

Designation: A 681 – 94 (Reapproved 1999)

Standard Specification for Tool Steels Alloy¹

This standard is issued under the fixed designation A 681; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the chemical, mechanical, and physical requirements for available wrought alloy tool steel products.

1.2 These products, which include hot or cold finished bar, plate, sheet, strip, rod, wire, or forgings, are normally fabricated into tools, dies, or fixtures. The selection of a material for a particular application will depend upon design, service conditions, and desired properties.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

2. Referenced Documents

- 2.1 ASTM Standards:
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products²
- A 561 Practice for Macroetch Testing of Tool Steel Bars³
- A 600 Specification for Tool Steel High Speed³
- A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment³
- E 3 Methods of Preparation of Metallographic Specimens⁴
- E 30 Test Methods for Chemical Analysis of Steel, Cast
- Iron, Open-Hearth Iron, and Wrought Iron⁵
- E 45 Test Methods for Determining the Inclusion Content of $Steel^4$
- E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition⁵
- E 527 Practice for Numbering Metals and Alloys (UNS)⁶ 2.2 *Military Standard:*
- MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage⁷

- ⁵ Annual Book of ASTM Standards, Vol 03.05.
- ⁶ Annual Book of ASTM Standards, Vol 01.01.

2.3 Federal Standards:

 Fed. Std. No. 123 Marking and Shipment (Civil Agencies)⁷
 Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products⁷

- 2.4 Other Standards:
- SAE J1086 Recommended Practice for Numbering Metals and Alloys (UNS)⁸

3. Classification

3.1 Material in accordance with this specification is classified by chemical composition. Types correspond to respective AISI designations.

3.1.1 Hot Work Tool Steels, Identification H:

13.1.1.1 Types H10 to H19 are characterized by a controlled chromium content along with other alloying elements. The first four, containing molybdenum, offer excellent toughness and high hardenability and are frequently used in cold work applications requiring toughness at relatively high hardness levels.

3.1.1.2 Types H21 to H26 are characterized by a controlled tungsten content along with other alloying elements. These steels offer greater resistance to the softening effect of elevated service temperatures but exhibit a lower degree of toughness.

3.1.1.3 Types H41 to H43 are low-carbon modifications of molybdenum high speed tool steels (Note 1) and have characteristics similar to the tungsten types.

NOTE 1—High-speed tool steels are covered in Specification A 600.

3.1.2 *Cold Work Tool Steels, Identification A*—Types A2 to A10 cover a wide range of carbon and alloy contents but all have high hardenability and may be hardened in air. The low carbon Types A8 and A9 have less wear resistance but offer greater toughness than others in this group. Type A7, with high carbon and vanadium, offers exceptional wear resistance but at a very low level of toughness.

3.1.3 *Cold Work Tool Steels, Identification D*—Types D2 to D7 are characterized by high carbon and high chromium contents and exhibit high resistance to abrasion. The types containing molybdenum may be hardened in air and offer a high degree of dimensional stability in heat treatment.

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¹ This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.29 on Tool Steels.

Current edition approved June 15, 1994. Published August 1994. Originally published as A 681 – 73. Last previous edition A 681 – 92.

² Annual Book of ASTM Standards, Vol 01.03.

³ Annual Book of ASTM Standards, Vol 01.05.

⁴ Annual Book of ASTM Standards, Vol 03.01.

⁷ Available from the Standardization Documents, Order Desk, Bldg. 4, Section D 700 Robbins Ave. Philadelphia, PA 19111-5094 Attn: NPODS.

⁸ Available from the Society of Automotive Engineers, 400 Commonwelth drive, Warrendale, PA 15096.

3.1.4 *Cold Work Tool Steels, Identification O*—Types O1 to O7 are low-alloy types that must be hardened by quenching in oil. Sizes over about 2 in. (50 mm) in cross section usually exhibit lower interior hardness.

3.1.5 *Shock-Resisting Steels, Identification S*—Types S1 to S7 vary in alloy content but are intended for shock-resisting applications.

3.1.6 Special-Purpose Tool Steels, Identification L—Types L2 to L6 are low-alloy steels with a wide range of carbon content. The low-carbon types are generally used for structural applications requiring good levels of toughness, while the high-carbon types may be used for short-run tools.

3.1.7 Special-Purpose Tool Steels, Identification F—Types F1 to F2 are high-carbon steels with varying tungsten content used primarily for relatively short-run fine edge cutting tools.

3.1.8 Mold Steels, Identification P:

3.1.8.1 Types P2 to P6 are very low-carbon steels and must be carburized after machining or hubbing.

3.1.8.2 Types P20 and P21 are usually supplied in the prehardened condition and can be placed in service directly after machining.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information, as required to describe adequately the desired material:

4.1.1 Class of material (hot work tool steel, etc.),

4.1.2 Type (H11, D2, etc.),

4.1.3 Shape (sheet, strip, plate, flat bar, round bar, square bar, hexagon bar, octagon, special shapes),

4.1.4 Dimensions (thickness, width, diameter, length),

4.1.5 Finish (hot rolled, forged, blasted or pickled, cold drawn, machined, ground, precision ground and polished),

4.1.6 Condition (annealed, hardened and tempered, etc.), 468

4.1.7 ASTM designation and year of issue, and stripsed 33

4.1.8 Special requirements.

5. Materials and Manufacture

5.1 Unless otherwise specified, material covered by this specification shall be made by an electric melting process. It shall be made from ingots that have been reduced in cross section in such a manner and to such a degree as to ensure proper refinement of the ingot structure.

6. Chemical Composition

6.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentage of the elements specified, and these values shall conform to the requirements for chemical composition specified in Table 1. If requested or required, the chemical composition shall be reported to the purchaser or his representative.

6.2 Analysis may be made by the purchaser from finished bars and forgings by machining off the entire cross section and drilling parallel to the axis of the bar or forging at any point midway between the center and surface in accordance with the latest issue of Practice E 59. The chemical analysis of the drilling chips shall be made in accordance with the latest issue of Test Methods E 30. The chemical composition thus determined shall not vary from the limits specified in Table 1.

7. Hardness Requirements

7.1 Annealed hardness values shall be obtained in accordance with the latest issue of Test Methods and Definitions A 370, and shall not exceed the Brinell hardness values (or equivalent Rockwell hardness values) specified in Table 2.

7.2 Specimens for determination of minimum response to hardening shall be $\frac{1}{4}$ -in. (6.4-mm) thick disks cut so as to represent either the full cross-sectional area or that midway between the center and outer surface of the material. If the material form or size does not lend itself to accurate hardness determination on $\frac{1}{4}$ -in. thick cross-sectional disks, then longitudinal specimens may be used for hardness testing. Examples are round bars less than $\frac{1}{2}$ in. (12.7 mm) in diameter or sheet. In this case, the specimen shall be a minimum of 3 in. (76 mm) in length and parallel flats shall be ground on the original mill surfaces. The specimens shall be heat treated as prescribed in Table 3.

7.2.1 The hardness of the specimen after the specified heat treatment shall meet the minimum hardness value for the particular type of steel shown in Table 3. Rockwell C tests should be used where possible but light load tests may be necessary on thin specimens. These tests should be specified by agreement between the seller and the purchaser. The hardness value shall be obtained in accordance with the latest issue of Test Methods and Definitions A 370, and shall be the average of at least five readings taken in an area midway between the center and surface of the largest dimension of the cross-sectional specimen or along the parallel surfaces of the longitudinal specimen.

8. Macrostructure

-98.1 Specimens for the determination of the macrostructure shall represent the entire cross-sectional area in the annealed condition and be prepared in accordance with the latest issue of Practice A 561. Material supplied to this specification shall be capable of exhibiting a structure free of excessive porosity, segregation, slag, dirt or other nonmetallic inclusions, pipe, checks, cracks, and other injurious defects.

8.2 Macroetch severity levels for center porosity and ingot pattern, illustrated photographically in Practice A 561, shall not exceed the ratings specification in Table 4 for the appropriate material size and composition. More stringent requirements are available by agreement between seller and purchaser.

9. Decarburization

9.1 Specimens for the determination of decarburization shall represent a cross section of the material and be prepared in accordance with the latest issue of Methods E 3. Material supplied to this specification shall be capable, when examined at 20 times or greater magnification, of not exceeding the values given in Tables 5-8 for the appropriate size and shape of material. Lower limits of decarburization may be specified by agreement between the seller and purchaser.

9.2 Material ordered as ground and polished or ground finished or machine finished shall be free of scale and decarburization.

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TABLE 1	Chemical	Requirements,	% ^A
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UNS		Ca	ırbon	Man	ganese ^C	Phos-	Sulfur, ^D	S	ilicon	Chr	omium	Van	adium	Tur	ngsten	Moly	bdenum		
Desig- nation ^B	Туре	min	max	min	max	 phorus, max 	max	min	max	min	max	min	max	min	max	min	max	-	
T20810	H10	0.35	0.45	0.20	0.70	0.030	0.030	0.80	1.25	3.00	3.75	0.25	0.75			2.00	3.00		
T20811	H11	0.33	0.43	0.20	0.60	0.030	0.030	0.80	1.25	4.75	5.50	0.30	0.60			1.10	1.60		
T20812	H12	0.30	0.40	0.20	0.60	0.030	0.030	0.80	1.25	4.75	5.50	0.20	0.50	1.00	1.70	1.25	1.75		
T20813	H13	0.32	0.45	0.20	0.60	0.030	0.030	0.80	1.25	4.75	5.50	0.80	1.20			1.10	1.75		
T20814	H14	0.35	0.45	0.20	0.60	0.030	0.030	0.80	1.25	4.75	5.50			4.00	5.25				
T20819	H19	0.32	0.45	0.20	0.50	0.030	0.030	0.15	0.50	4.00	4.75	1.75	2.20	3.75	4.50	0.30	0.55	Co 4	1.00-4.50
T20821	H21	0.26	0.36	0.15	0.40	0.030	0.030	0.15	0.50	3.00	3.75	0.30	0.60	8.50	10.00				
T20822	H22	0.30	0.40	0.15	0.40	0.030	0.030	0.15	0.40	1.75	3.75	0.25	0.50	10.00	11.75				
T20823	H23	0.25	0.35	0.15	0.40	0.030	0.030	0.15	0.60	11.00	12.75	0.75	1.25	11.00	12.75				
T20824	H24	0.42	0.53	0.15	0.40	0.030	0.030	0.15	0.40	2.50	3.50	0.40	0.60	14.00	16.00				
T20825	H25	0.22	0.32	0.15	0.40	0.030	0.030	0.15	0.40	3.75	4.50	0.40	0.60	14.00	16.00				
T20826	H26	0.45	0.55 ^E	0.15	0.40	0.030	0.030	0.15	0.40	3.75	4.50	0.75	1.25	17.25	19.00				
T20841	H41	0.60	0.75 ^E	0.15	0.40	0.030	0.030	0.20	0.45	3.50	4.00	1.00	1.30	1.40	2.10	8.20	9.20		
T20842	H42	0.55	0.70 ^E	0.15	0.40	0.030	0.030	0.20	0.45	3.75	4.50	1.75	2.20	5.50	6.75	4.50	5.50		
T20843	H43	0.50	0.65 ^E	0.15	0.40	0.030	0.030	0.20	0.45	3.75	4.50	1.80	2.20			7.75	8.50		
T30102	A2	0.95	1.05	0.40	1.00	0.030	0.030	0.10	0.50	4.75	5.50	0.15	0.50			0.90	1.40		
T30103	A3	1.20	1.30	0.40	0.60	0.030	0.030	0.10	0.70	4.75	5.50	0.80	1.40			0.90	1.40		
T30104	A4	0.95	1.05	1.80	2.20	0.030	0.030	0.10	0.70	0.90	2.20					0.90	1.40		
T30105	A5	0.95	1.05	2.80	3.20	0.030	0.030	0.10	0.70	0.90	1.40					0.90	1.40		
T30106	A6	0.65	0.75	1.80	2.50	0.030	0.030	0.10	0.70	0.90	1.40			· · ·	• • •	0.90	1.40		
T30107	A7	2.00	2.85	0.20	0.80	0.030	0.030	0.10	0.70	5.00	5.75	3.90	5.15	0.50	1.50	0.90	1.40		
130108	A8	0.50	0.60	0.20	0.50	0.030	0.030	0.75	1.10	4.75	5.50			1.00	1.50	1.15	1.65		~
130109	A9	0.45	0.55	0.20	0.50	0.030	0.030	0.95	1.15	4.75	5.50	0.80	1.40	• • •		1.30	1.80	Ni 1	.25-1.75
130110 Too too	A10	1.25	1.50	1.60	2.10	0.030	0.030	1.00	1.50						• • •	1.25	1.75	Ni 1	.55–2.05
130402	D2	1.40	1.60	0.10	0.60	0.030	0.030	0.10	0.60	11.00	13.00	0.50	1.10			0.70	1.20		
130403	D3	2.00	2.35	0.10	0.60	0.030	0.030	0.10	0.60	11.00	13.50		1.00		1.00				
T30404	D4 D5	2.05	2.40	0.10	0.60	0.030	0.030	0.10	0.60	11.00	13.00	0.15	1.00			0.70	1.20	0.0	
T30405	D5 D7	1.40	1.60	0.10	0.60	0.030	0.030	0.10	0.60	11.00	13.00	2 00	1.00	• • •	• • •	0.70	1.20	002	2.50-3.50
T30407	01	2.15	2.50	1.00	0.60	0.030	0.030	0.10	0.60	0.40	0.70	3.80	4.40			0.70	1.20		
T21501	01	0.05	0.05	1.00	1.40	0.030	0.030	0.10	0.50	0.40	0.70		0.30	0.40	0.00		0.20		
T21502	02	1.05	1 55	0.20	1.00	0.030	0.030	0.55	1 50		0.50		0.30			0.20	0.30		
T21500	00	1.20	1.00	0.30	1.10	0.030	0.030	0.55	0.60	0.25	0.30	0.15	0.40	1.00		0.20	0.30		
T41001	07 ©1	0.40	0.55	0.20	0.40	0.030	0.030	0.10	1.20	1.00	1.90	0.15	0.40	1.50	2.00		0.30		
T41901	60	0.40	0.55	0.10	0.40	0.030	0.030	0.15	1.20	1.00	1.00	0.15	0.50	1.50	3.00	0.20	0.50		
T/100/	52 S4	0.40	0.55	0.50	0.50	0.030	0.030	1 75	2.25	0.10	0.50	0.15	0.35			0.30	0.00		
T/1005	S5	0.50	0.05	0.00	1 00	0.030	0.030	1.75	2.25	0.10	0.50	0.15	0.35			0.20	1 35		
T41905	56	0.30	0.00	1 20	1.00	0.030	0.030	2 00	2.20	1 20	1 50	0.15	0.00			0.20	0.50		
T41900	S7	0.40	0.50	0.20	0.00	0.030	0.030	0.20	1.00	3.00	3 50	0.20	0.40			1 30	1.80		
T61202	12	0.45	1.00	0.20	0.30	0.030	0.030	0.20	0.50	0.70	1 20	0.10	0.30			1.50	0.25		
T61202	1.3	0.45	1 10	0.10	0.80	0.030	0.030	0.10	0.50	1.30	1 70	0.10	0.30				0.20		
http	s://sta	ndard	ls.iteh	.ai/ca	italog/	standa	rds/sist/	f788	d334	-86f4	-4b3c	-9f3e	-482	8dfae	9675	/astm	-a681	-941	lickel
Totooo	1.0	0.05	0 75	0.05	0.00			0.40	0.50	0.00	1 00						0.50	1 05	
161206	L6	0.65	0.75	0.25	0.80	0.030	0.030	0.10	0.50	0.60	1.20						0.50	1.25	2.00
160601	F1	0.95	1.25		0.50	0.030	0.030	0.10	0.50					1.00	1.75	• • •		• • •	
T60602	F2	1.20	1.40	0.10	0.50	0.030	0.030	0.10	0.50	0.20	0.40			3.00	4.50				
151602 T51000	P2		0.10	0.10	0.40	0.030	0.030	0.10	0.40	0.75	1.25					0.15	0.40	0.10	0.50
151603	P3	• • •	0.10	0.20	0.60	0.030	0.030		0.40	0.40	0.75			• • •				1.00	1.50
151604	P4		0.12	0.20	0.60	0.030	0.030	0.10	0.40	4.00	5.25			• • •		0.40	1.00	• • •	
151605	P5	0.06	0.10	0.20	0.60	0.030	0.030	0.10	0.40	2.00	2.50				• • •		• • •		0.35
151606	P6	0.05	0.15	0.35	0.70	0.030	0.030	0.10	0.40	1.25	1./5				• • •			3.25	3.75
151620	P20	0.28	0.40	0.60	1.00	0.030	0.030	0.20	0.80	1.40	2.00	0.15			• • •	0.30	0.55		
121021	P21'	0.18	0.22	0.20	0.40	0.030	0.030	0.20	0.40	0.20	0.30	0.15	0.25					3.90	4.20

^A Chemistry limits include product analysis tolerances. Unless otherwise specified, nickel plus copper equal 0.75 % max for all types.

^B New designation established in accordance with Practice E 527 and SAEJ1086.

^C Manganese limit is 1.0 % max for H13 resulfurized.

^D Where specified, sulfur may be 0.06 to 0.15 % to improve machinability.

^E Available in several carbon ranges.

F Also contains 1.05-1.25 % aluminum.

10. Permissible Variations for Dimensions

10.1 Permissible variations for dimensions shall not exceed the applicable limits stated in Tables 9-28.

11. Workmanship, Finish, and Appearance

11.1 All alloy tool steels shall be free of heavy scale, deep pitting, laps, porosity, injurious segregations, excessive non-

metallic inclusions, seams, cracks, checks, slivers, scale marks, dents, soft and hard spots, pipes, or any defects that would detrimentally affect the suitability of the material after removal of the recommended stock allowance.

TABLE 2 Maximum Brinell Hardness in Annealed or Cold-Drawn Condition

		0011			
Туре	Annealed BHN	Cold Drawn BHN	Туре	Annealed BHN	Cold Drawn BHN
H10	229	255	O1	212	241
H11	235	262	02	217	241
H12	235	262	O6	229	241
H13	235	262	07	241	255
H14	235	262			
H19	241	262	S1	229	255
H21	235	262	S2	217	241
H22	235	262	S4	229	255
H23	255	269	S5	229	255
H24	241	262	S6	229	255
H25	235	262	S7	229	255
H26	241	262			
			L2	197	241
H41	235	262	L3	201	241
H42	235	262	L6	235	262
H43	235	262			
			F1	207	241
A2	248	262	F2	235	262
A3	229	255			
A4	241	262	P2	100	
A6	248	262	P3	143	
A7	269	285	P4	131	
A8	241	262	P5	131	
A9	248	262	P6	212	
A10	269	285	P20	A	
			P21	A	
D2	255	269			
D3	255	269			
D4	255	269			
D5	255	269			
D7	262	277	<u>(ht</u>	tnc•//	cton

^A Normally furnished in prehardened condition.

12. Sampling

12.1 Each particular shipment of a heat of steel by type, size, and shape shall be considered a lot and must conform to the provisions of this specification.

13. Inspection

13.1 Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. The supplier may utilize his own facilities or any other acceptable to the purchaser.

13.2 When specified in the purchase order, the inspector representing the purchaser shall have access to the material subject to inspection for the purpose of witnessing the selection of samples, preparation of test pieces, and performance of the tests. For such tests, the inspector shall have the right to indicate the pieces from which samples will be selected.

Otherwise the seller shall report to the purchaser, or his representative, the results of the chemical analysis and the physical and mechanical property tests made in accordance with this specification.

13.3 The purchaser may perform any of the inspections set forth in this specification on the as-received material where such inspections are deemed necessary to ensure that supplies and services conform to the prescribed requirements.

14. Rejection and Rehearing

14.1 Unless otherwise specified, any rejections based on tests made in accordance with this specification shall be reported to the seller within 30 days from the date of receipt of the material.

14.2 Material that shows injurious defects subsequent to its acceptance by the purchaser shall be rejected and the seller notified.

14.3 Samples tested in accordance with this specification that represent rejected material shall be preserved for 30 days from the date of the test report. In case of dissatisfaction with the results of the test, the seller may make claim for a rehearing within that time.

15. Packaging, Loading, and Package Marking

15.1 Packaging and Loading:

15.1.1 Unless otherwise specified, shipments shall be packaged and loaded in accordance with Practices A 700.

15.1.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, when Level A is specified, preservation, packaging, and loading shall be in accordance with the Level A requirement of MIL-STD-163.

15.2 Markings:

15.2.1 Shipments shall be properly marked with the name or brand of manufacturer, purchaser's name and order number, designation (ASTM A 681), heat number, grade or type, and where appropriate, the size, length, and weight. Unless otherwise specified, method of marking is at the option of the manufacturer.

15.2.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment, in addition to any requirements specified in the contract or order, shall be in accordance with MIL-STD-163 for military agencies, and in accordance with Fed. Std. No. 123 for civil agencies.

15.2.3 For government procurement by the Defense Supply Agency, steel shall be continuously marked for identification in accordance with Fed. Std. No. 183.

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TABLE 3 Heat-Treating Requirements

NOTE 1—The austenitizing temperatures are stipulated for the response to hardening test only. Other combinations of austenitizing and tempering temperatures may be used for particular applications.

NOTE 2—Preheating temperature may be $\pm 25^{\circ}$ F (14°C), but austenitizing and tempering temperatures shall be $\pm 10^{\circ}$ F (5.6°C). If samples are austenitized in salt, the sample shall be at the austenitizing temperature for the minimum time shown. If a controlled atmosphere furnace is used, the sample shall be at the austenitizing temperature for D types). The time at temperature is the time after the sample reaches the austenitizing temperature. This range of time is given because of the difficulty in determining when the sample reaches temperature in some types of controlled atmosphere furnaces.

NOTE 3—Those steels tempered at 400°F (204°C) shall have a single 2-h temper, while those tempered at 950 (510), 1025 (552), or 1200°F (649°C) shall be double-tempered for 2 h each cycle.

NOTE 4—The P types shall not be tested for response to heat treatment since P2 to P6 are used in the carburized condition and P20 are normally furnished in the prehardened condition.

NOTE 5—Specimens as described in 7.2 shall be capable of producing the specified minimum hardness when the stipulated heat treating parameters are used.

Preheat Temperature. Saft Bath Controlled Austentization Quench Medium Tempering, Tempering, PF (*C) Minimum Hardness, PC H10 1450 (788) 1850 (1010) 1875 (1024) 5–15 Air 1025 (552) 53 H11 1440 (788) 1825 (996) 1850 (1010) 5–15 Air 1025 (552) 53 H12 1440 (788) 1826 (996) 1850 (1010) 5–15 Air 1025 (552) 52 H14 1440 (788) 1826 (996) 1850 (1010) 5–15 Air 1025 (552) 55 H14 1440 (788) 2150 (1177) 2175 (1191) 5–15 Air 1025 (552) 55 H21 1440 (788) 2150 (1177) 2175 (1191) 5–15 Air 1025 (552) 53 H22 1430 (788) 2250 (1224) 2250 (1226) 52 53 44 1420 (788) 2150 (1177) 2175 (1191) 5–15 Air 1025 (552) 53 H24 1440 (788) 2125 (1128) 2250 (1229)			Austenitizing Ten	nperature, °F (°C)					
H10H50 (78)H80 (1010)H87 (1024)5-15Air1025 (552)55H11H450 (78)H825 (986)H850 (1010)5-15Air1025 (552)53H12H450 (78)H825 (986)H850 (1010)5-15Air1025 (552)55H14H450 (78)H250 (1177)2175 (1191)5-15Air1025 (552)55H19H450 (78)2150 (1177)2175 (1191)5-15Air1025 (552)55H21H450 (78)2150 (1177)2175 (1191)5-15Air1025 (552)52H221450 (78)2205 (1224)2205 (128)5-15Air1025 (552)55H211450 (78)2205 (1232)2275 (1246)5-15Air1025 (552)54H241450 (78)2275 (1246)2205 (128)5-15Air1025 (552)68H411450 (78)2275 (1246)2205 (128)5-15Air1025 (552)60H421450 (78)2275 (1246)215 (1177)5-15Air1025 (552)60H431450 (78)2275 (1246)215 (1177)5-15Air1025 (552)60H441450 (78)2175 (1191)2200 (1204)5-15Air1025 (552)60H441450 (78)1775 (984)1775 (986)5-15Air400 (204)61A41250 (677)1550 (877)1550 (877)5-15Air400 (204)63A41250 (677)1550	Туре	Preheat Temperature, [–] °F (°C)	Salt Bath	Controlled Atmosphere Furnaces	Austenitiz- ing Time (minutes)	Quench Medium	Tempering Temperature, °F (°C)	Minimum Hardness, RC	
H11 1450 (788) 1825 (996) 1850 (1010) 5-15 Air 1025 (552) 53 H13 1450 (788) 1825 (996) 1850 (1010) 5-15 Air 1025 (552) 55 H14 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 55 H21 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 55 H21 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 55 H21 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 55 H23 1450 (788) 2250 (1234) 2250 (1244) 2255 (1246) 5-15 Air 1025 (552) 58 H41 1450 (788) 2175 (1191) 2200 (1244) 5-15 Air 1025 (552) 58 H42 1450 (788) 1775 (981) 1755 (843) 5-15 Air 1025 (552) 58 H44 1450 (788) 1755 (843) 1556 (843) 5-15 Air 400 (204) 60	H10	1450 (788)	1850 (1010)	1875 (1024)	5–15	Air	1025 (552)	55	
H12 1450 (788) 1825 (996) 1850 (1010) 5-15 Air 1025 (552) 52 H14 1450 (788) 1900 (1038) 1925 (1052) 5-15 Air 1025 (552) 55 H19 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 52 H21 1460 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 52 H22 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 53 H23 1500 (161) 2275 (1246) 2300 (1260) 5-15 Air 1025 (552) 64 H24 1450 (788) 2250 (1230) 2275 (1246) 5-15 Air 1025 (552) 60 H41 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 68 A2 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 68 A3 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 68 A2	H11	1450 (788)	1825 (996)	1850 (1010)	5–15	Air	1025 (552)	53	
H13H40H40R25R26H250H250H27H27H27H2105-15AirH225(552)55H19H450(788)2190H1772175(191)5-15Air1025(552)55H21H450(788)2190H1772175(191)5-15Air1025(552)55H221450(788)2200(1240)5-15Air1025(552)55H231450(788)2200(1244)2255(1280)5-15Air1025(552)55H241450(788)2250(1232)2275(1246)5-15Air1025(552)60H421450(788)2125(1177)215011775-15Air1025(552)60H431450(788)2175(1191)220012445-15Air1025(552)60H441450(788)1775(984)157586575-15Air1025(552)60H431450(788)1775(984)157586575-15Air102555260H441450(788)1775(984)157586575-15Air400(204)61A31450(788)1775(984)157586375-15Air400(204)63A571500(610)1	H12	1450 (788)	1825 (996)	1850 (1010)	5–15	Air	1025 (552)	53	
H14 1450 (788) 1900 (1038) 1925 (1052) 5-15 Air 1025 (552) 55 H19 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 55 H21 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 52 H22 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 53 H24 1450 (788) 2200 (1224) 2275 (1246) 5-15 Air 1025 (552) 54 H25 1450 (788) 2275 (1246) 2300 (1260) 5-15 Air 1025 (552) 60 H41 1450 (788) 2175 (1191) 2200 (1204) 5-15 Air 1025 (552) 60 H43 1450 (788) 2175 (1191) 2200 (1204) 5-15 Air 1025 (552) 60 H44 1450 (788) 2175 (1191) 2200 (1204) 5-15 Air 1025 (552) 68 A2 1450 (788) 1775 (968) 1750 (954) 5-15 Air 400 (204) 60 A3	H13	1450 (788)	1825 (996)	1850 (1010)	5-15	Air	1025 (552)	52	
H19 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 55 H21 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 52 H22 1450 (788) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 53 H23 1500 (816) 2275 (1246) 2300 (1260) 5-15 Air 1025 (552) 54 H24 1450 (788) 2200 (1224) 2225 (1246) 5-15 Air 1025 (552) 64 H26 1550 (843) 2125 (1163) 2105 (1177) 2175 (1191) 5-15 Air 1025 (552) 60 H41 1450 (788) 2175 (1191) 200 (1204) 5-15 Air 1025 (552) 58 H42 1450 (788) 2175 (1191) 2105 (1177) 2175 (1191) 5-15 Air 1025 (552) 58 A2 1450 (788) 1775 (968) 1800 (982) 5-15 Air 400 (204) 63 A3 1450 (788) 175 (968) 150 (843) 5-15 Air 400 (204) <t< td=""><td>H14</td><td>1450 (788)</td><td>1900 (1038)</td><td>1925 (1052)</td><td>5-15</td><td>Air</td><td>1025 (552)</td><td>55</td></t<>	H14	1450 (788)	1900 (1038)	1925 (1052)	5-15	Air	1025 (552)	55	
H21 1450 (786) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 53 H22 1450 (786) 2150 (1177) 2175 (1191) 5-15 Air 1025 (552) 53 H23 1500 (816) 2275 (1246) 2300 (1260) 5-15 Air 1025 (552) 55 H24 1450 (788) 2200 (1224) 2225 (1218) 5-15 Air 1025 (552) 58 H41 1450 (788) 2275 (1246) 2300 (1260) 10 5-15 Air 1025 (552) 58 H41 1450 (788) 2175 (1911) 2200 (1204) 5-15 Air 1025 (552) 58 H43 1450 (788) 2175 (1911) 2200 (1204) 5-15 Air 1025 (552) 58 A2 1450 (788) 1775 (968) 1800 (982) 5-15 Air 400 (204) 63 A4 1250 (647) 1550 (843) 5-15 Air 400 (204) 63 A4 1250 (647) 1550 (843) 5-15 Air 400 (204) 63 A4 1200 (649) 1825 (H19	1450 (788)	2150 (1177)	2175 (1191)	5-15	Air	1025 (552)	55	
H221450 (786)2150 (1177)2175 (1191)5-15Air1025 (552)53H231500 (816)2275 (1246)2300 (1260)5-15Oil1020 (640)42H241450 (788)2250 (1232)2275 (1246)5-15Air1025 (552)44H261550 (843)2275 (1246)2200 (1260)5-15Air1025 (552)60H411450 (788)2125 (1163)2150 (1177)5-15Air1025 (552)60H431450 (788)2175 (1191)200 (1200)5-15Air1025 (552)68A21450 (788)1775 (986)2150 (1177)5-15Air1025 (552)58A21450 (788)1775 (986)1575 (867)5-15Air400 (204)60A31450 (788)1775 (986)1550 (843)5-15Air400 (204)63A41250 (677)1550 (843)1557 (867)5-15Air400 (204)63A61200 (649)1525 (829)1850 (1010)5-15Air400 (204)63A71500 (816)1750 (954)1775 (968)5-15Air400 (204)63A81450 (788)1825 (996)1850 (1010)5-15Air400 (204)65A91450 (816)1826 (996)1850 (1010)5-15Air400 (204)66D41500 (816)1825 (996)1850 (1010)5-15Air400 (204)66D41500 (816)1825	H21	1450 (788)	2150 (1177)	2175 (1191)	5-15	Air	1025 (552)	52	
H23 1500 1700 1500 1700 1500 1700 1500 1700 1500 1700 1500 1700 1500 1700 1500 1700 1500 1700 1500 1700 1500 1700 1500 1700 1500 1700 1700 1700 1500 1700	H22	1450 (788)	2150 (1177)	2175 (1191)	5-15	Air	1025 (552)	53	
H24 1450 (788) 2200 (1204) 2225 (1218) 5-15 Air 1025 (552) 455 H25 1450 (788) 2250 (1232) 2275 (1246) 5-15 Air 1025 (552) 44 H26 1550 (R43) 2215 (1146) 2130 (1177) 5-15 Air 1025 (552) 60 H41 1450 (788) 2150 (1177) 2100 1275 (1191) 5-15 Air 1025 (552) 58 H42 1450 (788) 1725 (964) 5-15 Air 400 (204) 63 A2 1450 (788) 1725 (964) 155 (87) 5-15 Air 400 (204) 63 A4 1250 (677) 1550 (843) 155 (857) 5-15 Air 400 (204) 63 A7 1500 (846) 1755 (968) 5-15 Air 400 (204) 63 A8 <td>H23</td> <td>1500 (816)</td> <td>2275 (1246)</td> <td>2300 (1260)</td> <td>5-15</td> <td>Oil</td> <td>1200 (649)</td> <td>42</td>	H23	1500 (816)	2275 (1246)	2300 (1260)	5-15	Oil	1200 (649)	42	
H251450 (788)2250 (1232)2275 (1246)5-15Air1025 (552)44H261550 (843)2275 (1246)2300 (1260)5-15Air1025 (552)50H411450 (788)2175 (1191)2200 (1204)5-15Air1025 (552)60H421450 (788)2175 (1191)2200 (1204)5-15Air1025 (552)60H431450 (788)1775 (941)1750 (954)5-15Air1025 (552)60A31450 (788)1775 (968)1800 (982)5-15Air400 (204)60A41250 (677)1550 (843)1575 (857)5-15Air400 (204)61A61200 (649)1525 (829)1550 (843)5-15Air400 (204)63A81450 (788)1825 (996)1850 (1010)5-15Air400 (204)63A81450 (788)1825 (996)1850 (1010)5-15Air400 (204)63A91450 (788)1825 (996)1850 (1010)5-15Air400 (204)64D21500 (816)1275 (052)1500 (816)10-20Air400 (204)64D31500 (816)1825 (996)1280 (1010)5-15Air400 (204)64D41500 (816)1826 (996)10-20Air400 (204)64D41500 (816)1826 (996)10-20Air400 (204)64D41500 (816)1826 (996)10-20Air40	H24	1450 (788)	2200 (1204)	2225 (1218)	5-15	Air	1025 (552)	55	
H261550 (843)2275 (1246)2300 (1260)15-15Air1025 (552)58H411450 (788)2125 (1163)2150 (1177)5-15Air1025 (552)60H421450 (788)2150 (1177)2175 (1191)5-15Air1025 (552)58H431450 (788)1250 (1177)2175 (1191)5-15Air1025 (552)58A21450 (788)1775 (968)1800 (982)5-15Air400 (204)63A41250 (677)1550 (843)1550 (843)5-15Air400 (204)63A61200 (649)1755 (954)1775 (968)5-15Air400 (204)63A71500 (816)1750 (954)1775 (968)5-15Air400 (204)63A81450 (788)1825 (996)1850 (1010)5-15Air400 (204)63A91450 (788)1825 (996)1650 (1010)5-15Air400 (204)59D21500 (816)1825 (996)1650 (1010)10-20Air400 (204)59D31500 (816)1825 (996)1650 (1010)10-20Air400 (204)63D41500 (816)1825 (996)1650 (1010)10-20Air400 (204)63D51500 (816)1825 (996)16205-15Air400 (204)64D61<1200 (649)	H25	1450 (788)	2250 (1232)	-2275 (1246)	- 5-15	Air	1025 (552)	44	
Hat11450 (788)2125 (1163)2150 (1177)5-15Air1025 (552)60H421450 (788)2175 (1191)2200 (1204)5-15Air1025 (552)60H431450 (788)1725 (941)7175 (1911)5-15Air1025 (552)60A31450 (788)1775 (968)1800 (982)5-15Air400 (204)60A31450 (788)1775 (968)1800 (982)5-15Air400 (204)61A61200 (649)1525 (829)11550 (843)5-15Air400 (204)63A71500 (816)1750 (954)1775 (968)5-15Air400 (204)63A81450 (788)1825 (996)1850 (1010)5-15Air950 (510)56A101200 (649)1475 (802)1850 (1010)5-15Air950 (510)56A101200 (649)1475 (964)1750 (964)10-20Air400 (204)59D21500 (816)1800 (982)1850 (1010)10-20Air400 (204)62D31500 (816)1800 (982)1850 (1010)10-20Air400 (204)63D41500 (816)1802 (986)1455 (802)5-15Oil400 (204)63D41500 (816)1802 (982)1855 (1010)10-20Air400 (204)63D51500 (816)1925 (1052)1950 (1066)10-20Air400 (204)63D61750 (954)1755 (9	H26	1550 (843)	2275 (1246)	2300 (1260)	5-15	Air	1025 (552)	58	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	H41	1450 (788)	2125 (1163)	2150 (1177)	5-15	Air	1025 (552)	60	
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	H42	1450 (788)	2175 (1191)	2200 (1204)	5-15	Δir	1025 (552)	60	
A21450 (788)1725 (941)7750 (954)5-15Air400 (204)60A31450 (788)1775 (968)1800 (982)5-15Air400 (204)61A61200 (649)1525 (829)1550 (843)5-15Air400 (204)63A61200 (649)1525 (829)1550 (843)5-15Air400 (204)63A71500 (816)1750 (954)1775 (968)5-15Air400 (204)63A81450 (788)1825 (996)1850 (1010)5-15Air400 (204)63A91450 (788)1825 (996)1850 (1010)5-15Air400 (204)59A101200 (649)1475 (802)1500 (816)5-15Air400 (204)59D21500 (816)1750 (954)1775 (968)10-20Air400 (204)62D51500 (816)1880 (1010)10-20Air400 (204)62D51500 (816)1925 (1052)1950 (1066)10-20Air400 (204)62D51500 (816)1925 (1052)1950 (1066)10-20Air400 (204)59O21200 (649)1450 (788)1475 (802)5-15Oil400 (204)59O21200 (649)1450 (788)1475 (802)5-15Oil400 (204)59O21200 (649)1450 (788)1475 (802)5-15Oil400 (204)59O31200 (649)1450 (788)1475 (802)5-1	H43	1450 (788)	2150 (1177)	2175 (1191)	5-15	Air	1025 (552)	58	
A31450 (786)1775 (968)1800 (982)5-15Air400 (204)63A41250 (677)1550 (843)1575 (857)5-15Air400 (204)61A61200 (649)1525 (829)1150 (843)5-15Air400 (204)63A71500 (816)1750 (954)1775 (968)5-15Air400 (204)63A81450 (788)1825 (996)1850 (1010)5-15Air950 (510)56A101200 (649)1475 (802)1500 (816)1850 (1010)5-15Air400 (204)59D21500 (816)1825 (996)1850 (1010)5-15Air400 (204)61D41500 (816)1800 (982)1825 (996)10-20Oil400 (204)61D41500 (816)1800 (982)1825 (996)10-20Oil400 (204)62D51500 (816)1802 (996)1850 (1010)10-20Air400 (204)62D71500 (816)1825 (996)1850 (1010)10-20Air400 (204)63O11200 (649)1450 (788)1475 (802)5-15Oil400 (204)63O11200 (649)1450 (788)1475 (802)5-15Oil400 (204)59O21200 (649)1450 (788)1475 (802)5-15Oil400 (204)59O31200 (649)1575 (857)1600 (871)5-15Oil400 (204)58S41250 (677)1625	A2	1450 (788)	1725 (941)	1750 (954)	5-15	Air	400 (204)	60	
A41250 (677)1550 (843)1550 (843)1550 (843)1550 (843)Air400 (204)61A61200 (649)1525 (829)1550 (843)1550 (843)Air400 (204)58A71500 (816)1750 (954)1775 (968)5-15Air400 (204)63A81450 (788)1825 (996)1850 (1010)5-15Air950 (510)56A91450 (788)1825 (996)1850 (1010)5-15Air950 (510)56A101200 (649)1475 (802)1500 (816)5-15Air950 (510)56D21500 (816)1825 (996)1850 (1010)5-15Air960 (204)61D31500 (816)1825 (996)1850 (1010)10-20Air400 (204)61D41500 (816)1825 (996)1850 (1010)10-20Air400 (204)61D71500 (816)1825 (996)1850 (1010)10-20Air400 (204)61D71500 (816)1925 (1052)1950 (1066)10-20Air400 (204)63O11200 (649)1450 (788)1475 (802)5-15Oil400 (204)59O21200 (649)1450 (788)1475 (802)5-15Oil400 (204)59O31450 (788)1475 (802)5-15Oil400 (204)59O41450 (788)1475 (802)5-15Oil400 (204)58S21250 (677)1625	A3	1450 (788)	1775 (968)	1800 (982)	5-15	Air	400 (204)	63	
A61200 (649)1525 (829)1550 (843)5-15Air400 (204)58A71500 (816)1750 (954)1775 (968)5-15Air400 (204)63A81450 (788)1825 (996)1850 (1010)5-15Air950 (510)56A91450 (788)1825 (996)1850 (1010)5-15Air950 (510)56A101200 (649)1475 (802)1500 (816)10-20Air400 (204)59D21500 (816)1825 (996)1850 (1010)5-15Air400 (204)59D41500 (816)1800 (982)1825 (996)10-20Air400 (204)61D51500 (816)1825 (996)1850 (1010)10-20Air400 (204)61D71500 (816)1825 (996)1850 (1010)10-20Air400 (204)63D71500 (816)1925 (1052)1950 (1066)10-20Air400 (204)63D71500 (816)1925 (1052)1950 (1066)10-20Air400 (204)59D21200 (649)1450 (788)1475 (802)5-15Oil400 (204)59D21200 (649)1450 (788)1475 (802)5-15Oil400 (204)59D21200 (649)1575 (857)1600 (871)5-15Oil400 (204)59D31250 (677)1625 (885)1650 (899)5-15Oil400 (204)56S51250 (677)1625 (885) <td< td=""><td>A4</td><td>1250 (677)</td><td>1550 (843)</td><td>1575 (857)</td><td>5-15</td><td>Air</td><td>400 (204)</td><td>61</td></td<>	A4	1250 (677)	1550 (843)	1575 (857)	5-15	Air	400 (204)	61	
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F2 1200 (649) 1525 (829) 1550 (843) 5-15 Brine 400 (204) 64	 F1	1200 (649)	1525 (829)	1550 (843)	5-15	Brine	400 (204)	64	
	F2	1200 (649)	1525 (829)	1550 (843)	5-15	Brine	400 (204)	64	

^A 0.45-0.55 % carbon type.



TABLE 4Macroetch Standards
(Maximum Allowable Rating)^A

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	Low-Alloy	Tool Steels ^B	High-Alloy Tool Steels ^C		
Bar Size, in. (mm)	Porosity	Ingot Pattern	Porosity	Ingot Pattern	
Up to 2 (50.8), incl	4	6	3	6	
Over 2 to 3 (50.8 to 76), incl	41/2	6	31/2	6	
Over 3 to 4 (76 to 102), incl	41/2	6	4	6	
Over 4 to 5 (102 to 127), incl	5	6	41/2	6	
Over 5 to 6 (127 to 152), incl	5	6	5	6	
Over 6 (152)	As negotia	ted between seller and purc	haser.		

^A Refer to macroetch photographs in Practice A 561.

^B Low-alloy tool steels include H10-13, A2-6, A8-10, A11O,S,L,F, and P types.

^C High-alloy tool steels include H14-43, D2-7, and A7.

TABLE 5 Maximum Decarburization Limits (Rounds, Hexagons and Octagons Maximum Limit Per Side)

Note 1—The recommended minimum allowance for machining prior to heat treatment is 25 % greater than the maximum decarburization allowed.

Ordered Size, in. (mm)	Hot Rolled	Forged	Cold Drawn
Up to 1/2 (12.7), incl	0.013 (0.33)		0.013 (0.33)
Over 1/2 to 1 (12.7 to 25.4), incl	0.025 (0.64)		0.025 (0.64)
Over 1 to 2 (25.4 to 50.8), incl	0.038 (0.97)	0.058 (1.47)	0.038 (0.96)
Over 2 to 3 (50.8 to 76), incl	0.050 (1.27)	0.075 (1.91)	0.050 (1.27)
Over 3 to 4 (76 to 102), incl	0.070 (1.78)	0.096 (2.44)	0.070 (1.78)
Over 4 to 5 (102 to 127), incl	0.090 (2.29)	0.116 (2.95)	<u>с</u>
Over 5 to 6 (127 to 152), incl	0.120 (3.05)	0.136 (3.45)	
Over 6 to 8 (152 to 203), incl		0.160 (4.06)	
Over 8 to 10 (203 to 254), incl	anda	0.160 (4.06)	eh.ai

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