Designation: A 681 – 07$^{\epsilon 1}$

Standard Specification for Tool Steels Alloy[1]

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.

ε[1] NOTE—Table 7 and Table 8 corrected editorially in May 2008.

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 standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 561 Practice for Macroetch Testing of Tool Steel Bars

A 600 Specification for Tool Steel High Speed

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

E 3 Guide for Preparation of Metallographic Specimens

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[3]

E 45 Test Methods for Determining the Inclusion Content of Steel

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[3]

E 527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *Military Standard:*

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[4]

2.3 *Federal Standards:*

Fed. Std. No. 123 Marking and Shipment (Civil Agencies)[4]

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products[4]

2.4 *Other Standards:*

SAE J1086 Recommended Practice for Numbering Metals and Alloys (UNS)[5]

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*:

3.1.1.1 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

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

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

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

[5] Available from the Society of Automotive Engineers, 400 Commonwealth drive, Warrendale, PA 15096.

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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.

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.),

4.1.7 ASTM designation and year of issue, and

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* 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 ¼-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 ¼-in. thick cross-sectional disks, then longitudinal specimens may be used for hardness testing. Examples are round bars less than ½ 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

8.1 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 Guide E 3. Material supplied to this specification shall be capable, when examined

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TABLE 1 Chemical Requirements, %[A]

UNS Designation[B]	Type	Carbon		Manganese[C]		Phosphorus, max	Sulfur,[D] max	Silicon		Chromium		Vanadium		Tungsten		Molybdenum			
		min	max	min	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 4.00–4.50	
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		
T30108	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		
T30109	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	
T30110	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	
T30402	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	. . .	
T30403	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	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		
T30405	D5	1.40	1.60	0.10	0.60	0.030	0.030	0.10	0.60	11.00	13.00	. . .	1.00	. . .	. . .	0.70	1.20	Co 2.50–3.50	
T30407	D7	2.15	2.50	0.10	0.60	0.030	0.030	0.10	0.60	11.50	13.50	3.80	4.40	. . .	. . .	0.70	1.20		
T31501	O1	0.85	1.00	1.00	1.40	0.030	0.030	0.10	0.50	0.40	0.70	. . .	0.30	0.40	0.60	. . .	. . .		
T31502	O2	0.85	0.95	1.40	1.80	0.030	0.030	. . .	0.50	. . .	0.50	. . .	0.30	. . .	. . .	. . .	0.30		
T31506	O6	1.25	1.55	0.30	1.10	0.030	0.030	0.55	1.50	. . .	0.30	. . .	. . .	. . .	. . .	0.20	0.30		
T31507	O7	1.10	1.30	0.20	1.00	0.030	0.030	0.10	0.60	0.35	0.85	0.15	0.40	1.00	2.00	. . .	0.30		
T41901	S1	0.40	0.55	0.10	0.40	0.030	0.030	0.15	1.20	1.00	1.80	0.15	0.30	1.50	3.00	. . .	0.50		
T41902	S2	0.40	0.55	0.30	0.50	0.030	0.030	0.90	1.20	. . .	. . .	. . .	0.50	. . .	. . .	0.30	0.60		
T41904	S4	0.50	0.65	0.60	0.95	0.030	0.030	1.75	2.25	0.10	0.50	0.15	0.35	. . .	. . .	. . .	. . .	. . .	. . .
T41905	S5	0.50	0.65	0.60	1.00	0.030	0.030	1.75	2.25	0.10	0.50	0.15	0.35	. . .	. . .	0.20	1.35	. . .	. . .
T41906	S6	0.40	0.50	1.20	1.50	0.030	0.030	2.00	2.50	1.20	1.50	0.20	0.40	. . .	. . .	0.30	0.50	. . .	. . .
T41907	S7	0.45	0.55	0.20	0.90	0.030	0.030	0.20	1.00	3.00	3.50	. . .	0.35	. . .	. . .	1.30	1.80	. . .	. . .
T61202	L2	0.45	1.00	0.10	0.90	0.030	0.030	0.10	0.50	0.70	1.20	0.10	0.30	. . .	. . .	. . .	0.25	. . .	. . .
T61203	L3	0.95	1.10	0.25	0.80	0.030	0.030	0.10	0.50	1.30	1.70	0.10	0.30	. . .	. . .	. . .	. . .	. . .	. . .
																		Nickel	
T61206	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
T60601	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	. . .	. . .	. . .	. . .
T51602	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
T51603	P3	. . .	0.10	0.20	0.60	0.030	0.030	. . .	0.40	0.40	0.75	. . .	. . .	. . .	. . .	. . .	. . .	1.00	1.50
T51604	P4	. . .	0.12	0.20	0.60	0.030	0.030	0.10	0.40	4.00	5.25	. . .	. . .	. . .	. . .	0.40	1.00	. . .	. . .
T51605	P5	0.06	0.10	0.20	0.60	0.030	0.030	0.10	0.40	2.00	2.50	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.35
T51606	P6	0.05	0.15	0.35	0.70	0.030	0.030	0.10	0.40	1.25	1.75	. . .	. . .	. . .	. . .	. . .	. . .	3.25	3.75
T51620	P20	0.28	0.40	0.60	1.00	0.030	0.030	0.20	0.80	1.40	2.00	. . .	. . .	. . .	. . .	0.30	0.55	. . .	. . .
T51621	P21[F]	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	4.25

[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.

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 2 Maximum Brinell Hardness in Annealed or Cold-Drawn Condition

Type	Annealed BHN	Cold Drawn BHN	Type	Annealed BHN	Cold Drawn BHN
H10	229	255	O1	212	241
H11	235	262	O2	217	241
H12	235	262	O6	229	241
H13	235	262	O7	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			

[A] Normally furnished in prehardened condition.

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 nonmetallic 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.

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.

16. Keywords

16.1 alloy; cold work tool steels; decarburization; hardness; hot work tool steels; macrostructure; tool steel

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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 ±25°F (14°C), but austenitizing and tempering temperatures shall be ±10°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 5 to 15 min (10 to 20 min 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.

Type	Preheat Temperature, °F (°C)	Austenitizing Temperature, °F (°C)		Austenitizing Time (minutes)	Quench Medium	Tempering Temperature, °F (°C)	Minimum Hardness, RC
		Salt Bath	Controlled Atmosphere Furnaces				
H10	1450 (788)	1850 (1010)	1875 (1024)	5–15	Air	1025 (552)	55
H11	1450 (788)	1825 (996)	1850 (1010)	5–15	Air	1025 (552)	53
H12	1450 (788)	1825 (996)	1850 (1010)	5–15	Air	1025 (552)	53
H13	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)	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	Oil	1200 (649)	42
H24	1450 (788)	2200 (1204)	2225 (1218)	5–15	Air	1025 (552)	55
H25	1450 (788)	2250 (1232)	2275 (1246)	5–15	Air	1025 (552)	44
H26	1550 (843)	2275 (1246)	2300 (1260)	5–15	Air	1025 (552)	58
H41	1450 (788)	2125 (1163)	2150 (1177)	5–15	Air	1025 (552)	60
H42	1450 (788)	2175 (1191)	2200 (1204)	5–15	Air	1025 (552)	60
H43	1450 (788)	2150 (1177)	2175 (1191)	5–15	Air	1025 (552)	58
A2	1450 (788)	1725 (941)	1750 (954)	5–15	Air	400 (204)	60
A3	1450 (788)	1775 (968)	1800 (982)	5–15	Air	400 (204)	63
A4	1250 (677)	1550 (843)	1575 (857)	5–15	Air	400 (204)	61
A6	1200 (649)	1525 (829)	1550 (843)	5–15	Air	400 (204)	58
A7	1500 (816)	1750 (954)	1775 (968)	5–15	Air	400 (204)	63
A8	1450 (788)	1825 (996)	1850 (1010)	5–15	Air	950 (510)	56
A9	1450 (788)	1825 (996)	1850 (1010)	5–15	Air	950 (510)	56
A10	1200 (649)	1475 (802)	1500 (816)	5–15	Air	400 (204)	59
D2	1500 (816)	1825 (996)	1850 (1010)	10–20	Air	400 (204)	59
D3	1500 (816)	1750 (954)	1775 (968)	10–20	Oil	400 (204)	61
D4	1500 (816)	1800 (982)	1825 (996)	10–20	Air	400 (204)	62
D5	1500 (816)	1825 (996)	1850 (1010)	10–20	Air	400 (204)	61
D7	1500 (816)	1925 (1052)	1950 (1066)	10–20	Air	400 (204)	63
O1	1200 (649)	1450 (788)	1475 (802)	5–15	Oil	400 (204)	59
O2	1200 (649)	1450 (788)	1475 (802)	5–15	Oil	400 (204)	59
O6	. . .	1450 (788)	1475 (802)	5–15	Oil	400 (204)	59
O7	1200 (649)	1575 (857)	1600 (871)	5–15	Oil	400 (204)	62
S1	1250 (677)	1725 (941)	1750 (954)	5–15	Oil	400 (204)	56
S2	1250 (677)	1625 (885)	1650 (899)	5–15	Brine	400 (204)	58
S4	1250 (677)	1625 (885)	1650 (899)	5–15	Oil	400 (204)	58
S5	1250 (677)	1625 (885)	1650 (899)	5–15	Oil	400 (204)	58
S6	1450 (788)	1700 (927)	1725 (941)	5–15	Oil	400 (204)	56
S7	1250 (677)	1725 (941)	1750 (954)	5–15	Air	400 (204)	56
L2	1200 (649)	1575 (857)	1600 (871)	5–15	Oil	400 (204)	53[A]
L3	1200 (649)	1525 (829)	1550 (843)	5–15	Oil	400 (204)	62
L6	1200 (649)	1500 (816)	1525 (829)	5–15	Oil	400 (204)	58
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.

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TABLE 4 Macroetch Standards (Maximum Allowable Rating)[A]

Bar Size, in. (mm)	Low-Alloy Tool Steels[B]		High-Alloy Tool Steels[C]	
	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	4½	6	3½	6
Over 3 to 4 (76 to 102), incl	4½	6	4	6
Over 4 to 5 (102 to 127), incl	5	6	4½	6
Over 5 to 6 (127 to 152), incl	5	6	5	6
Over 6 (152)	As negotiated between seller and purchaser.			

[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.

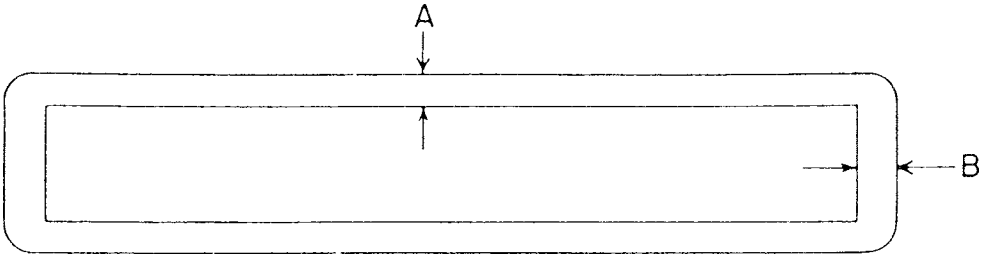
TABLE 5 Maximum Decarburization Limits (Rounds, Hexagons and Octagons Maximum Limit Per Side)

NOTE—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 ½ (12.7), incl	0.013 (0.33)	. . .	0.013 (0.33)
Over ½ 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)	. . .
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	. . .	0.160 (4.06)	. . .

TABLE 6 Maximum Decarburization Limits (Hot Rolled Square and Flat Bars Maximum Limit Per Side)

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

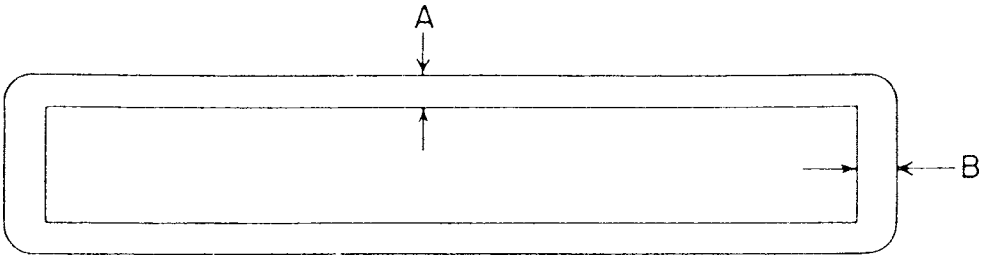


Specified Thickness, in. (mm)		Specified Widths, in. (mm)										
		0 to ½ (0 to 12.7) incl	Over ½ to 1 (12.7 to 25.4), incl	Over 1 to 2 (25.4 to 50.8), incl	Over 2 to 3 (50.8 to 76), incl	Over 3 to 4 (76 to 102), incl	Over 4 to 5 (102 to 127), incl	Over 5 to 6 (127 to 152), incl	Over 6 to 7 (152 to 178), incl	Over 7 to 8 (178 to 203), incl	Over 8 to 9 (203 to 229), incl	Over 9 to 12 (229 to 304), incl
0 to ½ (0 to 12.7), incl	A	0.020 (0.51)	0.020 (0.51)	0.024 (0.61)	0.028 (0.71)	0.032 (0.81)	0.036 (0.91)	0.040 (1.02)	0.044 (1.12)	0.048 (1.22)	0.048 (1.22)	0.048 (1.22)
	B	0.020 (0.51)	0.026 (0.66)	0.032 (0.81)	0.038 (0.97)	0.044 (1.12)	0.054 (1.37)	0.062 (1.57)	0.066 (1.68)	0.078 (1.98)	0.082 (2.08)	0.096 (2.44)
Over ½ to 1 (12.7 to 25.4), incl	A	. . .	0.036 (0.91)	0.036 (0.91)	0.036 (0.91)	0.040 (1.02)	0.044 (1.12)	0.052 (1.32)	0.056 (1.42)	0.060 (1.52)	0.060 (1.52)	0.060 (1.52)
	B	. . .	0.036 (0.91)	0.042 (1.07)	0.046 (1.17)	0.056 (1.42)	0.064 (1.63)	0.082 (2.08)	0.090 (2.29)	0.098 (2.49)	0.102 (2.59)	0.108 (2.74)
Over 1 to 2 (25.4 to 50.8), incl	A	. . .	. . .	0.052 (1.32)	0.052 (1.32)	0.056 (1.42)	0.056 (1.42)	0.060 (1.52)	0.060 (1.52)	0.064 (1.63)	0.068 (1.73)	0.072 (1.83)
	B	. . .	. . .	0.052 (1.32)	0.056 (1.42)	0.060 (1.52)	0.072 (1.83)	0.086 (2.18)	0.098 (2.49)	0.112 (2.84)	0.118 (3.00)	0.122 (3.10)
Over 2 to 3 (50.8 to 76), incl	A	. . .	. . .	. . .	0.064 (1.63)	0.064 (1.63)	0.068 (1.73)	0.068 (1.73)	0.072 (1.83)	0.072 (1.83)	0.080 (2.03)	0.080 (2.03)
	B	. . .	. . .	. . .	0.064 (1.63)	0.072 (1.83)	0.082 (2.08)	0.094 (2.39)	0.110 (2.79)	0.122 (3.10)	0.130 (3.30)	0.136 (3.45)
Over 3 to 4 (76 to 102), incl	A	. . .	. . .	. . .	. . .	0.080 (2.03)	0.080 (2.03)	0.086 (2.18)	0.092 (2.34)	0.094 (2.39)	0.100 (2.54)	0.100 (2.54)
	B	. . .	. . .	. . .	. . .	0.080 (2.03)	0.090 (2.29)	0.100 (2.54)	0.120 (3.05)	0.132 (3.35)	0.132 (3.35)	0.150 (3.81)

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TABLE 7 Maximum Decarburization Limits
(Forged Square and Flat Bars Maximum Limit Per Side)

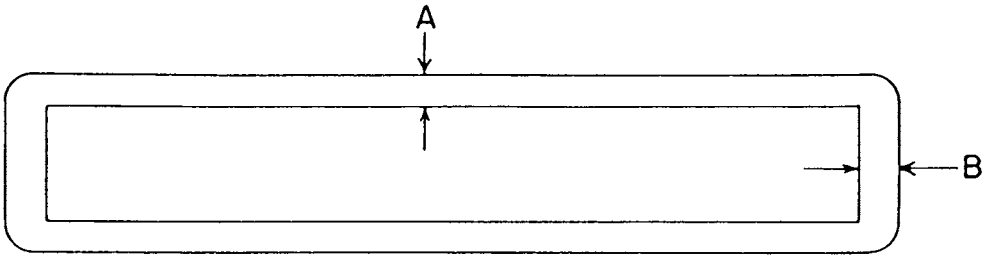
NOTE—The recommended minimum allowance for machining prior to heat treatment is 25 % greater than the maximum decarburization allowed.



Specified Thickness, in. (mm)		Specified Width, in. (mm)								
		Over 1 to 2 (25.4 to 50.0), incl	Over 2 to 3 (50.8 to 76), incl	Over 3 to 4 (76 to 102), incl	Over 4 to 5 (102 to 127), incl	Over 5 to 6 (127 to 152), incl	Over 6 to 7 (152 to 178), incl	Over 7 to 8 (178 to 203), incl	Over 8 to 9 (203 to 229), incl	Over 9 to 12 (229 to 305), incl
Over ½ to 1, (12.7 to 25.4), incl	A	0.038 (0.97)	0.042 (1.07)	0.048 (1.32)	0.052 (1.32)	0.056 (1.42)	0.062 (1.57)	0.066 (1.68)	0.072 (1.83)	0.080 (2.03)
	B	0.048 (1.22)	0.056 (1.42)	0.070 (1.78)	0.080 (2.03)	0.94 (2.39)	0.110 (2.79)	0.132 (3.35)	0.132 (3.35)	0.132 (3.35)
Over 1 to 2, (25.4 to 50.8), incl	A	0.058 (1.47)	0.062 (1.57)	0.066 (1.68)	0.070 (1.78)	0.074 (1.78)	0.080 (1.88)	0.084 (2.03)	0.094 (2.39)	0.106 (2.69)
	B	0.058 (1.47)	0.066 (1.68)	0.078 (1.98)	0.086 (2.18)	0.100 (2.54)	0.114 (2.90)	0.132 (3.35)	0.132 (3.35)	0.132 (3.35)
Over 2 to 3 (50.8 to 76), incl	A	. . .	0.080 (2.03)	0.084 (2.13)	0.088 (2.24)	0.092 (2.34)	0.098 (2.49)	0.106 (2.69)	0.114 (2.90)	0.126 (3.20)
	B	. . .	0.080 (2.03)	0.092 (2.34)	0.098 (2.49)	0.016 (2.69)	0.118 (3.00)	0.136 (3.45)	0.136 (3.45)	0.136 (3.45)
Over 3 to 4 (76 to 102), incl	A	. . .	. . .	0.102 (2.59)	0.106 (2.69)	0.112 (2.84)	0.120 (3.05)	0.132 (3.35)	0.140 (3.56)	0.158 (4.01)
	B	. . .	. . .	0.102 (2.59)	0.106 (2.69)	0.112 (2.84)	0.120 (3.05)	0.132 (3.35)	0.140 (3.56)	0.158 (4.01)
Over 4 to 5 (102 to 127), incl	A	. . .	. . .	. . .	0.126 (3.20)	0.130 (3.30)	0.138 (3.51)	0.146 (3.71)	0.156 (3.96)	0.170 (4.32)
	B	. . .	. . .	. . .	0.126 (3.20)	0.130 (3.30)	0.138 (3.51)	0.146 (3.71)	0.156 (3.96)	0.170 (4.32)
Over 5 to 6 (127 to 152), incl	A	. . .	. . .	. . .	. . .	0.150 (3.81)	0.158 (4.01)	0.166 (4.22)	0.176 (4.47)	0.188 (4.78)
	B	. . .	. . .	. . .	. . .	0.150 (3.81)	0.158 (4.01)	0.166 (4,22)	0.176 (4.47)	0.188 (4.78)
Over 6 to 7 (152 to 178) incl	A	. . .	. . .	. . .	. . .	. . .	0.176 (4.47)	0.186 (4.72)	0.186 (4.72)	0.198 (5.03)
	B	. . .	. . .	. . .	. . .	. . .	0.176 (4.47)	0.186 (4.72)	0.186 (4.72)	0.198 (5.03)

TABLE 8 Maximum Decarburization Limits
(Cold Drawn Square and Flat Bars Maximum Limits Per Side)

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



Specified Thickness, in. (mm)		Specified Width, in. (mm)					
		0 to ½ (0 to 12.7), incl	Over ½ to 1 (12.7 to 25.4), incl	Over 1 to 2 (25.4 to 50.8), incl	Over 2 to 3 (50.8 to 76), incl	Over 3 to 4 (76 to 102), incl	Over 4 to 5 102 to 127), incl
0 to ½ (0 to 12.7), incl	A	0.020 (0.51)	0.020 (0.51)	0.024 (0.61)	0.028 (0.71)	0.032 (0.81)	0.036 (0.91)
	B	0.020 (0.51)	0.026 (0.66)	0.032 (0.81)	0.038 (0.97)	0.044 (1.12)	0.054 (1.37)
Over ½ to 1 (12.7 to 25.4), incl	A	. . .	0.036 (0.91)	0.036 (0.91)	0.036 (0.91)	0.040 (1.02)	0.044 (1.12)
	B	. . .	0.036 (0.91)	0.042 (1.07)	0.046 (1.17)	0.056 (1.42)	0.064 (1.63)
Over 1 to 2 (25.4 to 50.8), incl	A	. . .	. . .	0.052 (1.32)	0.052 (1.32)	0.056 (1.42)	. . .
	B	. . .	. . .	0.052 (1.32)	0.056 (1.42)	0.060 (1.52)	. . .

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TABLE 9 Hot-Rolled Bars (Rounds, Squares, Octagons, Quarter Octagons, Hexagons Size Tolerance)

Specified Sizes, in. (mm)	Size Tolerances, in. (mm)	
	Under	Over
To ½ (12.7), incl	0.005 (0.13)	0.012 (0.30)
Over ½ to 1 (12.7 to 25.4), incl	0.005 (0.13)	0.016 (0.41)
Over 1 to 1½ (25.4 to 38.1), incl	0.006 (0.15)	0.020 (0.51)
Over 1½ to 2 (38.1 to 50.8), incl	0.008 (0.20)	0.025 (0.64)
Over 2 to 2½ (50.8 to 63.5), incl	0.010 (0.25)	0.030 (0.76)
Over 2½ to 3 (63.5 to 76.2), incl	0.010 (0.25)	0.040 (1.02)
Over 3 to 4 (76.2 to 101.6), incl	0.012 (0.30)	0.050 (1.27)
Over 4 to 5½ (101.6 to 139.7), incl	0.015 (0.38)	0.060 (1.52)
Over 5½ to 6½ (139.7 to 165.1), incl	0.018 (0.46)	0.100 (2.54)
Over 6½ to 8 (165.1 to 203.2), incl	0.020 (0.51)	0.150 (3.81)

TABLE 10 Forged Bars (Rounds, Squares, Octagons, Hexagons Size Tolerances)[A]

Specified Sizes, in. (mm)	Size Tolerances, in. (mm)	
	Under	Over
Over 1 to 2 (25.4 to 50.8), incl	0.030 (0.76)	0.060 (1.52)
Over 2 to 3 (50.8 to 76), incl	0.030 (0.76)	0.080 (2.03)
Over 3 to 5 (76 to 127), incl	0.060 (1.52)	0.125 (3.18)
Over 5 to 7 (127 to 177.8) incl	0.125 (3.18)	0.187 (4.75)
Over 7 to 9 (177.8 to 229), incl	0.187 (4.75)	0.312 (7.92)

[A] Out-of-section tolerances to be three fourths of the total tolerance.

TABLE 11 Rough-Turned Round Bars (Size Tolerance)[A]

Specified Sizes,[B] in. (mm)	Size Tolerance, in. (mm)	
	Under	Over
Over ¾ to 1½ (19.0 to 38.1), incl	0.00	0.010 (0.254)
Over 1½ to 3 1/16 (38.1 to 77.8), incl	0.00	0.015 (0.38)
Over 3 1/16 to 4 1/16 (77.8 to 103.2), incl	0.00	0.031 (0.79)
Over 4 1/16 to 6 1/16 (103.2 to 154), incl	0.00	0.062 (1.6)
Over 6 1/16 to 10 1/16 (154 to 255.6), incl	0.00	0.094 (2.4)
Over 10 1/16 Please consult producer		

[A] Out-of-round tolerances to be one half of the total tolerance.
[B] Consult producer for oversize allowance and decarburization limits for all sizes.

TABLE 12 Cold-Drawn Bars (Rounds, Octagons, Quarter Octagons, and Hexagons Size Tolerances)[A]

Size Range, in. (mm)	Tolerance, in. (mm) Plus and Minus
¼ to ½ (6.4 to 12.7), excl	0.002 (0.05)
½ to 1 (12.7 to 25.4), excl	0.0025 (0.06)
1 to 2¾ (25.4 to 69.8), incl	0.003 (0.08)

[A] Out-of-round tolerances to be one half of the total thickness.

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TABLE 13 Centerless Ground Bars Rounds (Diameter Tolerances)[A]

Diameter Range, in. (mm)	Tolerance, in. (mm)	
	Under	Over
¼ to ½ (6.4 to 12.7), excl	0.0015 (0.038)	0.0015 (0.038)
½ to 3 1/16 (12.7 to 77.8), excl	0.002 (0.05)	0.002 (0.05)
3 1/16 to 4 1/16 (77.8 to 103.2), excl	0.003 (0.08)	0.003 (0.08)

[A] Out of round tolerances to be ½ of the total tolerance.

TABLE 14 Hot-Rolled Flat Bars (Width and Thickness Tolerances Width Tolerances)[A]

Specified Widths, in. (mm)	Width Tolerances, in. (mm)	
	Under	Over
To 1 (25.4), incl	0.016 (0.41)	0.031 (0.79)
Over 1 to 3 (25.4 to 76), incl	0.031 (0.79)	0.047 (1.19)
Over 3 to 5 (76 to 127), incl	0.047 (1.19)	0.063 (1.60)
Over 5 to 7 (127 to 178), incl	0.063 (1.60)	0.094 (2.39)
Over 7 to 10 (178 to 254), incl	0.078 (1.98)	0.125 (3.18)
Over 10 to 12 (254 to 305), incl	0.094 (2.39)	0.156 (3.96)

Specified Widths, in. (mm)	Thickness Tolerances for Specified Thicknesses, in. (mm)											
	To ¼ (6.4), incl		Over ¼ to ½ (6.4 to 12.7), incl		Over ½ to 1 (12.7 to 25.4), incl		Over 1 to 2 (25.4 to 50.8), incl		Over 2 to 3 (50.8 to 76), incl		Over 3 to 4 (76 to 102), incl	
	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over
To 1 (25.4), incl	0.006 (0.15)	0.010 (0.25)	0.008 (0.20)	0.012 (0.30)	0.010 (0.25)	0.016 (0.41)	. . .	. . .	. . .	. . .	. . .	. . .
Over 1 to 2 (25.4 to 50.8), incl	0.006 (0.15)	0.014 (0.36)	0.008 (0.20)	0.016 (0.41)	0.010 (0.25)	0.020 (0.51)	0.020 (0.51)	0.024 (0.61)	. . .	. . .	. . .	. . .
Over 2 to 3 (50.8 to 76),incl	0.006 (0.15)	0.018 (0.46)	0.008 (0.20)	0.020 (0.51)	0.010 (0.25)	0.024 (0.61)	0.020 (0.51)	0.027 (0.69)	0.026 (0.66)	0.034 (0.86)	. . .	. . .
Over 3 to 4 (76 to 102), incl	0.008 (0.20)	0.020 (0.51)	0.010 (0.25)	0.022 (0.56)	0.013 (0.33)	0.024 (0.61)	0.024 (0.61)	0.030 (0.76)	0.032 (0.81)	0.042 (1.07)	0.040 (1.02)	0.048 (1.22)
Over 4 to 5 (102 to 127), incl	0.010 (0.25)	0.020 (0.51)	0.012 (0.30)	0.024 (0.61)	0.015 (0.38)	0.030 (0.76)	0.027 (0.69)	0.035 (0.89)	0.032 (0.81)	0.042 (1.07)	0.042 (1.07)	0.050 (1.27)
Over 5 to 6 (127 to 152), incl	0.012 (0.30)	0.020 (0.51)	0.014 (0.36)	0.030 (0.76)	0.018 (0.46)	0.030 (0.76)	0.030 (0.76)	0.035 (0.89)	0.036 (0.91)	0.046 (1.17)	0.044 (1.12)	0.054 (1.37)
Over 6 to 7 (152 to 178), incl	0.014 (0.36)	0.027 (0.69)	0.016 (0.41)	0.032 (0.81)	0.018 (0.46)	0.035 (0.89)	0.030 (0.76)	0.040 (1.02)	0.036 (0.91)	0.048 (1.22)	0.046 (1.17)	0.056 (1.42)
Over 7 to 10 (178 to 254), incl	0.018 (0.46)	0.030 (0.76)	0.020 (0.51)	0.035 (0.89)	0.024 (0.61)	0.040 (1.02)	0.035 (0.89)	0.045 (1.14)	0.040 (1.02)	0.054 (1.37)	0.052 (1.32)	0.064 (1.62)
Over 10 to 12 (254 to 305), incl	0.020 (0.51)	0.035 (0.89)	0.025 (0.64)	0.040 (1.02)	0.030 (0.76)	0.045 (1.14)	0.040 (1.02)	0.050 (1.27)	0.046 (1.17)	0.060 (1.52)	0.056 (1.42)	0.072 (1.83)

[A] Out of square tolerance to be ¾ of total width tolerance max.

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TABLE 15 Forged Flat Bars (Width Tolerances)

Specified Widths, in. (mm)	Width Tolerances, in. (mm)	
	Under	Over
Over 1 to 3 (25.4 to 76), incl	0.031 (0.79)	0.078 (1.98)
Over 3 to 5 (76 to 127), incl	0.062 (1.57)	0.125 (3.18)
Over 5 to 7 (127 to 178), incl	0.125 (3.18)	0.187 (4.75)
Over 7 to 9 (178 to 229), incl	0.187 (4.75)	0.312 (7.92)

Specified Widths, in. (mm)	Thickness Tolerances for Specified Thicknesses, in. (mm)									
	To 1 (25.4), incl		Over 1 to 3 (25.4 to 76), incl		Over 3 to 5 (76 to 127), incl		Over 5 to 7 (127 to 178), incl		Over 7 to 9 (178 to 229), incl	
	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over
Over 1 to 3 (25.4 to 76), incl	0.016 (0.41)	0.031 (0.79)	0.031 (0.79)	0.078 (1.98)	. . .	. . .	. . .	. . .	. . .	. . .
Over 3 to 5 (76 to 127), incl	0.031 (0.79)	0.062 (1.57)	0.047 (1.19)	0.094 (2.39)	0.062 (1.57)	0.125 (3.18)	. . .	. . .	. . .	. . .
Over 5 to 7 (127 to 178), incl	0.047 (1.19)	0.094 (2.39)	0.062 (1.57)	0.125 (3.18)	0.078 (1.98)	0.156 (3.96)	0.125 (3.18)	0.187 (4.75)	. . .	. . .
Over 7 to 9 (178 to 229), incl	0.062 (1.57)	0.125 (3.18)	0.078 (1.98)	0.156 (3.96)	0.094 (2.39)	0.187 (4.75)	0.156 (3.96)	0.219 (5.56)	0.187 (4.75)	0.312 (7.92)

TABLE 16 Cold Drawn Square and Flat Bars (Size Tolerances)

Size Range, in. (mm)	Tolerance, in. (mm) Plus and Minus
¼ to ¾ (6.4 to 19.1), incl	0.002 (0.05)
Over ¾ to 1½ (19.1 to 38.1), incl	0.003 (0.08)
Over 1½ (38.1)	0.004 (0.10)

TABLE 17 Drill Rod, Rounds, Polished or Ground (Size Tolerances)[A]

NOTE—Out-of-round to be ½ of total tolerance maximum.

Specified Size, in. (mm)	Standard Manufacturing Tolerance, in. (mm), plus and minus	Precision Tolerance, in. (mm), plus and minus
Up to 0.124 (3.15), incl	0.0003 (0.008)	0.0002 (0.005)
0.125 to 0.499 (3.18 to 12.7), incl	0.0005 (0.013)	0.00025 (0.006)
0.500 to 1.500 (12.7 to 38.1), incl	0.001 (0.025)	0.0005 (0.013)

[A] Out-of-round tolerances to be one half of the total tolerance.

TABLE 18 Drill Rod, Shapes Other than Rounds, Cold Drawn (Size Tolerances)[A]

Specified Size, in. (mm)	Tolerances, in. (mm), plus and minus
Up to ¼ (6.4), excl	0.0005 (0.013)
¼ to ¾ (6.4 to 19.0), excl	0.001 (0.025)
¾ to 1 (19.0 to 25.4), incl	0.0015 (0.038)

[A] Out-of-round tolerances to be one half of the total tolerance.

TABLE 19 Precision Ground Square and Flat Bars (Thickness and Width Tolerances)

NOTE—Surface Finish, 35 μin. (0.89 μm) rms maximum. Free of decarburization.

Thickness, in. (mm)	Tolerance, in. (mm)	
	Under	Over
	Thickness	
Up to 1¼ (31.8), incl	0.001 (0.03)	0.001 (0.03)
Over 1¼ to 2 (31.8 to 50.8), incl	0.002 (0.05)	0.002 (0.05)
	Width	
½ to 14 (12.7 to 355.6), incl	0.000	0.005 (0.13)

TABLE 20 Hot-Rolled or Forged Bars and Billets (Tolerances for Machine Cut Lengths)

Specified Sizes Apply to Rounds, Squares, Hexagons, Octagons, and Width of Flats, in. (mm)	Tolerances for Specified Lengths, 14 ft (4.27 m) max, in. (mm)	
	Over	Under
To 9 (229), incl	⅜ (9.5)	0
Over 9 to 12 (229 to 305), incl	½ (12.7)	0
Over 12 to 18 (305 to 457), incl	¾ (19.1)	0
Over 18 (457)	1 (25.4)	0

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TABLE 21 Straightened Hot-Rolled Annealed Bars or Cold-Finished Bars (Straightness Tolerances)

This table does not apply to flat bars having a width to thickness ratio of 6 to 1 or greater.

Measurement is taken on the concave side of the bar with a straightedge. Bars are furnished to the following straightness tolerances:

Hot rolled bars:

⅛ in. in any 5 ft, but may not exceed ⅛ in. × (no. of ft in length/5)

The foregoing formula applies also to bars under 5 ft in length. (3.2 mm in any 1.54 m, but may not exceed 3.2 mm × (no. of m in length/1.54). The foregoing formula applies also to bars under 1.54 m in length.)

Cold finished bars:

1/16 in. in any 5 ft, but may not exceed 1/16 in. × (no. of ft in length/5)

The foregoing formula applies also to bars under 5 ft in length. (1.6 mm in any 1.54 m, but may not exceed 1.6 mm × (no. of m in length/1.54). The foregoing formula applies also to bars under 1.54 m in length.)

TABLE 22 Forgings, Disks, Rings and Rectangular Blocks (Allowances for Machining; Tolerances Over Allowances)

NOTE 1—Unmachined tool steel forgings are furnished to size and surface allowances for machining and tolerances over allowances. Experience indicates that the allowances and tolerances in the tabulation below are satisfactory for many applications. When width and thickness differ, each dimension carries its individual allowance and tolerance in accordance with the tabulation; also, the ID and OD take their respective allowances and tolerances.

NOTE 2—When forgings are ordered, the purchaser should state whether the sizes are the forged or the finished sizes. The minimum sizes ordered for forgings should be the finished sizes plus allowances for machining; and the ordered forged sizes are subject to applicable tolerances.

Diameters of Disks and Rings and Dimension of Blocks			
Finished Size Diameters or Dimensions of Blocks, in. (mm)	Allowance for Machining Over Finished Size, in. (mm)	Tolerance Over the Allowance, in. (mm)	
		Plus	Minus
Up to 3 (76), incl	⅛ (3.2)	⅛ (3.2)	0
Over 3 to 5 (76 to 127), incl	3/16 (4.8)	3/16 (4.8)	0
Over 5 to 7 (127 to 178), incl	¼ (6.4)	¼ (6.4)	0
Over 7 to 10 (178 to 254), incl	5/16 (7.9)	5/16 (7.9)	0
Over 10 to 12 (254 to 305), incl	⅜ (9.5)	⅜ (9.5)	0
Over 12 to 15 (305 to 381), incl	7/16 (11.1)	7/16 (11.1)	0
Over 15 to 18 (381 to 457), incl	½ (12.7)	½ (12.7)	0
Over 18 to 24 (457 to 610), incl	⅝ (15.9)	½ (12.7)	0
Over 24 to 32 (610 to 813), incl	¾ (19.1)	½ (12.7)	0
Over 32 to 40 (813 to 1016), incl	⅞ (22.2)	½ (12.7)	0
Ring forgings: for the OD, use the same allowances and tolerances shown in the above tabulation; for the ID, double the tolerances shown in the above tabulation.			

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TABLE 23 Forgings, Disks, Rings, and Rectangular Blocks (Allowances for Machining: Tolerances Over Allowances)

Thickness of Disks and Ring Forgings

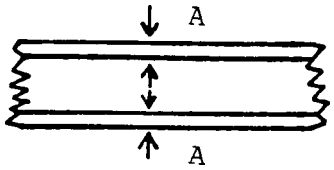
Finished Diameter, in. (mm)	Finished Thickness, in. (mm)														
	Up to 3 (76), incl			Over 3 to 5 (76 to 127), incl			Over 5 to 7 (127 to 178), incl			Over 7 to 10 (178 to 254), incl			Over 10 to 12 (254 to 305), incl		
	Allowance	Tolerance		Allowance	Tolerance		Allowance	Tolerance		Allowance	Tolerance		Allowance	Tolerance	
		Plus	Minus		Plus	Minus		Plus	Minus		Plus	Minus		Plus	Minus
Up to 3 (76), incl	⅛ (3.2)	⅛ (3.2)	0	⅛ (3.2)	⅛ (3.2)	0									
Over 3 to 5 (76 to 127), incl	⅛ (3.2)	⅛ (3.2)	0	⅛ (3.2)	⅛ (3.2)	0									
Over 5 to 7 (127 to 178), incl	3⁄16 (4.8)	3⁄16 (4.8)	0	3⁄16 (4.8)	3⁄16 (4.8)	0	5⁄16 (7.9)	5⁄16 (7.9)	0	⅜ (9.5)	⅜ (9.5)	0			
Over 7 to 10 (178 to 254), incl	3⁄16 (4.8)	3⁄16 (4.8)	0	¼ (6.4)	¼ (6.4)	0	5⁄16 (7.9)	5⁄16 (7.9)	0	⅜ (9.5)	⅜ (9.5)	0			
Over 10 to 12 (254 to 305), incl	3⁄16 (4.8)	3⁄16 (4.8)	0	¼ (6.4)	¼ (6.4)	0	5⁄16 (7.9)	5⁄16 (7.9)	0	⅜ (9.5)	⅜ (9.5)	0	⅜ (9.5)	⅜ (9.5)	0
Over 12 to 15 (305 to 381), incl	¼ (6.4)	¼ (6.4)	0	5⁄16 (7.9)	5⁄16 (7.9)	0	⅜ (9.5)	⅜ (9.5)	0	⅜ (9.5)	⅜ (9.5)	0	7⁄16 (11.1)	7⁄16 (11.1)	0
Over 15 to 18 (381 to 457), incl	¼ (6.4)	¼ (6.4)	0	5⁄16 (7.9)	5⁄16 (7.9)	0	⅜ (9.5)	⅜ (9.5)	0	7⁄16 (11.1)	7⁄16 (11.1)	0	7⁄16 (11.1)	7⁄16 (11.1)	0
Over 18 to 24 (457 to 610), incl	¼ (6.4)	¼ (6.4)	0	5⁄16 (7.9)	5⁄16 (7.9)	0	⅜ (9.5)	⅜ (9.5)	0	7⁄16 (11.1)	7⁄16 (11.1)	0	7⁄16 (11.1)	7⁄16 (11.1)	0
Over 24 to 32 (610 to 813), incl	5⁄16 (7.9)	5⁄16 (7.9)	0	⅜ (9.5)	⅜ (9.5)	0	7⁄16 (11.1)	7⁄16 (11.1)	0	½ (12.7)	½ (12.7)	0	½ (12.7)	½ (12.7)	0
Over 32 to 40 (813 to 1016), incl	5⁄16 (7.9)	5⁄16 (7.9)	0	⅜ (9.5)	⅜ (9.5)	0	7⁄16 (11.1)	7⁄16 (11.1)	0	½ (12.7)	½ (12.7)	0	½ (12.7)	½ (12.7)	0

Finished Thickness, in. (mm)[A]

Finished Diameter, in. (mm)	Over 12 to 15 (304 to 381), incl			Over 15 to 18 (381 to 475), incl			Over 18 to 24 (457 to 610), incl			Over 24 to 32 (610 to 813), incl			Over 32 to 40 (813 to 1016), incl		
	Allowance	Tolerance		Allowance	Tolerance		Allowance	Tolerance		Allowance	Tolerance		Allowance	Tolerance	
		Plus	Minus		Plus	Minus		Plus	Minus		Plus	Minus		Plus	Minus
Up to 3 (76), incl															
Over 3 to 5 (76 to 127), incl															
Over 5 to 7 (127 to 178), incl															
Over 7 to 10 (178 to 254), incl															
Over 10 to 12 (254 to 305), incl	7⁄16 (11.1)	7⁄16 (11.1)	0												
Over 12 to 15 (305 to 381), incl	½ (12.7)	½ (12.7)	0												
Over 15 to 18 (381 to 457), incl	½ (12.7)	½ (12.7)	0	½ (12.7)	½ (12.7)	0	5⁄8 (15.9)	5⁄8 (15.9)	0						
Over 18 to 24 (457 to 610), incl	½ (12.7)	½ (12.7)	0	½ (12.7)	½ (12.7)	0	5⁄8 (15.9)	5⁄8 (15.9)	0						
Over 24 to 32 (610 to 813), incl	9⁄16 (14.3)	9⁄16 (14.3)	0	5⁄8 (15.9)	5⁄8 (15.9)	0	¾ (19.1)	¾ (19.1)	0	¾ (19.1)	¾ (19.1)	0	¾ (19.1)	¾ (19.1)	0
Over 32 to 40 (813 to 1016), incl	9⁄16 (14.3)	9⁄16 (14.3)	0	5⁄8 (15.9)	5⁄8 (15.9)	0	¾ (19.1)	¾ (19.1)	0	¾ (19.1)	¾ (19.1)	0	⅞ (22.2)	⅞ (22.2)	0

[A] Forgings processed to the above allowances are free of decarburization and surface defects when machined or ground to the finished size by removal of equal amounts from opposite surfaces.

TABLE 24 Hot Rolled Sheet and Plate (Tolerances for Thickness and Minimum Allowances for Machining)



Thickness, in. (mm)	Thickness Tolerance, in. (mm)[A,B]	Machining Allowance, in. (mm)[C,D]
Up to 0.025 (0.64) incl.	0.006 (0.15)	0.013 (0.33)
Over 0.025 to 0.062 (0.64 to 1.6) incl.	0.012 (0.30)	0.013 (0.33)
Over 0.062 to 0.093 (1.6 to 2.4) incl.	0.016 (0.41)	0.015 (0.38)
Over 0.093 to 0.125 (2.4 to 3.2) incl.	0.020 (0.51)	0.015 (0.38)
Over 0.125 to 0.187 (3.2 to 4.8) incl.	0.028 (0.71)	0.018 (0.46)
Over 0.187 to 0.250 (4.8 to 6.4) incl.	0.050 (1.27)	0.023 (0.58)
Over 0.250 to 0.375 (6.4 to 9.5) incl.	0.060 (1.52)	0.035 (0.89)
Over 0.375 to 0.500 (9.5 to 12.7) incl.	0.070 (1.78)	0.035 (0.89)
Over 0.500 to 1.000 (12.7 to 25.4) incl.	0.100 (2.54)	0.063 (1.60)
Over 1.000 to 1.500 (25.4 to 38.1) incl.	0.125 (3.18)	0.063 (1.60)
Over 1.500 to 2.000 (38.1 to 50.8) incl.	0.125 (3.18)	0.075 (1.90)
Over 2.000 to 4.000 (50.8 to 101.6) incl.	0.250 (6.35)	0.094 (2.36)

[A] Thickness is measured along the longitudinal edges of the sheet or plate at least ⅜ in. (9.5 mm), but not more than 3.0 in. (76.2 mm) from the edge.
[B] All tolerances are over the specified thickness.
[C] Maximum decarburization limits are 80 % the allowance per side for machining.
[D] Additional cleanup for deviations from flatness may be added. Consult with producer.

TABLE 25 Hot Rolled Trimmed Sheet and Plate (Tolerances for Width and Length)[A]

Thickness, in. (mm)	Tolerance, in. (mm)[B]	
	Width	Length
Up to 0.187 (4.8) incl.	0.125 (3.18)	0.250 (6.35)
Over 0.187 to 0.375 (4.8 to 9.5)	0.1875 (4.76)	0.250 (6.35)
Over 0.375 to 4.000 (9.5 to 101.6)	0.250 (6.35)	0.250 (6.35)

[A] Tolerances shown are for all trimming methods.
[B] All tolerances are on the plus side of the specified width or length.

TABLE 26 Hot Rolled Sheet and Plate (Tolerances for Flatness)

Thickness, in. (mm)	Tolerances, in. (mm)[A]
Up to 0.125 (3.18) incl.	0.750 (19.05)
Over 0.125 to 0.500 (3.18 to 12.7) incl.	0.500 (12.70)
Over 0.500 to 1.500 (12.7 to 38.1) incl.	0.375 (9.52)
Over 1.500 to 4.000 (38.1 to 101.6) incl.	0.250 (6.35)

[A] Maximum deviation from a horizontal flat surface in any 10 ft (3.05 m).

TABLE 27 Hot Rolled Trimmed Sheet and Plate (Tolerances for Camber)

NOTE—Camber is the deviation of a side edge from a straight line. Measurement is taken by placing a 5 ft (1.52 m) straight edge on the concave side and measuring the greatest distance between the sheet or plate edge and the straight edge.

Maximum camber = 0.125 in. in any 5 ft (3.18 mm in any 1.52 m)

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TABLE 28 Machined Square and Flat Bars
(Size, Straightness and Squareness Tolerances, in. (mm))

NOTE—Bars shall be free of surface imperfections and decarburization and furnished oversize as shown. Surface finish shall be 125 μin. (3.18 μm) rms maximum for ground bars, and 250 μin. (6.36 μm) rms maximum for machined (milled) bars.

Specified Thickness	Thickness[A]		Width[A]			
	Machined or Plate		Machined		Cut From Plate	
	Oversize	Tolerance	Oversize	Tolerance	Oversize	Tolerance
½ to 4, incl (12.7 to 101.6)	0.015 (0.38)	+0.020, –0 (0.51)	0.015 (0.38)	+0.020, –0 (0.51)	0.015 (0.38)	+0.062, –0 (1.59)
Over 4 to 6, incl (101.6 to 152.4)	0.062 (1.59)	+0.031, –0 (0.79)	0.062 (1.59)	+0.031, –0 (0.79)	0.062 (1.59)	+0.062, –0 (1.59)
Straightness Tolerances						
1/16 in. in any 5 ft, but may not exceed 1/16 in. × no. of ft in length/5						
The foregoing formula applies also to bars under 5 ft in length.						
1.6 mm in any 1.54 m, but may not exceed 1.6 mm × no. of m in length/1.54						
The foregoing formula applies also to bars under 1.54 m in length.						
Squareness Tolerances						
The width and thickness dimensions specified must be attainable when surfaces are subsequently made to be parallel and square. Closer limits of squareness may be agreed upon between seller and purchaser.						

[A] For larger widths and thicknesses than shown, refer to producer.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order. Details of these supplementary requirements shall be agreed upon by the seller and the purchaser.

S1. Ultrasonic Quality

S1.1 Material shall be ultrasonically tested at appropriate stages of the manufacture to ensure the quality, when and as agreed upon between seller and purchaser.

S2. Cleanliness

S2.1 In special situations such as where the surface finish of the part requires optimum polishing characteristics, the cleanliness of the steel shall be ascertained in accordance with the latest issue of Test Methods E 45. The permissible limits shall be agreed upon between seller and purchaser.

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