again, the internal stresses may equal 90% or more of the total strength, in which case failure will develop in service under relatively light loads. It therefore appears that the useful strength of a part decreases in proportion as the internal stresses increase.

TABLE 2—APPROXIMATE COMPARISON OF TOOL AND DIE STEELS ON BASIS OF SOME HEAT TREATING CHARACTERISTICS

SAE Steel Designation	Quench Medium	Preheat Temperature, F	Hardening Temperature Range, [1] F	Hardness after Quenching, Rockwell C	Tempering Temperature Range, [1] F	Hardness after Tempering, Rockwell C	Decarburization (Prevention of During Heat Treatment)
Water Hardening Tool Steel							
W108	Water	—(2)	1420–1450	65–67	350–525	65-56	—(3)
W109	Water	—(2)	1420–1450	65–67	350–525	65-56	—(3)
W110	Water	—(2)	1420–1450	65–67	350–525	65-56	—(3)
W112	Water	—(2)	1420–1500	65–67	350–525	65-56	—(3)
W209	Water	—(2)	1420–1500	65–67	350–525	65-56	—(3)
W210	Water	—(2)	1420–1500	65–67	350–525	65-56	—(3)
W310	Water	—(2)	1420–1500	65–67	350–525	65-56	—(3)
Shock Resisting Tool Steels							
S1—Chromium-Tungsten	Oil	1200–1300	1650–1800	57–59	300–1000	57-45	—(4)
S2—Silicon-Molybdenum	Water	—(2)	1550–1575	60–62	300–500	60-54	—e
	Oil	—(2)	1600–1625	58–60	300–500	58-54	—e
S5—Silicon-Manganese	Water	—(2)	1550–1600	60–62	300–650	60-54	—e
	Oil	—(2)	1600–1675	58–60	300–650	58-54	—e
Cold Work Tool Steels							
Oil Hardening Types							
O1—Low Manganese	Oil	—(2)	1450–1500	63–65	300–800	62-50	—e
O2—High Manganese	Oil	—(2)	1420–1450	63–65	375–500	62-57	—e
O6—Molybdenum Graphitic	Oil	—(2)	1450–1500	63–65	300–800	63-50	—e
Medium Alloy Air Hardening Types							
A2—5% Chromium Air Hard	Air	1200–1300	1725–1775	61–63	400–700	60-57	—(4)
High Carbon-High Chromium Types							
D2—High Carbon-High Chromium	Air	1200–1300	1800–1875	61–63	400–700	60-58	—(4)
D3—High Carbon-High Chromium	Oil	1200–1300	1750–1800	62–64	400–700	62-58	—(4)
D5—High Carbon-High Chromium-Cobalt	Air	1200–1300	1800–1875	60–62	400–700	59-57	—(4)
D7—High Carbon-High Chromium-High Vanadium	Air	1200–1300	1850–1950	63–65	300–500	65-63	—(4)
					850–1000	62-58	
Hot Work Tool Steels							
Chromium Base Types							
H11—Chromium-Molybdenum-Y	Air	1450–1500	1825–1875	53–55	1000–1100	51-43	—(4)
H12—Chromium-Molybdenum-Tungsten	Oil, Air	1450–1500	1800–1900	53–55	1000–1100	51-43	—(4)
H13—Chromium-Molybdenum-VV	Air	1400–1450	1825–1875	53–55	1000–1100	51-43	—(4)
Tungsten Base Types							
H21—Tungsten	Oil, Air	1500–1550	2100–2150	50–52	950–1150	50-47	—(4)
High Speed Tool Steels							
Tungsten Base Types							
T1—Tungsten 18-4-1	Oil, Air, Salt	1500–1550	2300–2375	63–65	1025–1100	65-63	—(4)
T2—Tungsten 18-4-2	Oil, Air, Salt	1500–1550	2300–2375	63–65	1025–1100	65-63	—(4)
T4—Cobalt-Tungsten 18-4-1-5	Oil, Air, Salt	1500–1550	2300–2375	63–65	1025–1100	65-63	—(4)
T5—Cobalt-Tungsten 18-4-2-8	Oil, Air, Salt	1500–1550	2300–2400	63–65	1050–1100	65-63	—(4)
T8—Cobalt-Tungsten 14-4-2-5	Oil, Air, Salt	1500–1550	2300–2375	63–65	1025–1100	65-63	—(4)
Molybdenum Base Types							
M1—Molybdenum 8-2-1	Oil, Air, Salt	1400–1500	2150–2250	63–65	1025–1050	65-63	—(4)
M2—Molybdenum-Tungsten 6-6-2	Oil, Air, Salt	1450–1500	2175–2250	63–65	1025–1075	65-63	—(4)
M3—Molybdenum-Tungsten 6-6-3	Oil, Air, Salt	1450–1500	2150–2225	63–65	1025–1075	65-63	—(4)
M4—Molybdenum-Tungsten 6-6-4	Oil, Air, Salt	1450–1500	2150–2225	63–65	1025–1075	65-63	—(4)
Special Purpose Tool Steels							
Low Alloy Types							
L6—Nickel-Chromium	Oil	—(2)	1500–1600	62–64	400–800	62-48	—(3)
L7—Chromium	Oil	—(2)	1525–1550	63–65	350–500	62-60	—(3)

1. The purpose of these columns is to show the usual ranges of temperature employed in hardening and tempering and is not to be used as a specification.
2. For large tools and tools having intricate sections, preheating at 1050 to 1200 °F is recommended.
3. Use moderately oxidizing atmosphere in fumace or a suitable neutral salt bath.
4. Use protective pack from which volatile matter has been removed, carefully balanced neutral salt bath, or atmosphere controlled furnaces. In the latter case, the furnace atmosphere should be in equilibrium with the carbon content of the steel being treated. Furnace atmosphere dew point is considered a reliable method for measuring and controlling this equilibrium.

Internal stresses arise from many causes, but the most serious by far are those developed by differential cooling resulting from quenching. This differential cooling is largely a function of the size and shape of the piece being quenched; in other words, the design. Here, then, is the relation of design to heat treatment, and the basic principle of successful design is to plan shapes which allow the piece to cool as uniformly as possible during quenching.

Some shapes are almost impossible to harden because of the abruptness in the change of sections, but a certain latitude in design is recognized when using an oil hardening or air hardening steel.

Errors in design reach further than merely affecting the internal stress of hardening. A sharp angle serves to concentrate greatly the stresses of service. The design of the part may be entirely responsible for concentrating the service stresses at a point already weakened by internal stresses produced during hardening.

Reducing all the foregoing to a single statement, a part is properly designed from the standpoint of heat treatment when the entire piece may be heated and cooled at approximately the same rate during the heat treating operation. Perfection in this regard is unattainable because, even in a sphere, the surface cools more rapidly than the interior. The designer should, however, attempt to so shape his parts that they will heat and cool as uniformly as possible. The greater the temperature difference between any two points on a given part during quenching and the closer these two points are together, the greater will be the internal stress and, therefore, the poorer the design.

The principles described in this article are illustrated in Figure 1.

5. Heat Treat Data—The thermal treatments listed in Table 3 cover the generally used treatments for the forging, normalizing, and annealing of tool and die steels.

The thermal treatments listed in Table 2, under selection, cover the usual ranges of temperature for hardening and tempering tool and die steels.

The information listed in Tables 2 and 3 is not intended for specification because of the need for altering treatments for specific applications.

6. Allowance for Machining of Tool Steel Bars[1]

Tool and die steels should be ordered oversize with sufficient material to be removed from all surfaces by machining or grinding to allow for:

a. Surface decarburization.
b. Surface defects such as slivers, seams, laps, scale marks, and the like.
c. Undersize tolerance as given in Tables 6, 7, 8, and 9.

Table 4 lists the minimum allowance per side over finish size for machining or grinding rounds, squares, hexagons, and octagons.

Polished or ground tool steel quality round drill rod is free from decarburization or any surface defects requiring surface removal.

1. In cooperation with the American Iron and Steel Institute.

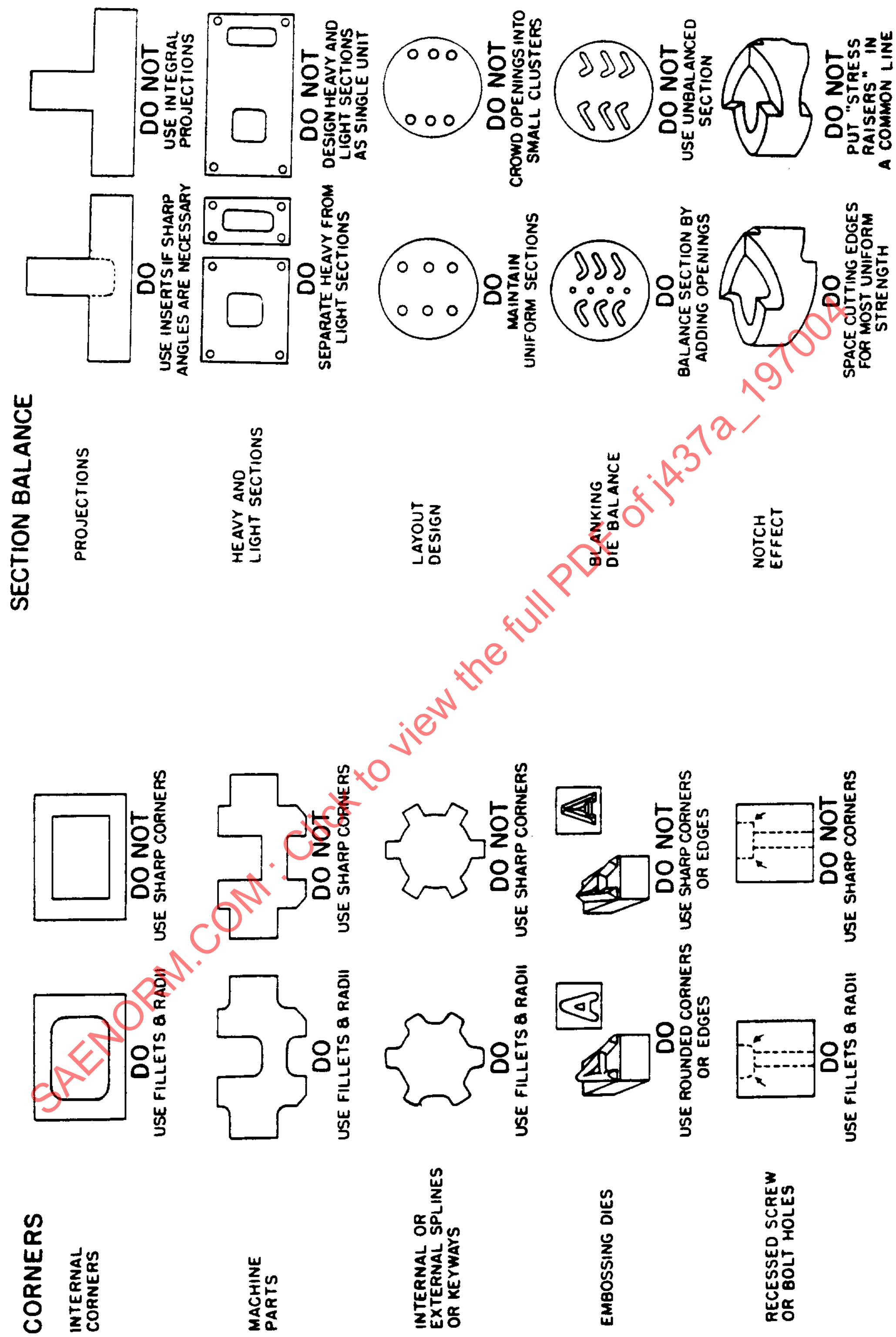

FIGURE 1—TOOL AND DIE DESIGN TIPS (TO REDUCE BREAKAGE IN HEAT TREATING)

TABLE 3—FORGING, NORMALIZING, AND ANNEALING TREATMENTS OF TOOL AND DIE STEELS

SAE Steel Designation [1]	Forging [2]			Normalizing [3]		Annealing[4]			
	Heat Slowly to	Start Forging at	Do Not Forge below	Heat Slowly to	Hold at	Temperature	Maximum Rate of Cooling, F/hr	Approximate Brinell Hardness	Approximate Rockwell B
Water Hardening Tool Steels									
W108	1450	1800–1950	1500	1450	1500	1400–1450	75	159–202	84–94
W109	1450	1800–1950	1500	1450	1500	1375–1425	75	159–202	84–94
W110	1450	1800–1900	1500	1450	1550	1400–1450	75	159–202	84–94
W112	1450	1800–1900	1500	1450	1625	1400–1450	75	159–202	84–94
W209	1450	1800–1950	1500	1450	1500	1375–1425	75	159–202	84–94
W210	1450	1800–1900	1500	1450	1550	1400–1450	75	159–202	84–94
W310	1450	1800–1900	1500	1450	1550	1400–1450	75	159–202	84–94
Shock Resisting Tool Steels									
S1—Chromium-Tungsten	1500	1800–2000	1600	Do not normalize		1450–1500	50	192–235	92–99
S2—Silicon-Molybdenum	1500	1900–2100	1600	1500	1650	1400–1450	50	192–229	92–98
S5—Silicon-Manganese	1500	1900–2050	1600	1500	1600	1400–1450	50	192–229	92–98
Cold Work Tool Steels									
Oil Hardening Types									
O1—Low Manganese	1500	1750–1900	1550	1500	1600	1425–1475	50	183–212	90–96
O2—High Manganese	1500	1750–1900	1550	1500	1550	1375–1425	50	183–212	90–96
O6—Molybdenum Graphitic	1500	1750–1900	1500	1500	1625	1425–1475	20	183–217	90–96
Medium Alloy Air Hardening Types									
A2—5% Chromium Air Hard	1600	1850–2000	1650	Do not normalize		1550–1600	40	202–229	94–98
High Carbon-High Chromium Types									
D2—High Carbon-High Chromium (Air)	1650	1850–2000	1650	Do not normalize		1600–1650	40	207–255	95–192
D3—High Carbon-High Chromium (Oil)	1650	1850–2000	1650	Do not normalize		1600–1650	50	212–255	96–102
D5—High Carbon-High Chromium-Cobalt	1600	1850–2000	1650	Do not normalize		1600–1650	40	207–255	95–102
D7—High Carbon-High Chromium-High Vanadium	1650	2050–2125	1800	Do not normalize		1600–1650	50	235–262	99–103
Hot Work Tool Steels									
Chromium Base Types									
H11—Chromium-Molybdenum-V	1650	1950–2100	1650	Do not normalize		1550–1600	50	192–229	92–98
H12—Chromium-Molybdenum-Tungsten	1650	1950–2100	1650	Do not normalize		1600–1650	50	192–229	92–98
H13—Chromium-Molybdenum-VV	1650	1950–2100	1650	Do not normalize		1550–1600	50	192–229	92–98
Tungsten Base Types									
H21—Tungsten	1600	2000–2150	1650	Do not normalize		1600–1650	50	202–235	94–99
High Speed Tool Steels									
Tungsten Base Types									
T1—Tungsten 18-4-1	1600	1950–2100	1750	Do not normalize		1600–1650	50	217–255	96–102
T2—Tungsten 18-4-2	1600	2000–2150	1750	Do not normalize		1600–1650	50	223–255	97–102
T4—Cobalt-Tungsten 18-4-1-5	1600	2000–2150	1750	Do not normalize		1600–1650	50	229–255	98–102
T5—Cobalt-Tungsten 18-4-2-8	1600	2000–2150	1800	Do not normalize		1600–1650	50	248–293	102–106
T8—Cobalt-Tungsten 14-4-2-5	1600	2000–2150	1750	Do not normalize		1600–1650	50	229–255	98–102
Molybdenum Base Types									
M1—Molybdenum 8-2-1	1500	1900–2050	1700	Do not normalize		1525–1600	50	207–248	95–102
M2—Molybdenum-Tungsten 6-6-2	1500	1950–2100	1700	Do not normalize		1550–1625	50	217–248	96–102
M3—Molybdenum-Tungsten 6-6-3	1500	2000–2150	1700	Do not normalize		1550–1625	50	223–255	97–102
M4—Molybdenum-Tungsten 6-6-4	1500	2000–2150	1700	Do not normalize		1550–1625	50	229–255	98–102
Special Purpose Tool Steels									
Low Alloy Types									
L6—Nickel-Chromium	1500	1800–2000	1600	1550	1650	1400–1450	50	183–212	90–96
L7—Chromium	1500	1800–2000	1550	1550	1650	1450–1500	50	174–212	88–96

1. These tool and die steels are the same as those listed in Table 1 of this report.
2. The temperature at which to start forging 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 reductions. As the alloy content of the steel increases, the time of soaking at forging temperature increases proportionately. Likewise, as the alloy content increases, it becomes more necessary to cool slowly from the forging temperature. With very high alloy steels, such as high speed or air hardening steels, this slow cooling is imperative in order to prevent cracking and to leave the steel in a semisoft condition. Either furnace cooling or burying in an insulating medium, such as lime, mica, or silocel, is satisfactory.
3. The length of time the steel is held after being uniformly heated through at the normalizing temperature, varies from about 15 min for a small section to about 1 hr for large sizes. Cooling from the normalizing temperature is done in still air. The purpose of normalizing after forging is to refine the grain strauctur and to produce a uniform structure throughout the forging. Normalizing should not be confused with low temperature (about 1200 F) annealing used for the relief of residual stresses resulting from heavy machining, bending, and forming.
4. The annealing temperature is given as a range, the upper limit of which should be used for large sections. The length of time the steel is held after being uniformly heated through at the annealing temperature varies from about 1 hr for light sections and small furnace charges of carbon or low alloy steel to about 4 hr for heavy sections and large furnace charges of high alloy steel.
For information on the forging and heat treating of tool steels, see ASM Handbook, 1948 edition, pp.653-655.

TABLE 4—MINIMUM ALLOWANCES FOR MACHINING AND MAXIMUM DECARBURIZATION LIMITS (ROUNDS, HEXAGONS, AND OCTAGONS)[1]

Ordered Size, in.	Minimum Allowance Per Side for Machining Prior to Heat Treatment, in.			
	Hot Rolled	Forged	Rounds Rough Turned	Cold Drawn
Up to 0.5, incl	0.016	—	—	0.016
Over 0.5 to 1, incl	0.031	—	—	0.031
Over 1 to 2, incl	0.048	0.072	—	0.048
Over 2 to 3, incl	0.063	0.094	0.020	0.063
Over 3 to 4, incl	0.088	0.120	0.024	0.088
Over 4 to 5, incl	0.112	0.145	0.032	—
Over 5 to 6, incl	0.150	0.170	0.040	—
Over 6 to 8, incl	0.200	0.200	0.048	—
Over 8	—	0.200	0.072	—
Maximum Decarburization Limits				
80% of above allowances per side				

1. Rounds 1/4 in. and over of high speed steel are normally furnished free of scale and decarburization.

TABLE 5A—SIZE TOLERANCES FOR HOT ROLLED BARS (ROUNDS,[1] SQUARES, OCTAGONS, QUARTER OCTAGONS, HEXAGONS)

Specified Sizes, in.	Size Tolerances, in.	
	Under	Over
To 0.5, incl	0.005	0.012
Over 0.5 to 1, incl	0.005	0.016
Over 1 to 1.5, incl	0.006	0.020
Over 1.5 to 2, incl	0.008	0.025
Over 2 to 2.5, incl	0.010	0.030
Over 2.5 to 3, incl	0.010	0.040
Over 3 to 4, incl	0.012	0.050
Over 4 to 5.5, incl	0.015	0.060
Over 5.5 to 6.5, incl	0.018	0.100
Over 6.5 to 8, incl	0.020	0.150

1. For high speed steel rounds free of scale and decarburization, Table 4.

TABLE 5B—WIDTH AND THICKNESS TOLERANCES FOR HOT ROLLED FLATS

Specified Widths, in.	Width Tolerances, in.	
	Under	Over
To 1, incl	0.016	0.031
Over 1 to 3, incl	0.031	0.047
Over 3 to 5, incl	0.047	0.063
Over 5	0.063	0.094

Specified Widths, in.	Thickness Tolerances for Thicknesses Given, in.							
	To 0.25 Incl		Over 0.25 to 0.5, Incl		Over 0.5 to 1, Incl		Over 1 to 2, Incl	
	Under	Over	Under	Over	Under	Over	Under	Over
To 1, incl	0.006	0.010	0.008	0.012	0.010	0.016	—	—
Over 1 to 2, incl	0.006	0.014	0.008	0.016	0.010	0.020	0.020	0.024
Over 2 to 3, incl	0.006	0.018	0.008	0.020	0.010	0.024	0.020	0.027
Over 3 to 4, incl	0.008	0.020	0.010	0.022	0.013	0.024	0.024	0.030
Over 4 to 5, incl	0.010	0.020	0.012	0.024	0.015	0.030	0.027	0.035
Over 5 to 6, incl	0.012	0.020	0.014	0.030	0.018	0.030	0.030	0.035

TABLE 6A—WIDTH AND TOLERANCES FOR FORGED FLATS

Specified Widths, in.	Width Tolerances, in.	
	Under	Over
Over 1 to 3, incl	0.031	0.078
Over 3 to 5, incl	0.062	0.125
Over 5 to 7, incl	0.125	0.187
Over 7	0.187	0.312

Specified Width, in.	Thickness Tolerances for Thicknesses Given, in.									
	To 1, Incl		Over 1 to 3, Incl		Over 3 to 5, Incl		Over 5 to 7, Incl		Over 7, Incl	
	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over
Over 1 to 3, incl	0.016	0.031	0.031	0.078	—	—	—	—	—	—
Over 3 to 5, incl	0.031	0.062	0.047	0.094	0.062	0.125	—	—	—	—
Over 5 to 7, incl	0.047	0.094	0.062	0.125	0.078	0.156	0.125	0.187	—	—
Over 7	0.062	0.125	0.078	0.156	0.094	0.187	0.156	0.219	0.187	0.312