BOMBARDIER
Toronto (de Havilland)
PROPRIETARY INFORMATION

PPS 20.08

PRODUCTION PROCESS STANDARD

Hardness Testing of Metals

Issue 16
- This standard supersedes PPS 20.08, Issue 15.
- Vertical lines in the left hand margin indicate technical changes over the previous issue.
- This PPS is effective as of the distribution date.
- Validation of issue status is the responsibility of the user.

Approved By: (Bruce Campbell) May 9, 2017
Materials Technology

(Stephen Pitt) May 10, 2017
Quality

Prepared By: (Michael Wright) May 5, 2017
Production Process Standards

Issue 16 - Summary of Changes (over the previous issue)

The following summaries are not detailed and are intended only to assist in alerting PPS users to changes which may affect them; refer to the applicable section(s) of this PPS for detailed procedure and requirements.

- Revised instructions regarding hardness testing methodology to specify performing hardness testing according to internationally recognized standards (e.g., ASTM E384-10e2) appropriate to the type of hardness testing equipment used, except that at Bombardier Toronto (de Havilland) it is also acceptable to perform hardness testing according to a suitable de Havilland Lab Procedure (DHLP).
- Clarified all AMS references to remove the space between AMS and the specification number (e.g., replaced reference to AMS 4902 with reference to AMS4902). Note: these clarifications are not considered technical changes and are not marked with change bars.
- Added hardness requirements for AMS6415 material to Table 8 (Hardness Values for Low Alloy Steels).
- Added hardness requirements for AMS5517 material to Table 9 (Hardness Values for Corrosion Resistant Steels).
- Clarified all instances in Table 11 where a Rockwell hardness requirement was specified in terms of a minimum B scale value and also an equivalent minimum E scale value. Note: these clarifications are not considered technical changes and are not marked with change bars.
- Revised Rockwell hardness requirements for 7075 T76 clad sheet and plate with thickness 0.033” – 0.062” to specify an acceptable Rockwell hardness of B-75 – B-91 (i.e., removed reference to an E scale lower limit).
- Revised Rockwell hardness requirements for 7075 T76 clad sheet and plate with thickness of 0.063” and over to specify only an acceptable Rockwell hardness of B-74 – B-87 (i.e., removed reference to an E scale lower limit).
- Revised Rockwell Hardness requirements for 7075 T76 all bare, all thicknesses, to specify only an acceptable Rockwell hardness of B-82 – B-91 (i.e., removed reference to an E scale lower limit).

Table of Contents

Sections **Page**

Figures

Tables

Table of Contents

Tables **Page**

1 Scope

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for hardness testing of metals for the verification of response to heat treatment.

1.1.1 This PPS complements the engineering drawings that specify its use as an authorized instruction. The procedure specified in this PPS must be followed to ensure compliance with all applicable specifications. In general, if this PPS conflicts with the engineering drawing, follow the engineering drawing. The requirements specified in this PPS are necessary to fulfil the engineering design and reliability objectives.

1.1.2 Refer to PPS 13.26 for the subcontractor provisions applicable to this PPS.

1.1.3 Procedure or requirements specified in a Bombardier BAPS, MPS, LES or P. Spec. **do not** supersede the procedure or requirements specified in this PPS.

2 Hazardous Materials

2.1 Before receipt at Bombardier Toronto (de Havilland), all materials must be approved and assigned Material Safety Data Sheet (MSDS) numbers by the Bombardier Toronto (de Havilland) Environment, Health and Safety Department. Refer to the manufacturer's MSDS for specific safety data on any of the materials specified in this PPS. If the MSDS is not available, contact the Bombardier Toronto (de Havilland) Environment, Health and Safety Department.

3 References

3.1 General

3.1.1 Unless a specific issue is indicated, the issue of the reference documents specified in this section in effect at the time of manufacture shall form a part of this specification to the extent indicated herein.

3.2 Bombardier Toronto (de Havilland) Specifications

3.2.1 PPS 13.26 - General Subcontractor Provisions.

3.2.2 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.2.3 PPS 20.07 - Electrical Conductivity Testing of Aluminum Alloys.

3.2.4 PPS 30.01 - Heat Treatment of Aluminum and Aluminum Alloys.

3.2.5 PPS 30.04 - Heat Treatment of Carbon and Low Alloy Steels.

3.2.6 PPS 30.05 - Steel Case Hardening (Gas Nitriding).

3.2.7 PPS 30.06 - Heat Treatment of Precipitation Hardenable (PH) Stainless Steels.

3.2.8 PPS 30.07 - Heat Treatment of Beryllium Copper Alloys.

3.2.9 PPS 30.08 - Heat Treatment of Martensitic Stainless Steels.

3.2.10 PPS 30.11 - Steel Case Hardening (Carburizing).

3.2.11 PPS 30.13 - Heat Treatment of Nickel and Nickel Alloys.

3.2.12 PPS 30.16 - Steel Case Hardening (Liquid Nitriding).

3.2.13 PPS 30.17 - Steel Case Hardening (Ion Nitriding).

3.3 Bombardier Aerospace Engineering Requirement Documents

3.3.1 BAERD GEN-018 - Engineering Requirements for Laboratories.

3.4 International Standards

3.4.1 ASTM E384-10e2 - Standard Test Method for Knoop and Vickers Hardness of Materials.

4 Materials and Equipment

4.1 Materials

4.1.1 No materials are specified herein.

4.2 Equipment

4.2.1 Hardness testing equipment as applicable: Rockwell standard and superficial, Brinell, Wilson, Knoop, Vickers.

4.3 Facilities

4.3.1 This PPS has been categorized as a “Controlled Special Process” according to PPS 13.39 and as such only facilities specifically approved according to PPS 13.39 are authorized to perform hardness testing of metals according to this PPS.

4.3.2 Bombardier subcontractors must direct requests for approval to Bombardier Aerospace Supplier Quality Management. Bombardier Aerospace facilities must direct requests for approval to the appropriate internal Quality Manager.

4.3.3 Facility approval shall be based on a facility report, a facility survey and completion of a qualification test program, if required. The facility report must detail the materials and equipment to be used, the process sequence to be followed and the laboratory facilities used to show compliance with the requirements of this PPS. Any deviation from the procedure or requirements of this PPS must be detailed in the facility report. Based

upon the facility report, Bombardier Toronto (de Havilland) Materials Technology may identify additional qualification and/or process control test requirements. During the facility survey, the facility requesting qualification must be prepared to demonstrate their capability. Once approved, no changes to subcontractor facilities may be made without prior written approval from Bombardier Aerospace Supplier Quality Management.

4.3.3.1 Unless otherwise specified by Bombardier Aerospace Supplier Quality Management, approval of subcontractor facilities to perform hardness testing of metals according to this PPS does not require completion of a test program or submission of test samples.

5 Procedure

5.1 General

5.1.1 Unless otherwise specified herein, perform hardness testing according to internationally recognized standards appropriate for the type of equipment being used (e.g., ASTM E384-10e2 for Knoop and Vickers hardness testing equipment).

5.1.1.1 Alternatively, at Bombardier Toronto (de Havilland) it is also acceptable to perform hardness testing according to a suitable de Havilland Lab Procedure (DHLP).

5.1.2 Hardness testing is performed to determine if the hardness of a material meets the requirements of an engineering drawing or specification value, to confirm tensile strength or to confirm that the material has responded to processing by determining that the hardness corresponds with the hardness of a known standard.

5.1.3 Hardness testing is also used to check the temper or condition of metals. A properly performed hardness test differentiates between the standard tempers of an alloy.

5.1.4 Some materials exhibit a relatively good correlation between hardness numbers and tensile strengths, but most materials exhibit a scatter band of hardness values for a given set of conditions (see Table 1).

5.1.5 Electrical conductivity testing according to PPS 20.07 is used along with hardness testing to confirm the temper or condition of aluminum and aluminum alloys.

5.1.6 The alloy, heat treat condition or temper, size, thickness and surface finish of the part will determine the type of hardness testing machine, penetrator and load to use.

5.1.7 Refer to Table 2 for a general description of Rockwell and Brinell hardness testing machines and scales (penetrator and load combinations).

5.1.7.1 Use the lightest possible load when hardness testing carburized or nitrided surfaces. Select a load and penetrator combination applicable to a material thickness approximately equal to the depth of surface hardening.

5.1.7.2 Hardness test shot peened wrought aluminum alloy surfaces using Rockwell B or E scales only.

5.1.7.3 Brinell hardness testing is the preferred method for forgings and castings and on parts where the Brinell impression can be tolerated and is suitable.

5.1.7.4 If the impression left by the Brinell penetrator is not acceptable, use the standard Rockwell hardness testing method.

5.1.7.5 Use the superficial Rockwell hardness testing method (N and T scales) on case hardened steel parts and parts which are too thin for the standard Rockwell penetrator scales.

5.1.8 For material inaccessible by standard hardness testers, use a suitable calibrated portable hardness tester.

5.1.9 Refer to Table 18 or Table 20 for the relationship between ultimate tensile strength, Brinell hardness values and Rockwell hardness values for carbon and low alloy steel.

5.1.10 In this PPS, the hardness number is prefixed by the scale used (e.g., A-80, 30T-72, etc.).

5.1.11 Give careful consideration to the load or scale selection to avoid damaging the material. Ensure that the load selected will not be so great that an anvil effect is obtained from the ball or diamond penetrator (i.e., bulging of the underside of the material).

5.2 Condition of Surfaces to be Hardness Tested

5.2.1 Surfaces to be hardness tested must be clean, flat, smooth and free from scale or corrosion. This applies to both upper and lower surfaces of parts being tested on a Rockwell hardness tester.

5.2.2 A finish ground surface is sufficient for a 150 kgf load on a Rockwell diamond indenter or a 100 kgf load on a ball indenter. As loads become lighter, surface requirements become more rigorous (e.g. for a 15 kgf load, a polished or lapped surface is usually required).

5.2.3 If the hardness test is performed on a curved surface with a diameter of 1" or less, add a correction factor to the observed Rockwell hardness number according to Table 3.

5.2.4 Except as noted in paragraph 5.2.5, it is preferable to prepare a small flat surface on a curved part for hardness testing rather than apply a correction factor provided that it does not result in a visual, dimensional or functional defect which cannot be tolerated or in removal of a protective coating which cannot be restored. Refer questionable cases to Liaison Engineering.

5.2.5 Unless otherwise authorized, do not alter the following surfaces when preparing them for hardness testing:

- Shot peened surfaces.
- Hard chrome plated surfaces.
- Hard anodized surfaces.
- Surfaces of parts heat treated over 200 ksi.
- Carburized and nitrided surfaces.
- Ceramic coated surfaces.
- Dry film lubricant coated surfaces.
- Clad aluminum surfaces.
- Titanium surfaces.

5.3 Set-Up and Use of Hardness Testing Equipment

5.3.1 General

5.3.1.1 The anvil or supporting surface directly below the penetrator must be clean, smooth, steady and perpendicular (within ±2°) to the axis of the penetrator.

5.3.1.2 Do not strike, scratch or indent the surface of the anvil with the penetrator. Do not use any scratched, dented or nicked anvil until the surface has been reworked and restored to its original condition.

5.3.1.3 The top of the elevator screw and the underside of the anvil must be free from dirt, grease and any other foreign material which could cause inaccurate readings.

5.3.1.4 Firmly support the test piece to prevent movement while under load. Cylindrical parts are best supported using V-anvils. Any overhang of parts beyond anvil edges must be supported or counterbalanced to maintain true levels. Oddly shaped parts may be wedged or blocked to maintain a level surface provided that there is no unsupported area directly under the penetrator and the wedging does not cause or allow movement of the part under load.

5.3.1.5 Penetrators must be free from dust, dirt, grease and scale. Replace chipped diamond penetrators and flattened ball penetrators.

5.3.1.6 Perform hardness testing away from a change in section thickness and away from part edges. For standard Rockwell diamond and ball penetrators, allow a 1/8" space between indentations. For superficial Rockwell diamond or ball penetrators, allow a 1/16" space between indentations. For Brinell penetrators, allow a 3/8" space between indentations. Disregard readings from any indentations spaced closer than specified above.

5.3.1.7 Check hardness testing machines for accuracy, at least once per shift, by taking hardness readings on standard hardness test blocks. When performing this check, five impressions should be made on the hardness test block closest in range to the part hardness to be measured. Discard the first 2 readings and record the last 3 readings.

5.3.2 Rockwell Hardness Testers

5.3.2.1 Set-up Rockwell hardness testers as follows:

Step 1. If it is necessary to change the anvil or penetrator, lower the elevating screw and place a finger over the penetrator to protect it from contacting the anvil surface.

Step 2. Determine the minimum acceptable hardness value for the material being tested from Table 8 to Table 17.

Step 3. Check Table 4 or Table 5 to determine if the part has sufficient thickness for accurate hardness testing. If the part thickness is greater than the specified minimum thickness, continue to Step 4. If the part thickness is less than the specified minimum thickness, try the next lower scale (next scale column to the right).

Step 4. Use the penetrator and load specified in Table 2 for the selected scale.

Step 5. Select an anvil to meet the following criteria (see Figure 1).

- The part must be firmly seated with no unbalanced overhang.
- Minimize potential surface irregularities by selecting an anvil with the smallest surface area capable of obtaining accurate readings.

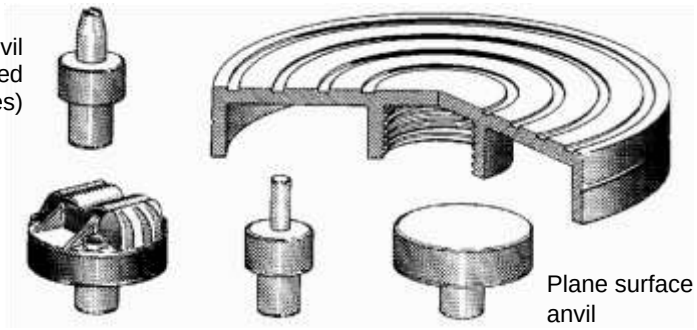

Figure 1. Typical Rockwell Hardness Testing Anvils

Step 6. Ensure that the surface to be tested is level and perpendicular (within ±2°) to the direction of load application.

Step 7. Position the part such that two complete test cycles can be performed. One cycle is used to seat all components of the test set-up and the second is used to take the hardness readings.

Step 8. Ensure that the entire part is lifted and balanced by the elevating screw. For unusually long or large parts which must be supported independently from the elevating screw, ensure that the part is level and held firmly after the application of the minor load, as the elevating screw will be slightly raised with application of the minor load.

Step 9. If application of the major load results in any movement of the part, disregard the test and repeat the positioning and testing of the part. A movement of only 0.001" can result in an error of over 10 Rockwell points.

5.3.2.2 Use manual Wilson hardness testers as follows:

Step 1. Apply the minor load by slowly rotating the elevator screw nut until the part is in contact with the penetrator and the large pointer and small set pointer are approximately vertical (±5 divisions).

Step 2. Set the dial by turning the dial face or, on some models, by turning the knurled wheel at the base of the elevator screw until the set mark on the dial is directly behind the large pointer.

Step 3. Ensure that the proper weights have been placed on the weight platform.

Step 4. Trip the release lever and allow it to rotate freely until it ceases to move. Do not force it by hand.

Step 5. Remove the major load by returning the release lever to the forward position. On motorized testers, a light tap on the depresser bar at the base of the screw will release the major load and the tester will cycle automatically. Do not release the minor load.

Step 6. Read the hardness number on the dial directly behind the pointer. A chart on the front of the tester indicates the correct scale colour.

5.3.2.3 Use semi-automatic Wilson series 500 hardness testers as follows:

Step 1. Set the minor load by turning the minor load changing nut located at the bottom of the plunger sleeve to align with either “S” (3 kg) for superficial testing or “R” (10 kg) for regular testing.

Step 2. Select the major load by turning the load selection dial on the right side of the tester to the correct position.

Step 3. Slowly raise the elevator screw by turning the handwheel clockwise until the LED indicator bar enters the SET box at the right end of the display. At this point, the minor load has been set and the instrument automatically applies the major load.

Step 4. Read the hardness number from the digital display.

5.3.2.4 Use fully automatic Rockwell hardness testers as follows:

Step 1. Select the proper minor and major loads for the scale being used.

Step 2. Raise the setscrew slowly until the part is nearly in contact with the penetrator, but not touching.

Step 3. Press the button to apply the minor and major loads.

Step 4. Read the hardness number from the proper scale on the dial or digital display.

5.3.3 **Brinell Hardness Testers**

Step 1. Position the part under the ball penetrator such that there is no tendency for any overhang to move under load. Long parts may be hand supported, tested on auxiliary supports or counter-balanced with weights. Solidly support the underside of the part being tested. An air gap under the part directly below the penetrator is not acceptable.

Step 2. Apply the full load gradually and without impact for a minimum of 15 seconds when testing steel alloys and for a minimum of 30 seconds when testing softer alloys. Do not apply an additional or repeat load into the same impression.

Step 3. Take two measurements of the impression diameter at right angles to each other. Determine the average of these measurements. Use a Brinell microscope to measure the impression diameters to the nearest 0.03 mm. Measurements are made by superimposing the scale graduated in millimetres over the impression.

Step 4. If the difference between the average diameter and either individual diameter exceeds 0.03 mm, re-test the part.

Step 5. Use the average diameter to determine the Brinell Hardness Number according to Table 7.

6 Requirements

6.1 Except as noted in paragraph 6.1.1, do not base acceptance or rejection of parts solely on hardness values. If necessary, run additional metallurgical, mechanical or chemical tests to establish or confirm a reason for rejection. Hardness values are adequate for segregating non-hardened (non-processed) material from material which has been hardened in the same alloy form.

6.1.1 If parts are controlled by hardness specified on the engineering drawing, accept or reject the parts according to the engineering drawing. Refer questionable parts to the Bombardier Toronto (de Havilland) Materials Laboratory (or an alternative Materials Laboratory accredited according to BAERD GEN-018) for confirmation of acceptance or

rejection.

6.2 Refer to the following PPS's for the frequency of hardness testing, acceptable hardness values and additional requirements for hardness testing various materials.

- Heat treated aluminum and aluminum alloys - PPS 30.01
- Heat treated carbon and low alloy steels - PPS 30.04
- Heat treated corrosion resistant steels - PPS 30.06 or PPS 30.08
- Case hardened steels - PPS 30.05, PPS 30.11, PPS 30.16 or PPS 30.17
- Heat treated copper alloys - PPS 30.07
- Heat treated nickel alloys - PPS 30.13

6.3 If the engineering drawing or heat treat PPS does not specify a hardness value, use the values given in Table 8 through Table 17.

6.4 If a hardness value specified on an engineering drawing or in a heat treat PPS differs from the value specified in the tables in this PPS, the engineering drawing or heat treat PPS shall govern.

6.5 Check hardness testing machines for accuracy, at least once per shift, by taking hardness readings on standard blocks of known hardness. Also, check machine accuracy whenever the scale or anvil has been changed.

7 Safety Precautions

7.1 **The safety precautions specified herein are specific to Bombardier Toronto (de Havilland) to meet Canadian Federal and Provincial government environmental, health and safety regulations. It is recommended that other facilities consider these safety precautions; however, suppliers, subcontractors and partners are responsible for ensuring that their own environmental, health and safety precautions satisfy the appropriate local government regulations.**

7.2 **Observe general shop safety precautions when performing the procedure specified herein.**

8 Personnel Requirements

8.1 This PPS has been categorized as a "Controlled Special Process" by PPS 13.39. Refer to PPS 13.39 for personnel requirements.

Table 1. Hardness/Tensile Strength Correlation

Hardness/Tensile Strength Correlation	Notes	Material
Good	For materials with a **good** hardness/tensile strength correlation hardness values may be used for heat treat acceptance.	Carbon and low alloy steels
		Precipitation hardened corrosion resistant steel
Fair	For materials with a **fair** hardness/tensile strength correlation hardness values may be used for heat treat acceptance if accompanied with other control criteria such as conductivity, tensile strength, etc. Hardness values alone may be used to determine the effectiveness of heat treat operations, cold working or that the temper is correct.	Aluminum alloy rivets
		Aluminum alloy wrought products and forgings
		Corrosion resistant steels and nickel alloys (Note 1)
Poor	For materials with a **poor** hardness/tensile strength correlation hardness values shall not be used as a basis for acceptance of any hardened condition unless backed with a tensile test. Values are adequate for segregating non-hardened (non-processed) material from material which has not hardened in the same alloy form.	Aluminum alloy castings
		Aluminum alloy, non heat treatable
		Copper alloys
		Magnesium alloys (Note 2)
		Titanium alloys

Note 1. 300 series corrosion resistant steels have a poor hardness/tensile strength correlation. Magnesium alloys AZ31B, AZ91C, AZ92A and HK31A have a fair hardness/tensile strength correlation.

Note 2. Magnesium alloys AZ31B, AZ91C, AZ92A and HK31A have a fair hardness/tensile strength correlation.

Table 2. Hardness Scales

Machine Type	Scale	Load (kgf)	Penetrator Type
Brinell	---	3,000	10 mm tungsten carbide ball
		1,000	
		500	
Rockwell Standard	A	60	Brale (diamond)
	B	100	1/16" steel ball
	C	150	Brale (diamond)
	D	100	Brale (diamond)
	E	100	1/8" steel ball
	F	60	1/16" steel ball
	G	150	1/16" steel ball
	H	60	1/8" steel ball
	K	150	1/8" steel ball
Rockwell Superficial	15N	15	N Brale (diamond)
	30N	30	N Brale (diamond)
	45N	45	N Brale (diamond)
	15T	15	1/16" steel ball
	30T	30	1/16" steel ball
	45T	45	1/16" steel ball

Table 3. Correction of Hardness Values for the Effect of Diameter

Scales	Hardness Reading	Part Diameter							
		1/8"	1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	1"
15T,30T & 45T	20	13.0	9.0	6.0	4.5	3.5	3.0	---	2.0
	30	11.5	7.5	5.0	4.0	3.5	2.5	---	2.0
	40	10.0	6.5	4.5	3.5	3.0	2.5	---	2.0
	50	8.5	5.5	4.0	3.0	2.5	2.0	---	1.5
	60	6.5	4.5	3.0	2.5	2.0	1.5	---	1.5
	70	5.0	3.5	2.5	2.0	1.5	1.0	---	1.0
	80	3.0	2.0	1.5	1.5	1.0	1.0	---	0.5
	90	1.5	1.0	1.0	0.5	0.5	0.5	---	0.5
15N, 30N & 45N	20	6.0	3.0	2.0	1.5	---	1.5	---	1.5
	25	5.5	3.0	2.0	1.5	---	1.5	---	1.0
	30	5.5	3.0	2.0	1.5	---	1.0	---	1.0
	35	5.0	2.5	2.0	1.5	---	1.0	---	1.0
	40	4.5	2.5	1.5	1.5	---	1.0	---	1.0
	45	4.0	2.0	1.5	1.0	---	1.0	---	1.0
	50	3.5	2.0	1.5	1.0	---	1.0	---	0.5
	55	3.5	2.0	1.5	1.0	---	0.5	---	0.5
	60	3.0	1.5	1.0	1.0	---	0.5	---	0.5
	65	2.5	1.5	1.0	0.5	---	0.5	---	0.5
	70	2.0	1.0	1.0	0.5	---	0.5	---	0.5
	75	1.5	1.0	1.0	0.5	---	0.5	---	---
	80	1.0	0.5	0.5	0.5	---	---	---	---
	85	0.5	0.5	0.5	0.5	---	---	---	---
	90	---	---	---	---	---	---	---	---

Note 1. The values shown are to be added to the hardness measured on the round surface.

Table 3. Correction of Hardness Values for the Effect of Diameter

Scales	Hardness Reading	Part Diameter							
		1/8"	1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	1"
A, C & D	20	---	6.0	4.5	3.5	2.5	2.0	1.5	1.5
	25	---	5.5	4.0	3.0	2.5	2.0	1.5	1.0
	30	---	5.0	3.5	2.5	2.0	1.5	1.5	1.0
	35	---	4.0	3.0	2.0	1.5	1.5	1.0	1.0
	40	---	3.5	2.5	2.0	1.5	1.0	1.0	1.0
	45	---	3.0	2.0	1.5	1.0	1.0	1.0	0.5
	50	---	2.5	1.5	1.5	1.0	1.0	0.5	0.5
	55	---	2.0	1.0	1.0	1.0	0.5	0.5	0.5
	60	---	1.5	1.0	1.0	0.5	0.5	0.5	0.5
	65	---	1.5	1.0	1.0	0.5	0.5	0.5	0.5
	70	---	1.0	1.0	0.5	0.5	0.5	0.5	0.5
	75	---	1.0	0.5	0.5	0.5	0.5	0.5	---
	80	---	0.5	0.5	0.5	0.5	0.5	---	---
	85	---	0.5	0.5	0.5	---	---	---	---
	90	---	0.5	---	---	---	---	---	---
B, E, F, G, H & K	0	---	12.5	8.5	6.5	5.5	4.5	3.5	3.0
	10	---	12.0	8.0	5.0	5.0	4.0	3.5	3.0
	20	---	11.0	7.5	5.5	4.5	4.0	3.5	3.0
	30	---	10.0	6.5	5.0	4.5	3.5	3.0	2.5
	40	---	9.0	6.0	4.5	4.0	3.0	2.5	2.0
	50	---	8.0	5.5	4.0	3.5	3.0	2.5	2.0
	60	---	7.0	5.0	3.5	3.0	2.5	2.0	2.0
	70	---	6.0	4.0	3.0	2.5	2.0	2.0	1.5
	80	---	5.0	3.5	2.5	2.0	1.5	1.5	1.5
	90	---	4.0	3.0	2.0	1.5	1.5	1.5	1.0
	100	---	3.5	2.5	1.5	1.5	1.0	1.0	0.5

Note 1. The values shown are to be added to the hardness measured on the round surface.

Table 4. Minimum Part Thickness for Standard Rockwell Scales

A Scale	B Scale	C Scale	F Scale	Minimum Thickness
- - -	- - -	- - -	- - -	0.014"
86	- - -	- - -	- - -	0.016"
84	- - -	- - -	- - -	0.018"
82	- - -	- - -	- - -	0.020"
79	- - -	69	- - -	0.022"
76	94	67	98	0.024"
71	87	65	91	0.026"
67	80	62	85	0.028"
60	71	57	77	0.030"
- - -	62	52	69	0.032"
- - -	52	45	- - -	0.034"
- - -	40	37	- - -	0.036"
- - -	28	28	- - -	0.038"
- - -	- - -	20	- - -	0.040"

Note 1. For a given hardness, material of any greater thickness than that corresponding to that hardness can be tested on the indicated scale.

Table 5. Minimum Part Thickness for Superficial Rockwell Scales

15N Scale	30N Scale	45N Scale	15T Scale	30T Scale	45T Scale	Minimum Thickness
92	- - -	- - -	- - -	- - -	- - -	0.006"
90	- - -	- - -	- - -	- - -	- - -	0.008"
88	- - -	- - -	91	- - -	- - -	0.010"
83	82	77	86	- - -	- - -	0.012"
76	78.5	74	81	80	- - -	0.014"
68	74	72	75	72	71	0.016"
- - -	66	68	68	64	62	0.018"
- - -	57	63	- - -	55	53	0.020"
- - -	47	58	- - -	45	43	0.022"
- - -	- - -	51	- - -	34	31	0.024"
- - -	- - -	37	- - -	- - -	18	0.026"
- - -	- - -	20	- - -	- - -	4	0.028"

Note 1. For a given hardness, material of any greater thickness than that corresponding to that hardness can be tested on the indicated scale.

Table 6. Minimum Part Thickness for Brinell Scales

Brinell Hardness Number	Load	Thickness
30	500 kg	0.196"
40	500 kg	0.157"
50	500 kg	0.125"
60	500 kg	0.080"
70	500 kg	0.072"
80	1,000 kg	0.137"
100	1,000 kg	0.125"
120	1,000 kg	0.093"
140	1,000 kg	0.072"
160	1,000 kg	0.068"
180	3,000 kg	0.238"
200	3,000 kg	0.190"
300	3,000 kg	0.125"
400	3,000 kg	0.100"
500	3,000 kg	0.072"
600	3,000 kg	0.062"

Table 7. Brinell Hardness Numbers

Impression Diameter	Brinell Hardness Number		
	500 kg load	1000 kg load	3000 kg load
2.00 mm	---	---	945
2.05 mm	---	---	899
2.10 mm	---	---	856
2.15 mm	---	---	817
2.20 mm	---	---	780
2.25 mm	---	---	745
2.30 mm	---	---	712
2.35 mm	---	---	682
2.40 mm	---	---	653
2.45 mm	---	---	627
2.50 mm	---	---	601
2.55 mm	---	---	578
2.60 mm	---	185	555
2.65 mm	---	178	534
2.70 mm	---	171	514
2.75 mm	82.6	165	495
2.80 mm	79.6	159	477
2.85 mm	76.8	154	461
2.90 mm	74.1	148	444
2.95 mm	71.5	143	429
3.00 mm	69.1	138	415

Table 7. Brinell Hardness Numbers

Impression Diameter	Brinell Hardness Number		
	500 kg load	1000 kg load	3000 kg load
3.05 mm	66.8	134	401
3.10 mm	64.6	129	388
3.15 mm	62.5	125	375
3.20 mm	60.5	121	363
3.25 mm	58.6	117	352
3.30 mm	56.8	114	341
3.35 mm	55.1	110	331
3.40 mm	53.4	107	321
3.45 mm	51.8	104	311
3.50 mm	50.3	101	302
3.55 mm	48.9	97.7	293
3.60 mm	47.5	94.9	285
3.65 mm	46.1	92.3	277
3.70 mm	44.9	89.7	269
3.75 mm	43.6	87.2	262
3.80	42.4	84.9	255
3.85 mm	41.3	82.6	248
3.90 mm	40.2	80.4	241
3.95 mm	39.1	78.3	235
4.00 mm	38.1	---	229
4.05 mm	37.1	---	223
4.10 mm	36.2	---	217

Table 7. Brinell Hardness Numbers

Impression Diameter	Brinell Hardness Number		
	500 kg load	1000 kg load	3000 kg load
4.15 mm	35.3	---	212
4.20 mm	34.4	---	207
4.25 mm	33.6	---	201
4.30 mm	32.8	---	197
4.35 mm	32	---	192
4.40 mm	31.2	---	187
4.45 mm	30.5	---	183
4.50 mm	29.8	---	179
4.55 mm	29.1	---	174
4.60 mm	28.4	---	170
4.65 mm	27.8	---	167
4.70 mm	27.1	---	163
4.75 mm	26.5	---	159
4.80 mm	25.9	---	156
4.85 mm	25.4	---	152
4.90 mm	24.8	---	149
4.95 mm	24.3	---	146
5.00 mm	23.8	---	143
5.05 mm	23.3	---	140

Table 8. Hardness Values for Low Alloy Steels

Material	Temper	Surface Condition	Thickness	Brinell Hardness	Rockwell Hardness
ASTM A108 (SAE 1018, 1020)	Annealed	All	All	---	B-98 max.
ASTM A36 AISI (1020-1030)	---	All	All	---	B-68 - B-83
ASTM A682 (SAE 1095)	Annealed	Cold finished strip	up to 0.188"	165 max.	B-93 - B-85
			over 0.188"	165 max.	B-91 - B-85
ASTM A686	Drill rod W_1, W_2, W_3	All	up to 0.125"	341 max.	C-37 max.
			0.126" - 0.250"	275 max.	C-28 max.
			0.251" - 0.500"	241 max.	C-23 max.
			0.501" and over	207 max.	B-96 max.
MIL-S-18729 (SAE 4130) & MIL-S-18728 (SAE 8630) plate, sheet & strip	Annealed condition A	All	All	171 max.	B-87 max.
MIL-T-6736 (SAE 4130) tubing	Annealed condition A	All	All	198 max.	B-93 max.
MIL-S-18729 (SAE 4130) & MIL-S-18728 (SAE 8630) plate, sheet & strip MIL-T-6736 (SAE 4130) tubing	Normalized by mill, condition N	All	up to 0.188"	198 min.	B-93 min.
			over 0.188"	188 min.	B-91 min.
	Normalized by user, condition "normalized"	All	up to 0.188"	188 min.	B-91 min.
			over 0.188"	156 min.	B-83 min.

Table 8. Hardness Values for Low Alloy Steels

Material	Temper	Surface Condition	Thickness	Brinell Hardness	Rockwell Hardness
MIL-S-6758 (SAE 4130) & MIL-S-6050 (SAE 8630) bar, rod & forging stock	Annealed, condition C	Black, as forged or rolled. Pickled or blast cleaned or rough turned.	All	229 max.	C-21 max.
		Cold finished	All	241 max.	C-23 max.
	Normalized by mill or user condition D	All	up to 0.188"	188 min.	B-91 min.
			over 0.188"	156 min.	B-83 min.
AMS6294 (SAE 4620)	Bars, annealed condition	Cold finished	up to 0.500"	271 max.	---
			over 0.500"	241 max.	---
		Hot finished	over 0.500"	229 max.	---
MIL-S-6098 (SAE 8735), MIL-S-5626 (SAE 4140) & MIL-S-6049 (SAE 8740) bar, rod & forging stock	Annealed, condition C	Black, as forged or rolled. Pickled or blast cleaned or rough turned.	All	229 max.	C-21 max.
		Cold finished	All	241 max.	C-23 max.
	Normalized & tempered, condition E. Normalized without tempering, condition D	Black, as forged or rolled. Pickled or blast cleaned or rough turned.	up to 0.188"	198 - 229	B-93 - C-21
			over 0.188"	186 - 229	B-91 - C-21
		Cold finished	up to 0.188"	198 - 241	B-93 - C-23
			over 0.188"	186 - 241	B91 - C-23
		Turned, ground & polished	up to 0.188"	198 min.	B-93 min.
			over 0.188"	186 min.	B-91 min.

Table 8. Hardness Values for Low Alloy Steels

Material	Temper	Surface Condition	Thickness	Brinell Hardness	Rockwell Hardness
MIL-S-5000 (SAE 4340) bar & reforging stock	Annealed, condition C	Black, as forged or rolled. Pickled or blast cleaned or rough turned.	All	235 max.	C-22 max.
		Cold finished	All	265 max.	C-27 max.
	Normalized & tempered, condition E	Black, as forged or rolled. Pickled or blast cleaned or rough turned.	up to 0.188"	198 - 235	B-93 - C-22
			over 0.188"	186 - 235	B-91 - C-22
		Cold finished	up to 0.188"	198 - 265	B-93 - C-27
			over 0.188"	186 - 265	B-91 - C-27
		Turned, ground & polished	up to 0.188"	198 min.	B-93 min.
			over 0.188"	186 min.	B-91 min.
AMS6415	Bars	Cold finished	up to 0.500"	---	C-27 max.
			over 0.500"	255 max.	---
		Hot finished & annealed	over 0.500"	235 max.	---
	Forgings	Normalized and tempered	All	269 max.	---

Table 9. Hardness Values for Corrosion Resistant Steels

Material	Form	Temper	Size	Rockwell Hardness
MIL-S-5059 compositions 301, 302 & 304	Sheet, strip & plate	Annealed	All	B-92 max.
		1/4 hard	All	C-26 - C-31
		1/2 hard	All	C-32 - C-36
		3/4 hard	All	C-38 - C-40
		Full hard	All	C-41 min.
ASTM A582 composition 303 & MIL-S-7720 compositions 302 & 316	Bar & forgings	A	up to 0.250"	C-27 max.
			over 0.250"	C-23 max.
		B	up to 0.751"	C-27 min.
			0.751 - 1.000"	C-23 min.
			1.001 - 1.250"	B-97 min.
			1.251 - 1.500"	B-93 min.
			1.501 - 3.000"	B-88 min.
			over 3.000"	B-85 min.
AMS5637 composition 304	Bar	---	All	C-27 min.
AMS5515 composition 302	Sheet & plate	Annealed	All	C-26 max.
AMS5518 composition 301	Sheet & strip	1/2 hard	All	C-32 min.
ASTM A167 & ASTM A240 composition 304	Sheet, strip & plate	Annealed	All	B-92 max.
MIL-T-6845 composition 304	Tube	1/8 hard	All	C-22 min.
MIL-S-4043 composition 304	Sheet	Annealed	All	B-94 max.
MIL-S-5059 composition 316	Sheet, strip & plate	Annealed	All	B-96 max.
		1/4 hard	All	C-26 - C-35

Table 9. Hardness Values for Corrosion Resistant Steels

Material	Form	Temper	Size	Rockwell Hardness
MIL-T-8808 composition 321 Types I & II	Tube	Annealed	All	B-95 max.
AMS5510 composition 321 & AMS5512 composition 347	Sheet, strip & plate	Annealed	All	B-96 max.
AMS5645 & QQ-S-763 composition 321 & AMS5646 composition 347	Bar & forging	Annealed	All	C-25 max.
AMS5362 composition 347	Investment castings	Annealed	All	B-88 max.
AMS5613 composition 410 & AMS5610 composition 416	Bar & forging	Annealed	All	B-95 max.
		100 ksi	All	B-91 min.
		115 ksi	All	B-97 min.
		180 - 200 ksi	All	C-38 - C-44
AMS5621 composition 420	Bar & forging	Annealed	All	B-95 max.
MIL-S-18732 composition 431	Bar, forging & tubing	Annealed	All	C-30 max.
		125 - 145 ksi	All	C-27 - C-32
		195 - 220 ksi	All	C-43 - C-46
AMS5630 composition 440-C	Bar & forging	Annealed	All	C-30 max.
		Hardened	All	C-55 - C-62
MIL-T-8506	Tube	Annealed	All	15T-77.5 max.
AMS5350 composition 410	Investment casting	95 - 115 ksi	All	B-94 - B-100
		125 - 160 ksi	All	C-27 - C-32
		180 - 215 ksi	All	C-40 - C-43
AMS5561 alloy 21-6-9	Tube	Cold drawn	All	C-30 - C-35
AMS5656 alloy 21-6-9	Bar	Cold rolled	All	B-90 - B-100

Table 9. **Hardness Values for Corrosion Resistant Steels**

Material	Form	Temper	Size	Rockwell Hardness
AMS5629, AMS5864 & PH 13-8 Mo	Bar, forging & plate	ST	All	C-39 max.
		H1000	All	C-43 - C-48
		H1025	All	C-41 - C-46
		H1050	All	C-40 - C-46
		H1100	All	C-34 - C-42
		H1150	All	C-30 - C-38
AMS5659 & 15-5 PH	Bar & forging	Annealed	All	C-38 max.
		H900	All	C-40 - C-47
		H925	All	C-38 - C-45
		H1000	All	C-36 - C-41
		H1025	All	C-34 - C-42
		H1075	All	C-31 - C-38
		H1100	All	C-30 - C-37
		H1150	All	C-28 - C-37
AMS5862 & 15-5 PH	Sheet, strip & plate	Solution heat treated	All	C-38 max.
		H900	All	C-40 - C-47
		H925	All	C-38 - C-45
		H1025	All	C-35 - C-42
		H1075	All	C-33 - C-39
		H1100	All	C-32 - C-38
		H1150	All	C-28 - C-37
AMS5517	Sheet & strip	Cold rolled	All	C-25 min.

Table 9. Hardness Values for Corrosion Resistant Steels

Material	Form	Temper	Size	Rockwell Hardness
AMS5528, MIL-S-25043 & 17-7 PH	Sheet, strip & plate	RH950	All	C-42 - C-49
		RH1000	All	C-42 - C-46
		RH1050	All	C-40 - C-44
		TH950	All	C-44 - C-48
		TH1000	All	C-42 - C-46
		TH1050	All	C-38 - C-44
		TH1100	All	C-34 - C-38
	Bar	RH950	All	C-41 - C-45
		RH1000	All	C-39 - C-43
		RH1050	All	C-38 - C-42
		TH950	All	C-42 - C-46
		TH1000	All	C-40 - C-44
		TH1050	All	C-38 - C-42
	Wire	CH900	up to 0.375"	C-46 min.
AMS5520, AMS5657 & PH 15-7 Mo	Sheet	TH1050	up to 0.187"	C-40 - C-44
	Bar & forging	TH1050	All	C-40 - C-47
AMS5621 composition 420	Bar & forging	230 - 260 ksi	All	C-47 - C-52

Table 10. Hardness Values for Nickel and Nickel Alloys

Specification & Alloy	Form	Temper	Thickness	Rockwell Hardness
AMS5540 Inconel 600	Sheet, strip & plate	Annealed	All	B-88 max.
		Hard		C-24 min.
		Spring		C-30 min.
AMS5665 Inconel 600	Bar	Annealed	All	B-85 max.
		Cold drawn		B-90 min.
AMS5666 Inconel 625	Bar & forging	Annealed	All	C-30 max.
AMS5596 Inconel 718	All	Annealed	All	C-25 max.
		Hard		C-36 min.
AMS5599 Inconel 625	Sheet	Annealed	All	C-30 max.
MIL-N-7786 Inconel X-750	Sheet, strip & plate	Annealed	All	B-75 - B-95
		H1350	All	C-32 - C-40
		H1400	All	C-32 - C-40
AMS5667 Inconel X-750	Bar	Annealed	up to 1.000"	C-25 max.
			over 1.000"	C-30 max.
		H1300	All	C-30 - C-38
		H1350	All	C-32 - C-40
		H1400	All	C-32 - C-40
AMS5732	Bar, wire & forging	A286	All	C-24.5 - C-35
AMS5532 Alloy N-155	Sheet & strip	Annealed	up to 0.049"	30T-72 - 30N-50
			0.050" and over	B-87 - C-31
AMS5536 Hastelloy X	Sheet & plate	Annealed	All	B-80 - C-20

Table 11. Hardness Values for Wrought Aluminum Alloys (except Rivets)

Alloy	Temper (Note 2)	Form	Thickness	Rockwell Hardness	Minimum Brinell Hardness (Note 3)
1100	O	All	All	H-50 max.	---
	H14	All	All	H-77 - H-84	---
2004	T42	Sheet	All	E-92 min.	---
	T62	Sheet	All	E-92 min.	---
2014 (Note 1)	O	All	All	H-95 max.	---
	T3, T4	All	over 0.032"	B-65 min. or E-95 min.	100
			0.032" and under	15T-82 min.	100
	T6	All	over 0.032"	B-78 min. or E-102 min.	125
			0.032" and under	15T-86	125
2017	T4	Bare sheet	over 0.024"	B-61 min.	---
2024 (Note 1)	O	All	All	H-95 max.	---
	T86	All	All	B-83 min.	---
	T3	All bare	All	B-69 min.	---
	T4	All bare	0.032" and under	15T-82 min.	---
			0.033" and over	B-63 min. or E-94 min.	---
	T36 or T361	Clad sheet	up to 0.063"	E-85 min.	---
			0.064" and over	E-84 min.	---

Note 1. If values for clad products are not specified, remove the cladding and use the values for bare products.

Note 2. For heat treated aluminum alloys having temper designations of 2, 3 or 4 digits not specified in this table, use the hardness value for the basic temper.

Note 3. Based on a 500 kg load and 10 mm ball.

Table 11. Hardness Values for Wrought Aluminum Alloys (except Rivets)

Alloy	Temper (Note 2)	Form	Thickness	Rockwell Hardness	Minimum Brinell Hardness (Note 3)
2024 (Note 1)	T3, T4	Clad sheet	0.032" and under	15T-79 min.	---
			0.033" - 0.062"	B-57 min or E-91 min.	---
			0.063" and over	B-60 min. or E-93 min.	---
	T6	Clad sheet	0.032" and under	15T-82 min.	---
			0.033" - 0.062"	B-60 min. or E-93 min.	---
			0.063" and over	B-62 min. or E-94 min.	---
	T8	Clad sheet	0.032" and under	15T-82 min.	---
			0.033" and over	B-65 min. or E-97 min.	---
	T6, T8	Extrusions	All	B-74 min.	---
	T6	All except clad sheet & extrusions	0.032" and under	15T-84 min.	118
			0.033" and over	B-72 min. or E-98 min.	118
	T8	All except clad sheet & extrusions	0.032" and under	15T-85 min.	120
			0.033" and over	B-74 min. or E-99 min.	120

Note 1. If values for clad products are not specified, remove the cladding and use the values for bare products.

Note 2. For heat treated aluminum alloys having temper designations of 2, 3 or 4 digits not specified in this table, use the hardness value for the basic temper.

Note 3. Based on a 500 kg load and 10 mm ball.

Table 11. Hardness Values for Wrought Aluminum Alloys (except Rivets)

Alloy	Temper (Note 2)	Form	Thickness	Rockwell Hardness	Minimum Brinell Hardness (Note 3)
2219	O	All	All	H-95 max.	---
	T3	All	All	B-60 min. or E-92 min.	98
	T4	All	0.032" and under	15T-78 min.	100
			0.033" and over	B-58 min. or E-90 min.	100
	T6	All	0.032" and under	15T-80 min.	110
			0.033" and over	B-62 min. or E-93 min.	110
	T8	All	0.032" and under	15T-83 min.	115
			0.033" and over	B-71 min. or E-98 min.	115
3003	O	All	All	H-65 max.	---
	H14	All	All	15T-55 - 15T-63	---
	H16	All	All	H-89 - H-95	---
	H18	All	All	H-94 - H-100	---
5052	O	All	All	H-95 max.	---
	H32	All	All	H-92 min.	---
	H34	All	All	H-96 min.	---
5456	O, H112	All	All	E-69 - E-79	---
	H343	Sheet & plate	All	E-84 - E-92	---
6013	T4	Sheet & plate	All	B-40 min.	---
	T6	Sheet & plate	All	B-61 min. or E-96 min.	---

Note 1. If values for clad products are not specified, remove the cladding and use the values for bare products.

Note 2. For heat treated aluminum alloys having temper designations of 2, 3 or 4 digits not specified in this table, use the hardness value for the basic temper.

Note 3. Based on a 500 kg load and 10 mm ball.

Table 11. Hardness Values for Wrought Aluminum Alloys (except Rivets)

Alloy	Temper (Note 2)	Form	Thickness	Rockwell Hardness	Minimum Brinell Hardness (Note 3)
6053	O	All	All	H-65 max.	---
	T4	All	All	H-73 min.	---
	T5	All	All	E-44 min.	---
	T6	All	All	H-92 min.	---
6061	O	All	All	H-75 max.	---
	T4	All	0.032" and under	15T-64 min.	50
			0.033" and over	E-60 min.	50
	T6	All	0.032" and under	15T-78 min.	80
			0.033" and over	B-42 min. or E-85 min.	80
6063	T5	Extrusions	All	E-44 min.	---
	T6	Extrusions	All	E-70 min.	---
6351	T5	Extrusions	All	E-85 min.	---
	T5X	Extrusions	All	E-70 min.	---
	T6	Extrusions	All	B-56 min.	---
7010	T4	All	All	E-105 min.	---
	T6	All	All	E-106 min.	---
	T73,T73XX, T73510 or T73511	All	All	E-100 min.	---
	T736	All	All	E-100 min.	---
	T76	All	All	B-84 min.	---

Note 1. If values for clad products are not specified, remove the cladding and use the values for bare products.

Note 2. For heat treated aluminum alloys having temper designations of 2, 3 or 4 digits not specified in this table, use the hardness value for the basic temper.

Note 3. Based on a 500 kg load and 10 mm ball.

Table 11. Hardness Values for Wrought Aluminum Alloys (except Rivets)

Alloy	Temper (Note 2)	Form	Thickness	Rockwell Hardness	Minimum Brinell Hardness (Note 3)
7050	O	All	All	B-70 max.	---
	T74	Plate	0.250" - 3.000"	B-83 - B-90	---
			3.001" - 4.000"	B-82 - B-88	---
			4.001" - 6.000"	B-81 - B-88	---
		All except plate	All	B-85 - B-92	---
	T76	Plate	All	B-86 - B-94	---
		Extrusions	All	B-86.5 - B97.5	---
7075	O	All	All	E-70 max.	---
	W	All	All	E-75 max.	---
	O1	All	All	B-70 max.	---
	T6	Clad sheet	0.032" and under	15T-86 min.	---
			0.033" - 0.062"	B-76 min. or E-102 min.	---
			0.063" and over	B-75 min. or E-101 min.	---
		All bare, except plate	All	B-84 min. or E-106 min.	142
	T73,T73XX, T73510 or T73511	Clad sheet	up to 0.063"	B-77 - B-94	---
			0.064" and over	B-72 - B-85	---
		Bare sheet	up to 0.250"	B-77 - B-89	---
		All bare, except sheet	All	B-78 min. or E-102 min.	---

Note 1. If values for clad products are not specified, remove the cladding and use the values for bare products.

Note 2. For heat treated aluminum alloys having temper designations of 2, 3 or 4 digits not specified in this table, use the hardness value for the basic temper.

Note 3. Based on a 500 kg load and 10 mm ball.

Table 11. Hardness Values for Wrought Aluminum Alloys (except Rivets)

Alloy	Temper (Note 2)	Form	Thickness	Rockwell Hardness	Minimum Brinell Hardness (Note 3)
7075	T76	Clad sheet & plate	0.032" and under	15T-84 min.	---
			0.033" - 0.062"	B-75 - B-91	---
			0.063" and over	B-74 - B-87	---
		All bare	All	B-82 - B-91	136
	T651,T6510 or T6511	Bare & clad plate	0.250" - 2.000"	B-85 min.	---
			2.001" - 2.500"	B-82 min.	---
			2.501" - 3.500"	B-80 min.	---
			3.501" - 4.000"	B-78 min.	---
			4.001" - 5.000"	B-76 min.	---
			5.001" - 6.000"	B-74 min.	---
7079	T6	All	All	B-81 min.	---
7150	T7751 or T77511	All	All	B-85 min.	---
7178	O	Clad sheet	All	H-92 max.	---
		All bare	All	H-95 max.	---
	W	Clad sheet	All	E-90 max.	---
	T6	Clad sheet	0.032" - 0.091"	B-78 min. or E-103 min.	---
		All bare	All	B-87 min.	---

Note 1. If values for clad products are not specified, remove the cladding and use the values for bare products.

Note 2. For heat treated aluminum alloys having temper designations of 2, 3 or 4 digits not specified in this table, use the hardness value for the basic temper.

Note 3. Based on a 500 kg load and 10 mm ball.

Table 11. Hardness Values for Wrought Aluminum Alloys (except Rivets)

Alloy	Temper (Note 2)	Form	Thickness	Rockwell Hardness	Minimum Brinell Hardness (Note 3)
7475	O	All	All	H-95 max.	---
	T73,T73XX, T73510 or T73511	Bare & clad plate	0.250" - 2.000"	B-80 - B-90	---
			2.001" - 3.000"	B-78 min.	---
			3.001" - 4.000"	B-77 min.	---
	T76	Bare sheet & plate	All	E-105 min.	---
		Clad sheet	All	B-80 - B-94	---

Note 1. If values for clad products are not specified, remove the cladding and use the values for bare products.

Note 2. For heat treated aluminum alloys having temper designations of 2, 3 or 4 digits not specified in this table, use the hardness value for the basic temper.

Note 3. Based on a 500 kg load and 10 mm ball.

Table 12. Minimum Rockwell Hardness Values for Aluminum Alloy Rivets

Alloy & Temper	Symbol	Rivet Diameter				
		3/32"	1/8"	5/32"	3/16"	1/4"
2017-T4	D	F-73	F-75	F-78	F-82	F-83
2117-T4	AD	F-41	F-53	F-58	F-63	F-63
2024-T4	DD	F-89	F-89	F-91	F-91	F-91
7050-T73	KE	B-78	B-79	B-80	B-81	B-82
1100-F	A	H-50	H-50	H-50	H-50	H-50
5056-H32	B	F-64	---	---	---	---

Table 13. Hardness Values for Aluminum Alloy Castings

Alloy	Type Of Casting	Temper	Minimum Brinell Hardness	Minimum Rockwell Hardness
13X	Die	As cast	52	E-59
201.0	NAI 1362	T7	110	B-65
S195.0	Investment or Sand Casting	T6	65	E-74
242.0	Investment or Sand Casting	T571	85	E-88
	Permanent mould	T61	110	E-96
295.0	Investment or Sand Casting	T4	50	E-58
		T62	65	E-74
B295.0	Permanent mould	T6	80	E-85
A332.0	Permanent mould	T65	125	E-78
355.0	Investment or Sand Casting	T51	55	E-60
		T6	65	E-74
	Permanent mould	T6	80	E-82
356.0	Investment or Sand Casting	T4	45	H-86
		T51	50	E-58
		T6	65	E-74
	Permanent mould	T6/T61	65	E-74
A356.0	Investment or Sand Casting	T6	70	E-78
	Permanent mould	T6/T61	80	E-85
A357 Class 11	Permanent mould	T6	79	E-84
413.0	Die	As cast	62	E-70
B443.0	Investment or Sand Casting	As cast	40	H-76
520.0	Investment or Sand Casting	T4	66	E-77
AMS4260C	Investment casting	T6	70	B-27

Table 14. Hardness Values for Aluminum Alloy Forgings

Alloy	Temper	Minimum Brinell Hardness	Minimum Rockwell Hardness
2014	T4 (Notes 1 & 2)	100	B-65
	T6 (Note 2)	125	B-78
2017	T4 (Notes 1 & 2)	100	B-63
2018	T6 (Note 2)	100	B-63
2025	T6 (Note 2)	100	B-63
2219	T6 (Note 2)	110	B-69
	T852	96	B-58
4032	T6 (Note 2)	115	B-71
6061	T6 (Note 2)	80	E-85
6151	T6 (Note 2)	90	E-89
7050	01	112 max.	B-70 max.
	T74	137	B-82
	T76	147	B-86
7075	01	112 max.	B-70 max.
	T6 (Note 2)	142	B-84
	T73, T73XX, T73510 or T73511	129	B-78
	T76	136	B-82
7079	T6 (Note 2)	142	B-86
	T611	135	B-83

Note 1. For heat treated aluminum alloys having temper designations with two, three or four digits and are not shown in this table, use the hardness value for the basic temper with the same first digit (e.g., for 7075-T652, use the hardness value for 7075-T6).

Note 2. After 96 hours aging at room temperature.

Table 15. Hardness Values for Titanium Alloys

Material	Temper	Surface Condition	Thickness	Rockwell Hardness
AMS4902 MIL-T-9046 CP-3 40 ksi yield	Sheet & plate	Annealed	All	B-88 max.
AMS4900 MIL-T-9046 CP-2 55 ksi yield	Sheet & plate	Annealed	All	B-82 - B-90
AMS4901 MIL-T-9046 CP-1 70 ksi yield	Sheet & plate	Annealed	All	B-92 - B-100
AMS4942 40 ksi yield	Tubing	Annealed	All	B-88 max.
MIL-T-9047 CP-70 70 ksi yield	Bar & forging	Annealed	All	B-102 max.
Ti-6Al-4V MIL-T-9046 AB-1	Sheet & plate	Annealed	All	C-28 - C-36
		Solution heat treated & aged	up to 0.750"	C-45 min.
			0.751" - 1.000"	C-43 min.
			1.001" - 2.500"	C-42 min.
Ti-6Al-4V MIL-T-9047	Bar & forging	Annealed	All	C-31 - C-39
		Solution heat treated & aged	up to 0.500"	C-45 min.
			0.501" - 1.000"	C-44 min.
			1.001" - 1.500"	C-42 min.
			1.501" - 2.000"	C-41 min.
			2.001" - 3.000"	C-40 min.
Ti-6Al-6V-2Sn MIL-T-9046 AB-3	Sheet & plate	Annealed	All	C-30 - C-38
		Solution heat treated & aged	up to 1.500"	C-47 min.
			1.501" - 2.500"	C-45 min.

Table 15. Hardness Values for Titanium Alloys

Material	Temper	Surface Condition	Thickness	Rockwell Hardness
Ti-6Al-6V-2Sn MIL-T-9047	Bar & forging	Annealed	up to 3.999"	C-33 - C-41
		Solution heat treated & aged	up to 3.999"	C-37 - C-41
			4.000" and over	C-37 - C-39
Ti-6Al-6V-2Sn MIL-T-81556 AB-3	Extrusion	Annealed	All	C-30 - C-38
Ti-8Mn AB-6	Sheet & plate	Annealed	All	C-22 - C-30

Table 16. Hardness Values for Copper, Brass and Bronze

Specification & Alloy	Form	Temper	Thickness	Rockwell Hardness
AMS4631 aluminum bronze	All	Stress relieved	All	B-80 min.
AMS4640 aluminum bronze	Rounds	Heat treated	up to 2.000"	B-96 - C-24
		Heat treated	2.001" - 5.000"	B-93 - C-23
	Flats	Heat treated	up to 3.00"	B-93 - C-23
		Heat treated	over 3.00"	B-92 - C-23
	Forgings	Heat treated	All	B-96 - C-24
ASTM B152 C11000 & C10200	Sheet, plate & forging	H00 (1/8 hard)	up to 0.019"	30T-49 max.
			0.020" and over	F-54 - F-82
ASTM B152 C10100 & C11000	Sheet, plate & rolled bar	OS025 deep drawing anneal	0.020" and over	F-30 - F-75

Note 1. Based on a 3,000 kgf load and 10 mm carbide ball.

Table 16. Hardness Values for Copper, Brass and Bronze

Specification & Alloy	Form	Temper	Thickness	Rockwell Hardness
QQ-B-613 brass composition 11	All	Annealed soft drawing	over 0.030"	F-54 - F-67
		Annealed drawing	over 0.030"	F-61 - F-81
		Annealed light	over 0.030"	F-67 - F-87
		1/4H	over 0.030"	B-40 - B-65
		1/2H	over 0.030"	B-57 - B-77
		Hard	over 0.030"	B-76 - B-86
		Extra hard	over 0.030"	B-83 - B-91
		Spring	over 0.030"	B-87 - B-93
QQ-B-613 brass composition 260	All	Annealed	over 0.020"	F-50 min.
QQ-B-626 brass composition 11	Round rod	1/2H	over 0.030"	B-60 - B-90
	Bar & rod, except round	1/2H	0.030" - 1.000"	B-50 - B-80
		1/2H	over 1.000"	B-40 - B-70
	Flat wire & strip	Annealed soft drawing	over 0.030"	F-54 - F-67
		Annealed drawing	over 0.030"	F-61 - F-81
		Annealed light	over 0.030"	F-67 - F-87
		1/4H	over 0.030"	B-40 - B-65
		1/2H	over 0.030"	B-57 - B-77
		Hard	over 0.030"	B-76 - B-86
		Extra hard	over 0.030"	B-83 - B-91
		Spring	over 0.030"	B-87 - B-93
QQ-B-626 brass composition 260	Wire & strip	Annealed	over 0.020"	F-50 - F-62
QQ-B-637 naval brass compositions 462, 464, 482, 485	All	1/2H	All	B-60 min.

Note 1. Based on a 3,000 kgf load and 10 mm carbide ball.

Table 16. Hardness Values for Copper, Brass and Bronze

Specification & Alloy	Form	Temper	Thickness	Rockwell Hardness
QQ-B-679 aluminum bronze	Bar	Cold worked & strain annealed	All	B-80 (core) min.
QQ-C-390 aluminum bronze composition 953	Castings (including cast bar)	Heat treated	All	Brinell 160 (Note 1) or B-86 min.
QQ-C-390 aluminum bronze composition 955	Castings (including cast bar)	Heat treated	All	Brinell 200 (Note 1) or B-93 min.
QQ-C-390 high leaded tin bronze composition 932	Castings (including cast bar)	As cast	All	B-42 min.
QQ-C-390 silicon bronze composition 874	Castings (including cast bar)	As cast	All	B-52 min.
QQ-C-450 composition 613	All	Soft	All	B-75 min.
QQ-C-465 aluminum bronze composition 630	High strength rounds	Annealed	All	Brinell 187 (Note 1) or B-93 min.
QQ-C-465 aluminum bronze composition 642	Wire, rod, strip, bar, shapes, forgings	---	up to 0.500"	B-83 min.
			0.501" - 1.000"	B-80 min.
			1.001" - 3.000"	B-78 min.
QQ-C-502 copper	All	Soft	All	F-62 max.
		Hard	up to 0.125"	F-85 - F-97
			0.126" and over	F-80 - F-95
QQ-C-576 copper	Sheet, plate & bar	Light cold rolled	up to 0.019"	30T-49 max.
			0.020" and over	F-40 - F-82
		1/2 hard	up to 0.019"	30T-43 - 30T-57
			0.020" and over	F-77 - F-89
		Annealed	All	F-65 max.

Note 1. Based on a 3,000 kgf load and 10 mm carbide ball.

Table 16. Hardness Values for Copper, Brass and Bronze

Specification & Alloy	Form	Temper	Thickness	Rockwell Hardness
QQ-B-750 phosphor bronze composition A	Sheet	Annealed	0.010" - 0.019"	30T-46 max.
			0.020" - 0.039"	B-45 max.
			over 0.039"	B-50 max.
		1/2H	0.010" - 0.019"	30T-52 - 30T-71
			0.020" - 0.039"	B-53 - B-78
			over 0.039"	B-60 - B-81
		Hard	0.010" - 0.019"	30T-69 - 30T-75
			0.020" - 0.039"	B-80 - B-88
			over 0.039"	B-82 - B-90
		Spring	0.010" - 0.019"	30T-75 - 30T-79
			0.020" - 0.039"	B-88 - B-94
			over 0.039"	B-90 - B-96
	Bar	Hard	All	B-65 - B-90

Note 1. Based on a 3,000 kgf load and 10 mm carbide ball.

Table 17. Hardness Values for Precipitation Hardened Beryllium Copper

Specification & Alloy	Form	Temper	Thickness	Rockwell Hardness
QQ-C-390 alloy 820	Casting	AT (condition B)	All	B-92 min.
QQ-C-390 alloy 825	Casting	AT (condition B)	All	C-38 min.
QQ-C-390 alloy 827	Casting	AT (condition B)	All	C-39 min.
QQ-C-390 alloy 829	Casting	AT (condition B)	All	C-39 min.
QQ-C-530 Alloy 172	Bar & rod	A	All	B-45 - B-85
		AT	0.025" and over	C-34 min.
		HT	0.250" - 0.375"	C-39 min.
			0.376" - 1.000"	C-38 min.
			1.001" and over	C-37 min.
QQ-C-533 alloy 170	Strip	AT	0.020" - 0.029"	30N-53 min.
			0.030" and over	C-33 min.
		1/4 HT	0.020" - 0.029"	30N-55 min.
			0.030" and over	C-35 min.
		1/2 HT	0.020" - 0.029"	30N-56 min.
			0.030" and over	C-37 min.
		HT	0.020" - 0.029"	30N-59 min.
			0.030" and over	C-39 min.
QQ-C-533 alloy 170 & 172	Strip	A (cold rolled & solution heat treated)	0.020" - 0.039"	30T-46 - 30T-67
			0.040" and over	B-45 - B-78
QQ-C-533 alloy 172	Strip	AT	0.020" - 0.029"	30N-56 min.
			0.030" and over	C-36 min.
		1/4 HT	0.020" - 0.029"	30N-58 min.
			0.030" and over	C-38 min.
		1/2 HT	0.020" - 0.029"	30N-59 min.
			0.030" and over	C-39 min.
		HT	0.020" - 0.029"	30N-60 min.
			0.030" and over	C-40 min.

Table 18. Rockwell Scale Conversion for Softer Metals

B	F	G	H	15T	30T	45T	E	K	A
100	---	82.5	---	93	82	72	---	---	---
99	---	81	---	92.5	81.5	71	---	---	---
98	---	79	---	---	81	70	---	---	---
97	---	77.5	---	92	80.5	69	---	---	59.5
96	---	76	---	---	80	68	---	---	59
95	---	74	---	91.5	79	67	---	---	58
94	---	72.5	---	---	78.5	66	---	---	57.5
93	---	71	---	91	78	65.5	---	---	57
92	---	69	---	90.5	77.5	64.5	---	100	56.5
91	---	67.5	---	---	77	63.5	---	99.5	56
90	---	66	---	90	76	62.5	---	98.5	55.5
89	---	64	---	89.5	75.5	61.5	---	98	55
88	---	62.5	---	---	75	60.5	---	97	54
87	---	61	---	89	74.5	59.5	---	96.5	53.5
86	---	59	---	88.5	74	58.5	---	95.5	53
85	---	57.5	---	---	73.5	58	---	94.5	52.5
84	---	56	---	88	73	57	---	94	52
83	---	54	---	87.5	72	56	---	93	51
82	---	52.5	---	---	71.5	55	---	92	50.5
81	---	51	---	87	71	54	---	91	50
80	---	49	---	86.5	70	53	---	90.5	49.5
79	---	47.5	---	---	69.5	52	---	89.5	49
78	---	46	---	86	69	51	---	88.5	48.5
77	---	44	---	85.5	68	50	---	88	48
76	---	42.5	---	---	67.5	49	---	87	47
75	99.5	41	---	85	67	48.5	---	86	46.5
74	99	39	---	---	66	47.5	---	85	46
73	98.5	37.5	---	84.5	65.5	46.5	---	84.5	45.5

Table 18. Rockwell Scale Conversion for Softer Metals

B	F	G	H	15T	30T	45T	E	K	A
72	98	36	---	84	65	45.5	---	83.5	45
71	97.5	34.5	---	---	64	44.5	100	82.5	44.5
70	97	32.5	---	83.5	63.5	43.5	99.5	81.5	44
69	96	31	---	83	62.5	42.5	99	81	43.5
68	95.5	29.5	---	---	62	41.5	98	80	43
67	95	28	---	82.5	61.5	40.5	97.5	79	42.5
66	94.5	26.5	---	82	60.5	39.5	97	78	42
65	94	25	---	---	60	38.5	96	77.5	---
64	93.5	23.5	---	81.5	59.5	37.5	95.5	76.5	41.5
63	93	22	---	81	58.5	36.5	95	75.5	41
62	92	20.5	---	---	58	35.5	94.5	74.5	40.5
61	91.5	19	---	80.5	57	34.5	93.5	74	40
60	91	17.5	---	---	56.5	33.5	93	73	39.5
59	90.5	16	---	80	56	32	92.5	72	39
58	90	14.5	---	79.5	55	31	92	71	38.5
57	89.5	13	---	---	54.5	30	91	70.5	38
56	89	11.5	---	79	54	29	90.5	69.5	---
55	88	10	---	78.5	53	28	90	68.5	37.5
54	87.5	8.5	---	---	52.5	27	89.5	68	37
53	87	7	---	78	51.5	26	89	67	36.5
52	86.5	5.5	---	77.5	51	25	88	66	36
51	86	4	---	---	50.5	24	87.5	65	35.5
50	85.5	2.5	---	77	49.5	23	87	64.5	35
49	85	---	---	76.5	49	22	86.5	63.5	---
48	84.5	---	---	---	48.5	20.5	85.5	62.5	34.5
47	84	---	---	76	47.5	19.5	85	61.5	34
46	83	---	---	75.5	47	18.5	84.5	61	33.5
45	82.5	---	---	---	46	17.5	84	60	33

Table 18. Rockwell Scale Conversion for Softer Metals

B	F	G	H	15T	30T	45T	E	K	A
44	82	---	---	75	45.5	16.5	83.5	59	32.5
43	81.5	---	---	74.5	45	15.5	82.5	58	32
42	81	---	---	---	44	14.5	82	57.5	31.5
41	80.5	---	---	74	43.5	13.5	81.5	56.5	31
40	79.5	---	---	73.5	43	12.5	81	55.5	---
39	79	---	---	---	42	11	80	54.5	30.5
38	78.5	---	---	73	41.5	10	79.5	54	30
37	78	---	---	72.5	40.5	9	79	53	29.5
36	77.5	---	100	---	40	8	78.5	52	29
35	77	---	99.5	72	39.5	7	78	51.5	28.5
34	76.5	---	99	71.5	38.5	6	77	50.5	28
33	75.5	---	---	---	38	5	76.5	49.5	---
32	75	---	98.5	71	37.5	4	76	48.5	27.5
31	74.5	---	98	---	36.5	3	75.5	48	27
30	74	---	---	70.5	36	2	75	47	26.5
29	73.5	---	97.5	70	35.5	1	74	46	26
28	73	---	97	---	34.5	---	73.5	45	25.5
27	72.5	---	96.5	69.5	34	---	73	44.5	25
26	72	---	---	69	33	---	72.5	43.5	24.5
25	71	---	96	---	32.5	---	72	42.5	---
24	70.5	---	95.5	68.5	32	---	71	41.5	24
23	70	---	---	68	31	---	70.5	41	23.5
22	69.5	---	95	---	30.5	---	70	40	23
21	69	---	94.5	67.5	29.5	---	69.5	39	22.5
20	68.5	---	---	---	29	---	68.5	38	22
19	68	---	94	67	28.5	---	68	37.5	21.5
18	67	---	93.5	66.5	27.5	---	67.5	36.5	---
17	66.5	---	93	---	27	---	67	35.5	21

Table 18. Rockwell Scale Conversion for Softer Metals

B	F	G	H	15T	30T	45T	E	K	A
16	66	---	---	66	26	---	66.5	35	20.5
15	65.5	---	92.5	65.5	25.5	---	65.5	34	20
14	65	---	92	---	25	---	65	33	---
13	64.5	---	---	65	24	---	64.5	32	---
12	64	---	91.5	64.5	23.5	---	64	31.5	---
11	63.5	---	91	---	23	---	63.5	30.5	---
10	63	---	90.5	64	22	---	62.5	29.5	---
9	62	---	---	---	21.5	---	62	29	---
8	61.5	---	90	63.5	20.5	---	61.5	28	---
7	61	---	89.5	63	20	---	61	27	---
6	60.5	---	---	---	19.5	---	60.5	26	---
5	60	---	89	62.5	18.5	---	60	25.5	---
4	59.5	---	88.5	62	18	---	59	24.5	---
3	59	---	88	---	17	---	58.5	23.5	---
2	58	---	---	61.5	16.5	---	58	23	---
1	57.5	---	87.5	61	16	---	57.5	22	---
0	57	---	87	---	15	---	57	21	---

Table 19. Conversion from Rockwell B (Carbon and Low Alloy Steels)

Rockwell		Rockwell Superficial			Brinell (Note 1)	Vickers (Note 2)	U.T.S. (Ksi)
B	A	15T	30T	45T			
100	61.5	93.1	83.1	72.9	240	240	115
99	60.9	92.8	82.5	71.9	234	234	112
98	60.2	92.5	81.8	70.9	228	228	108
97	59.5	92.1	81.1	69.9	222	222	104
96	58.9	91.8	80.4	68.9	216	216	101
95	58.3	91.5	79.8	67.9	210	210	99
94	57.6	91.2	79.1	66.9	205	205	97
93	57.0	90.8	78.4	65.9	200	200	95
92	56.4	90.5	77.8	64.8	195	195	92
91	55.8	90.2	77.1	63.8	190	190	91
90	55.2	89.9	76.4	62.8	185	185	89
89	54.6	89.5	75.8	61.8	180	180	87
88	54.0	89.2	75.1	60.8	176	176	86
87	53.4	88.9	74.4	59.8	172	172	85
86	52.8	88.6	73.8	58.8	169	169	84
85	52.3	88.2	73.1	57.8	165	165	82
84	51.7	87.9	72.4	56.8	162	162	81
83	51.1	87.6	71.8	55.8	159	159	80
82	50.6	87.3	71.1	54.8	156	156	78
81	50.0	86.9	70.4	53.8	153	153	74

Note 1. Brinell values are based on a 3,000 kgf load and 10 mm carbide ball.

Note 2. Vickers values are based on a 10 kg load.

Table 19. Conversion from Rockwell B (Carbon and Low Alloy Steels)

Rockwell		Rockwell Superficial			Brinell (Note 1)	Vickers (Note 2)	U.T.S. (Ksi)
B	A	15T	30T	45T			
80	49.5	86.6	69.7	52.8	150	150	71
79	48.9	86.3	69.1	51.8	147	147	69
78	48.4	86.0	68.4	50.8	144	144	68
77	47.9	85.6	67.7	49.8	141	141	67
76	47.3	85.3	67.1	48.8	139	139	66
75	46.8	85.0	66.4	47.8	137	137	65

Note 1. Brinell values are based on a 3,000 kgf load and 10 mm carbide ball.
Note 2. Vickers values are based on a 10 kg load.

Table 20. Conversion from Rockwell C (Carbon and Low Alloy Steels)

Rockwell			Rockwell Superficial			Knoop (500g)	Brinell (Note 1)	Vickers (Note 2)	U.T.S. (ksi)
C	A	D	15N	30N	45N				
68	85.6	76.9	93.2	84.4	75.4	920	---	940	---
67	85.0	76.1	92.9	83.6	74.2	895	---	900	---
66	84.5	75.4	92.5	82.8	73.3	870	---	865	---
65	83.9	74.5	92.2	81.9	72.0	846	739	832	---
64	83.4	73.8	91.8	81.1	71.0	822	722	800	---
63	82.8	73.0	91.4	80.1	69.9	799	705	772	---
62	82.3	72.2	91.1	79.3	68.8	776	688	746	---
61	81.8	71.5	90.7	78.4	67.7	754	670	720	---
60	81.2	70.7	90.2	77.5	66.6	732	654	697	---
59	80.7	69.9	89.8	76.6	65.5	710	634	674	---
58	80.1	69.2	89.3	75.7	64.3	690	615	653	---

Note 1. Brinell values are based on a 3,000 kgf load and 10 mm carbide ball.
Note 2. Vickers values are based on a 10 kg load.

Table 20. Conversion from Rockwell C (Carbon and Low Alloy Steels)

Rockwell			Rockwell Superficial			Knoop (500g)	Brinell (Note 1)	Vickers (Note 2)	U.T.S. (ksi)
C	A	D	15N	30N	45N				
57	79.6	68.5	88.9	74.8	63.2	670	595	633	---
56	79.0	67.7	88.3	73.9	62.0	650	577	613	---
55	78.5	66.9	87.9	73.0	60.9	630	560	595	301
54	78.0	66.1	87.4	72.0	59.8	612	543	577	292
53	77.4	65.4	86.9	71.2	58.6	594	525	560	283
52	76.8	64.6	86.4	70.2	57.4	576	512	544	273
51	76.3	63.8	85.9	69.5	56.1	558	496	528	264
50	75.9	63.1	85.5	68.5	55.0	542	481	513	255
49	75.2	62.1	85.0	67.6	53.8	526	469	498	246
48	74.7	61.4	84.5	66.7	52.5	510	455	484	237
47	74.1	60.8	83.9	65.8	51.4	495	443	471	229
46	73.6	60.0	83.5	64.8	50.3	480	432	458	222
45	73.1	59.2	83.0	64.0	49.0	466	421	446	215
44	72.5	58.5	82.5	63.1	47.8	452	409	434	208
43	72.0	57.7	82.0	62.2	46.7	438	400	423	201
42.8	---	---	---	---	---	---	---	---	200
42	71.5	56.9	81.5	61.3	45.5	426	390	412	194
41	70.9	56.2	80.9	60.4	44.3	414	381	402	188
40	70.4	55.4	80.4	59.5	43.1	402	371	392	181
39.8	---	---	---	---	---	---	---	---	180
39	69.9	54.6	79.9	58.6	41.9	391	362	382	176
38	69.4	53.8	79.4	57.7	40.8	380	353	372	170
37	68.9	53.1	78.8	56.8	39.6	370	344	363	165
36	68.4	52.3	78.3	55.9	38.4	360	336	354	160

Note 1. Brinell values are based on a 3,000 kgf load and 10 mm carbide ball.

Note 2. Vickers values are based on a 10 kg load.

Table 20. Conversion from Rockwell C (Carbon and Low Alloy Steels)

Rockwell			Rockwell Superficial			Knoop (500g)	Brinell (Note 1)	Vickers (Note 2)	U.T.S. (ksi)
C	A	D	15N	30N	45N				
35	67.9	51.5	77.7	55.0	37.2	351	327	345	155
34	67.4	50.8	77.2	54.2	36.1	342	319	336	150
33	66.8	50.0	76.6	53.3	34.9	334	311	327	147
32.6	---	---	---	---	---	---	---	---	145
32	66.3	49.2	76.1	52.1	33.7	326	301	318	142
31	65.8	48.4	75.6	51.3	32.5	318	294	310	139
30	65.3	47.7	75.0	50.4	31.3	311	286	302	136
29	64.6	47.0	74.5	49.5	30.1	304	279	294	132
28	64.3	46.1	73.9	48.6	28.9	297	271	286	129
27	63.8	45.2	73.3	47.7	27.8	290	264	279	126
26.7	---	---	---	---	---	---	---	---	125
26	63.3	44.6	72.8	46.8	26.7	284	258	272	123
25	62.8	43.8	72.2	45.9	25.5	278	253	266	120
24	62.4	44.1	71.6	45.0	24.3	272	247	260	118
23	62.0	42.1	71.0	44.0	23.1	266	243	254	115
22	61.5	41.6	70.5	43.2	22.0	261	237	248	112
21	61.0	40.9	69.9	42.3	20.7	256	231	243	110
20	60.5	40.1	69.4	41.5	19.6	251	226	238	107

Note 1. Brinell values are based on a 3,000 kgf load and 10 mm carbide ball.

Note 2. Vickers values are based on a 10 kg load.