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Designation: A 914/A 914M – 92 (Reapproved 1999)ε1

Standard Specification for Steel Bars Subject to Restricted End-Quench Hardenability Requirements[1]

This standard is issued under the fixed designation A 914/A 914M; 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.

ε[1] NOTE—Fig. 19 was editorially replaced with the correct information on Hardenability Band 8620 RH in February 2002.

1. Scope

1.1 This specification covers hot-worked alloy and carbon-boron steels designed to attain restricted depth of hardening in the end-quench test. These steel compositions are identified by the suffix letter "RH" added to the conventional grade number.

1.2 In general, steels with restricted hardenability (RH steels) will exhibit a hardness range not greater than 5 HRC at the initial position on the end-quench hardenability bar and not greater than 65 % of the hardness range for standard H-band steels (Specification A 304) in the inflection region. Generally the restricted hardenability band follows the middle of the corresponding standard H-band. An example of the RH band compared with the H band is given for Grade 4140 in Fig. 1.

1.3 This specification is expressed in both inch-pound units and SI units. However, the material will be supplied to inch-pound units unless the purchase order specifies the "M" specification designation.

2. Referenced Documents

2.1 *ASTM Standards:*

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold Finished, General Requirements for[2]

A 255 Test Methods for Determining Hardenability of Steel[2]

A 304 Specification for Steel Bars, Alloy, Subject to End-Quench Hardenability Requirements[2]

E 112 Test Method for Determining Average Grain Size[3]

E 527 Practice for Numbering Metals and Alloys (UNS)[4]

2.2 *SAE Standards:*[5]

J 406 Methods of Determining Hardenability of Steels

J 1268 Hardenability Bands for Carbon and Alloy H Steels

J 1868 Restricted Hardenability Bands for Selected Alloy Steels

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *hardenability*—the relative ability of a steel to harden under heat treatment becomes apparent in the degree to which the material hardens when quenched at different cooling rates.

3.1.1.1 *Discussion*— Hardenability is measured quantitatively, usually by noting the extent or depth of hardening of a standard size and shape test specimen in a standardized quench. In the end-quench test the depth of hardening is the distance along the specimen from the quenched end to a given hardness.

4. Ordering Information

4.1 Orders for material under this specification should include the following information, in proper sequence:

4.1.1 Quantity (weight),
4.1.2 Name of material (alloy or carbon-boron steel),
4.1.3 Cross-sectional shape,
4.1.4 Size,
4.1.5 Length,
4.1.6 Grade,
4.1.7 End-quenched hardenability (see Section 9),
4.1.8 Report of heat analysis, if desired (see Section 7),
4.1.9 Special straightness, if required,
4.1.10 ASTM designation and date of issue, and
4.1.11 End use or special requirements.

NOTE 1—A typical ordering description is as follows: 10 000 lb, alloy bars, round, 4.0-in. diameter by 10 ft, Grade 4140RH, heat analysis required, complete hardenability data required, ASTM AXXX, [AXXXM] dated _____ worm gear.

4.2 The purchaser shall specify the desired grade, including the suffix letters "RH", in accordance with Table 1.

4.3 Band limits are shown graphically and as tabulations in Figs. 2-23, inclusive. For specification purposes, one must use tabulated values of Rockwell hardness (HRC) as a function of distance from the quenched end of the hardenability bar, either

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.15 on Bars.

Current edition approved Dec. 15, 1992. Published February 1993.

[2] *Annual Book of ASTM Standards*, Vol 01.05.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

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

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in inch-pound units (sixteenths of an inch) or in SI units (millimetres). Values below 20 HRC are not specified because such values are not accurate.

4.3.1 Band limits shown graphically are so depicted for convenience in estimating the hardness values at various intermediate locations on the end quench test bar for quick comparisons of the various RH grades. The values of "Approximate Diameter of Rounds with Same As-Quenched Hardness" shown above each RH-band, were selected from ranges appearing in Fig. 7 of SAE J406. The RH-bands are presented graphically, with distances from the quenched end in both inch-pound units and also SI units.

4.4 For specification purposes, RH-band steels shall exhibit hardness within the minimum and maximum HRC range specified at the J1 (J1.5-mm) position and shall meet one additional minimum and one additional maximum value. In this specification, the two additional hardness values shall represent the approximate hardness for 50 % martensite for the minimum and maximum specified carbon content, respectively (except where hardenability is too high; then the two additional hardness control values shall be five HRC points below the maximum hardness value specified at the J1 (J1.5-mm) position).

4.4.1 In general, these points define the critical locations of the Jominy hardenability band for purposes of characterizing heat treatment response. The four specification points are circled in the tables of hardness versus Jominy distance and on the RH-bands. For all other Jominy positions, a tolerance of two points HRC is permitted for a maximum consecutive 3/16 -in. or 5-mm Jominy distance on the restricted hardenability band.

4.4.2 For example, referring to Fig. 9, a hardenability test bar of a steel meeting the requirements for 4140RH must exhibit a hardness at J1 not less than 54 HRC, nor more than 59 HRC. At J12, the test bar must exhibit hardness not less than 43 HRC, but the maximum hardness can be as high as 52 HRC (or even 54 HRC if the region of the test bar is chosen as the exception). At J20, the bar must exhibit hardness not greater than 47 HRC, but the minimum hardness can be as low as 37 HRC (or as low as 35 HRC if this region of the test bar is chosen as the exception).

4.4.3 A similar example, referring to Fig. 9, for 4140RH with distances from the quenched end in millimetres would limit hardness at J1.5 mm to not less than 54 HRC nor more than 59 HRC. At J20 mm, the test bar must exhibit hardness not less than 42 HRC. At J30 mm, the test bar must exhibit hardness not greater than 48 HRC.

5. Manufacture

5.1 *Melting Practice*—The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric furnace. The primary melting may incorporate separate degassing or ladle refining and may be followed by secondary melting using electroslag remelting or vacuum arc remelting. Where secondary melting is employed, the heat shall be defined as all the ingots remelted from a single primary heat.

5.2 *Slow Cooling*—Immediately after hot working, the bars shall be allowed to cool when necessary to a temperature below the critical range under suitable conditions, to prevent injury by too rapid cooling.

6. General Requirements

6.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 29/A 29M, unless otherwise provided for herein.

7. Chemical Requirements

7.1 The heat analysis shall conform to the requirements as to chemical composition prescribed in Table 1 for the grade specified by the purchaser.

8. Grain Size Requirements

8.1 The steel shall have an austenitic grain size of five to eight. The grain structure shall be considered satisfactory when a minimum of 70 % of the rated grains are within the specified size limits.

8.2 Hardenability values specified are based on fine-grain steels and are not applicable to coarse-grain steel.

9. End-Quench Hardenability Requirements

9.1 The end-quench hardenability shall conform to the requirements specified on the purchase order.

9.2 Hardenability values shall be specified in accordance with the applicable values in Figs. 2-23, inclusive, for the grade specified.

10. Test Specimens

10.1 *Number and Location*—The number and location of test specimens shall be in accordance with the manufacturer's standard practice and shall adequately represent the hardenability of each heat.

10.2 *Thermal Treatment*—All forged and rolled hardenability test specimens must be normalized prior to testing. Cast specimens need not be normalized.

11. Test Methods

11.1 *Grain Size*—Test Method E 112.

11.2 *End-quench Hardenability*—Test Methods A 255.

12. Certification and Reports of Testing

12.1 The hardenability shall be reported by listing hardness values at the following distances from the quenched end of the test specimen:

12.1.1 For inch-pound units (J distance in sixteenths of an inch): 1 through 16 sixteenths, then 18, 20, 22, 24, 28, and 32 sixteenths of an inch.

12.1.2 For SI units (J distance in millimetres): 1.5, 3, 5, 7, 9, 11, 13, 15, 20, 25, 30, 35, 40, 45, and 50 mm.

13. Keywords

13.1 bars; restricted hardenability

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TABLE 1 Chemical Requirements of Restricted Hardenability Steels

NOTE 1—Phosphorus and sulfur in open-hearth steel is 0.035 %, max, and 0.040 %, max respectively. Phosphorus and sulfur in electric-furnace steel is 0.025 %, max.

NOTE 2—Small quantities of certain elements are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: copper, 0.35 %; nickel, 0.25 %; chromium, 0.20 %; molybdenum, 0.06 %.

NOTE 3—Chemical ranges and limits shown in this table are subject to the permissible variation for product analysis shown in Specification A 29/A 29M.

Grade Designation	Chemical Composition, %					
	Carbon	Manganese	Silicon	Nickel	Chromium	Molybdenum
15B21RH[A]	0.17–0.22	0.80–1.10	0.15–0.35			
15B35RH[A]	0.33–0.38	0.80–1.10	0.15–0.35			
3310RH	0.08–0.13	0.40–0.60	0.15–0.35	3.25–3.75	1.40–1.75	
4027RH	0.25–0.30	0.70–0.90	0.15–0.35	. . .	. . .	0.20–0.30
4118RH	0.18–0.23	0.70–0.90	0.15–0.35	. . .	0.40–0.60	0.08–0.15
4120RH	0.18–0.23	0.90–1.20	0.15–0.35	. . .	0.40–0.60	0.13–0.20
4130RH	0.28–0.33	0.40–0.60	0.15–0.35	. . .	0.80–1.10	0.15–0.25
4140RH	0.38–0.43	0.75–1.00	0.15–0.35	. . .	0.80–1.10	0.15–0.25
4145RH	0.43–0.48	0.75–1.00	0.15–0.35	. . .	0.80–1.10	0.15–0.25
4161RH	0.56–0.64	0.75–1.00	0.15–0.35	. . .	0.70–0.90	0.25–0.35
4320RH	0.17–0.22	0.45–0.65	0.15–0.35	1.65–2.00	0.40–0.60	0.20–0.30
4620RH	0.17–0.22	0.45–0.65	0.15–0.35	1.65–2.00	. . .	0.20–0.30
4820RH	0.18–0.23	0.50–0.70	0.15–0.35	3.25–3.75	. . .	0.20–0.30
50B40RH[A]	0.38–0.43	0.75–1.00	0.15–0.35	. . .	0.40–0.60	
5130RH	0.28–0.33	0.70–0.90	0.15–0.35	. . .	0.80–1.10	. . .
5140RH	0.38–0.43	0.70–0.90	0.15–0.35	. . .	0.70–0.90	. . .
5160RH	0.56–0.64	0.75–1.00	0.15–0.35	. . .	0.70–0.90	. . .
8620RH	0.18–0.23	0.70–0.90	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8622RH	0.20–0.25	0.70–0.90	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8720RH	0.18–0.23	0.70–0.90	0.15–0.35	0.40–0.70	0.40–0.60	0.20–0.30
8822RH	0.20–0.25	0.75–1.00	0.15–0.35	0.40–0.70	0.40–0.60	0.30–0.40
9310RH	0.08–0.13	0.45–0.65	0.15–0.35	3.00–3.50	1.00–1.40	0.08–0.15

[A]These steels can be expected to have 0.0005 to 0.003 % boron.

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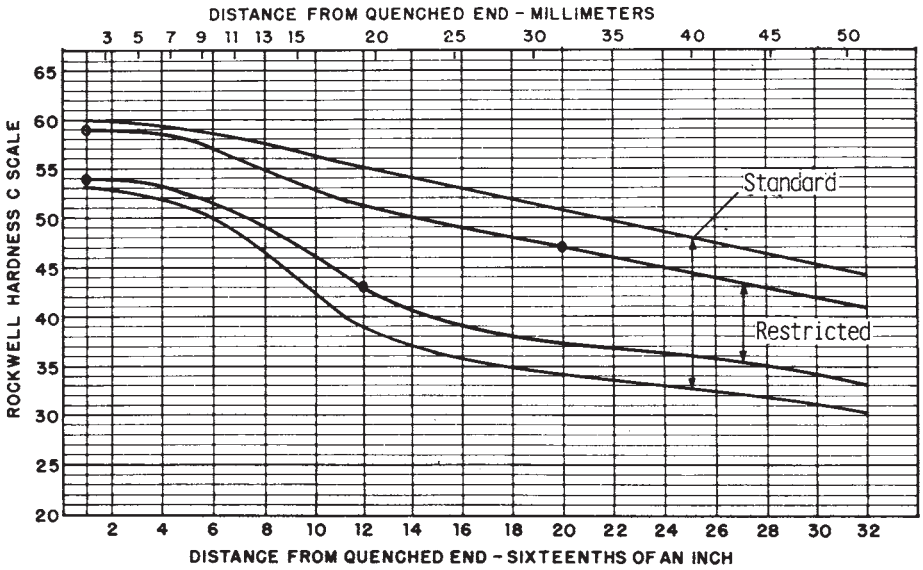
HARDENABILITY BAND

4140 H/RH

	%C	%Mn	%Si	%Ni	%Cr	%Mo	
H	0.37/0.44	0.65/1.10	0.15/0.35	--	0.75/1.20	0.15/0.25	
RH	0.38/0.43	0.75/1.00	0.15/0.35	--	0.80/1.10	0.15/0.25	



HARDENESS LIMITS FOR SPECIFICATION PURPOSES

"J" DISTANCE MILLIMETERS	MAX HRC		MIN HRC	
	4140 H	4140 RH	4140 RH	4140 H
1.5	60	(59)	(54)	53
3	60	59	54	52
5	60	59	59	52
7	59	59	53	51
9	59	58	52	50
11	58	56	50	48
13	57	55	49	46
15	57	54	47	43
20	55	51	(42)	38
25	53	49	39	35
30	51	(48)	38	33
35	49	46	37	32
40	48	44	36	32
45	46	43	35	31
50	45	41	33	30

HEAT TREATING TEMPERATURES

*NORMALIZE	870 °C
AUSTENITIZE	845 °C

*For forged or rolled specimens only

HARDENESS LIMITS FOR SPECIFICATION PURPOSES

"J" DISTANCE SIXTEENTHS OF AN INCH	MAX HRC		MIN HRC	
	4140 H	4140 RH	4140 RH	4140 H
1	60	(59)	(54)	53
2	60	59	54	53
3	60	59	54	52
4	59	59	53	51
5	59	58	52	51
6	58	57	51	50
7	58	56	50	48
8	57	55	49	47
9	57	54	48	44
10	56	53	46	42
11	56	52	44	40
12	55	52	(43)	39
13	55	51	42	38
14	54	50	41	37
15	54	50	40	36
16	53	49	39	35
18	52	48	38	34
20	51	(47)	37	33
22	49	46	37	33
24	48	45	36	32
26	47	44	35	32
28	46	43	35	31
30	46	42	34	31
32	44	41	33	30

HEAT TREATING TEMPERATURES

*NORMALIZE	1600 °F
AUSTENITIZE	1550 °F

*For forged or rolled specimens only

FIG. 1 Comparison of H-Band and RH-Band for 4140 Steel[A]

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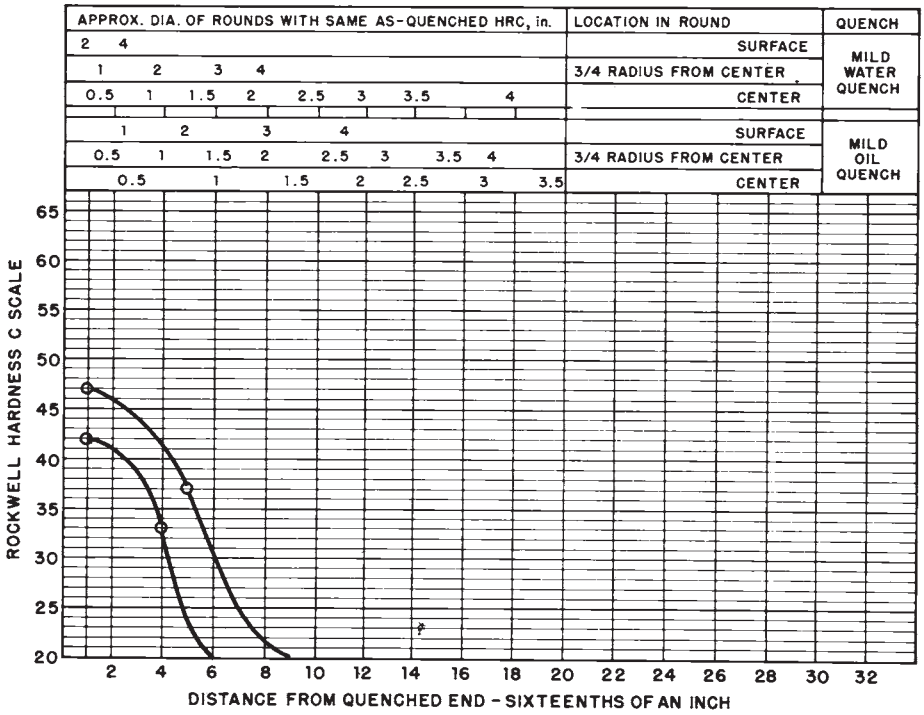
HARDENABILITY BAND 15B21 RH

%C	%Mn	%Si	%Ni	%Cr	%Mo	%B
0.17/0.22	0.80/1.10	0.15/0.35	--	--	--	*

* can be expected to contain 0.0005/0.003 percent boron.

HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE SIXTEENTHS OF AN INCH	HRC	
	MAX.	MIN.
1	(47)	(42)
2	46	41
3	44	39
4	42	(33)
5	(37)	24
6	30	20
7	24	--
8	22	--
9	20	--
10	--	--
11		
12		
13		
14		
15		
16		
18		
20		
22		
24		
26		
28		
30		
32		
HEAT TREATING TEMPERATURES		
*NORMALIZE	1700 °F	
AUSTENITIZE	1700 °F	
*For forged or rolled specimens only		



HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE MILLIMETERS	HRC	
	MAX.	MIN.
1.5	(47)	(42)
3	46	41
5	44	39
7	40	(31)
9	(34)	23
11	24	--
13	22	--
15	20	--
20	--	--
25		
30		
35		
40		
45		
50		
HEAT TREATING TEMPERATURES		
*NORMALIZE	925 °C	
AUSTENITIZE	925 °C	
*For forged or rolled specimens only		

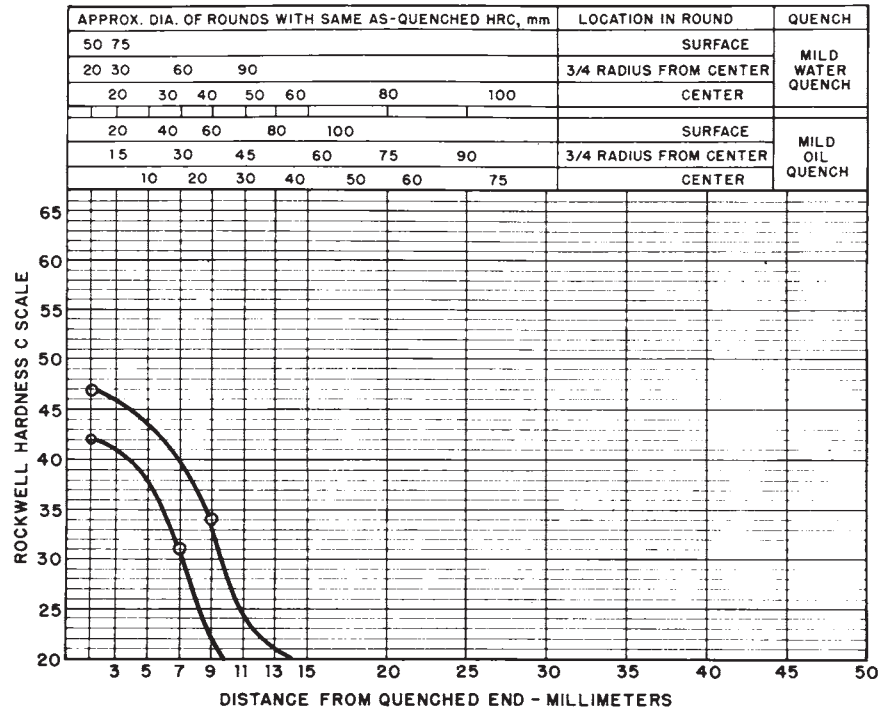


FIG. 2 Limits for Hardenability Band 15B21 RH

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HARDENABILITY BAND 15B35 RH

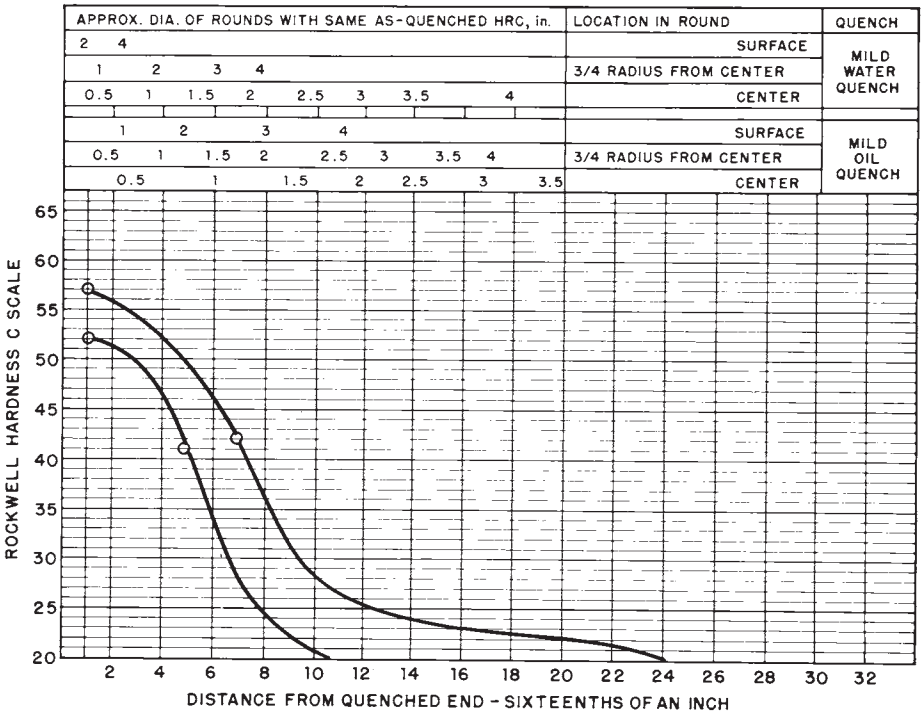
%C	%Mn	%Si	%Ni	%Cr	%Mo	%B
0.33/0.38	0.80/1.10	0.15/0.35	--	--	--	*

* can be expected to contain 0.0005/0.003 percent boron.

HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE SIXTEENTHS OF AN INCH	HRC	
	MAX.	MIN.
1	(57)	(52)
2	55	51
3	54	50
4	53	49
5	50	(41)
6	46	33
7	(42)	28
8	36	24
9	32	23
10	28	21
11		
12	25	--
13		
14	24	--
15		
16	23	--
18		
20	22	--
22		
24	20	--
26		
28	--	--
30		
32		

HEAT TREATING TEMPERATURES	
*NORMALIZE	1600 °F
AUSTENITIZE	1550 °F

*For forged or rolled specimens only



HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE MILLIMETERS	HRC	
	MAX.	MIN.
1.5	(57)	(52)
3	55	51
5	54	50
7	51	47
9	46	(37)
11	(42)	28
13	35	24
15	30	21
20	25	--
25	23	--
30	22	--
35	21	--
40	20	--
45		
50		

HEAT TREATING TEMPERATURES	
*NORMALIZE	870 °C
AUSTENITIZE	845 °C

*For forged or rolled specimens only

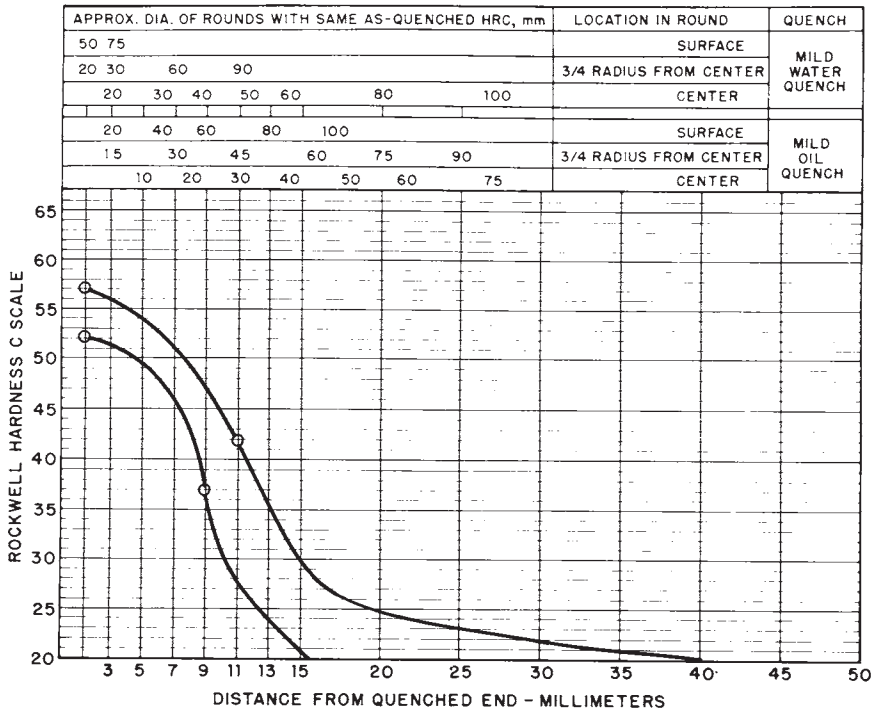


FIG. 3 Limits for Hardenability Band 15B35 RH

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HARDENABILITY BAND 3310 RH

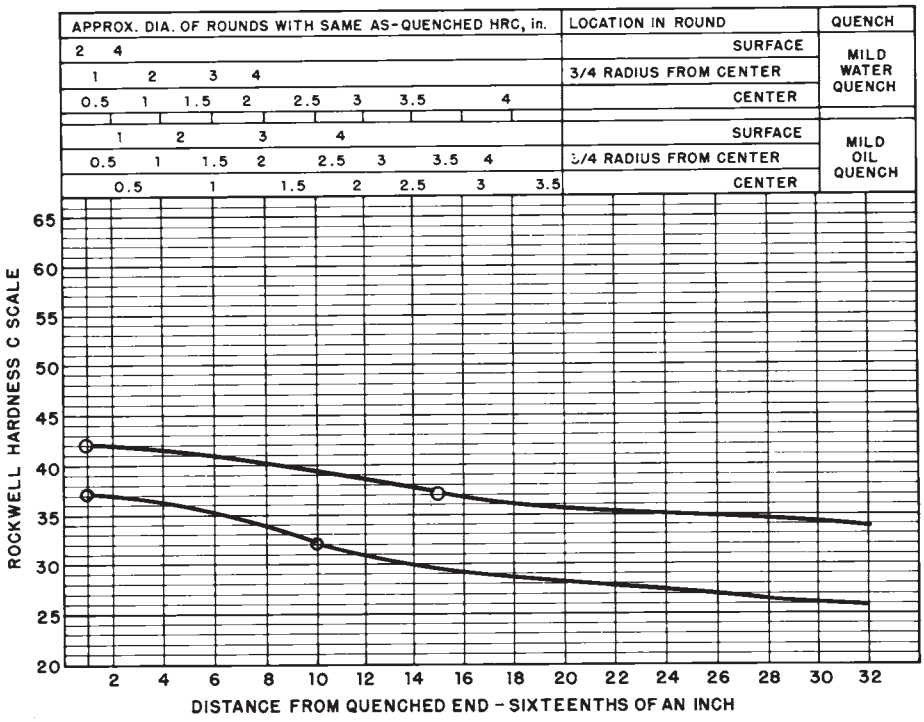
%C	%Mn	%Si	%Ni	%Cr	%Mo	
0.08/0.13	0.40/0.60	0.15/0.35	3.25/3.75	1.40/1.75	--	

HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE SIXTEENTHS OF AN INCH	HRC MAX.	HRC MIN.
1	(42)	(37)
2	42	37
3	42	37
4	41	36
5	41	36
6	41	35
7	40	34
8	40	33
9	39	32
10	39	(32)
11	39	31
12	39	31
13	38	30
14	38	30
15	(37)	29
16	37	29
18	36	28
20	36	28
22	35	27
24	35	27
26	35	27
28	34	26
30	34	26
32	34	26

HEAT TREATING TEMPERATURES

*NORMALIZE 1700 °F
AUSTENITIZE 1550 °F

*For forged or rolled specimens only



HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE MILLIMETERS	HRC MAX.	HRC MIN.
1.5	(42)	(37)
3	42	37
5	42	37
7	41	36
9	41	35
11	40	34
13	40	33
15	39	(32)
20	38	30
25	(37)	29
30	36	28
35	35	27
40	35	27
45	34	26
50	34	26

HEAT TREATING TEMPERATURES

*NORMALIZE 925 °C
AUSTENITIZE 845 °C

*For forged or rolled specimens only

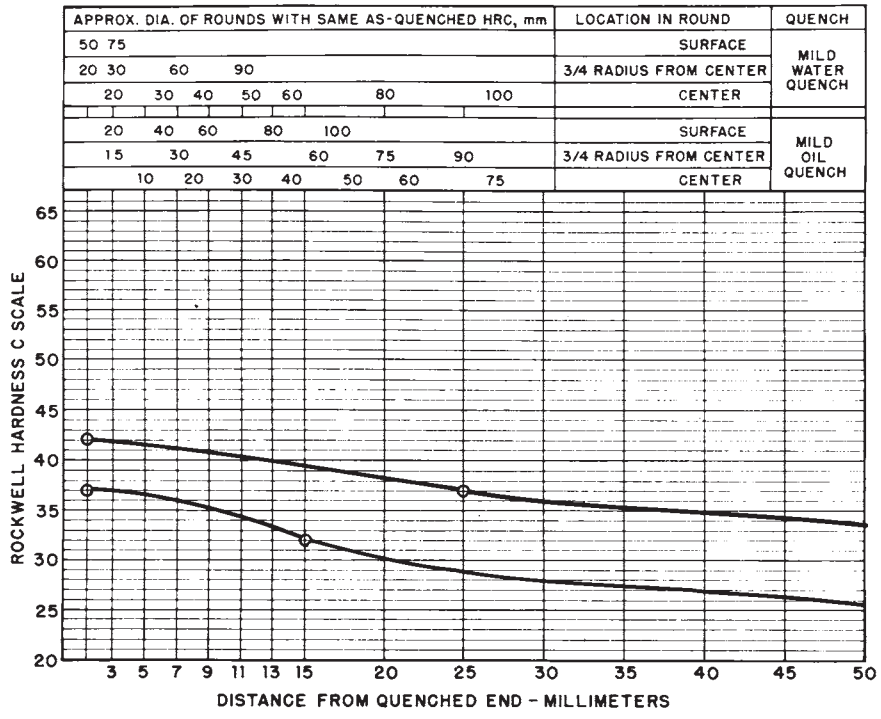


FIG. 4 Limits for Hardenability Band 3310 RH

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HARDENABILITY BAND 4027 RH

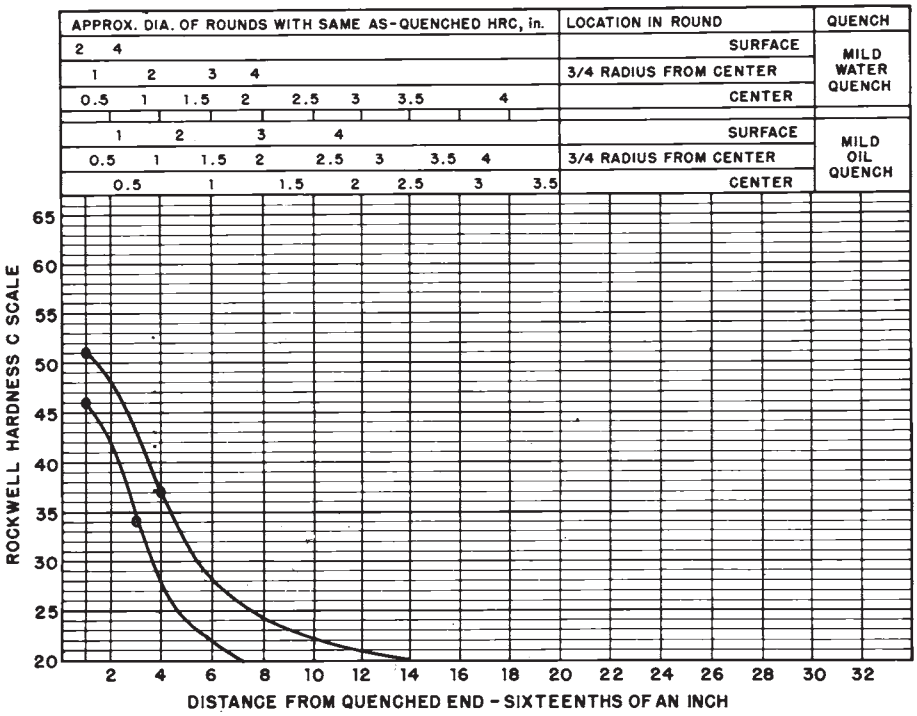
%C	%Mn	%Si	%Ni	%Cr	%Mo	
0.25/0.30	0.70/0.90	0.15/0.35	--	--	0.20/0.30	

HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE SIXTEENTHS OF AN INCH	HRC	
	MAX.	MIN.
1	(51)	(46)
2	48	42
3	43	(34)
4	(37)	28
5	32	24
6	28	22
7	26	20
8	24	--
9	23	--
10	22	--
11	22	--
12	21	--
13	21	--
14	20	--
15	--	--
16		
18		
20		
22		
24		
26		
28		
30		
32		

HEAT TREATING TEMPERATURES

*NORMALIZE	1650	°F
AUSTENITIZE	1600	°F

*For forged or rolled specimens only



HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE MILLIMETERS	HRC	
	MAX.	MIN
1.5	(51)	(46)
3	48	42
5	42	(33)
7	(35)	26
9	29	23
11	26	20
13	24	--
15	23	--
20	21	--
25	--	--
30		
35		
40		
45		
50		

HEAT TREATING TEMPERATURES

*NORMALIZE	900	°C
AUSTENITIZE	870	°C

*For forged or rolled specimens only

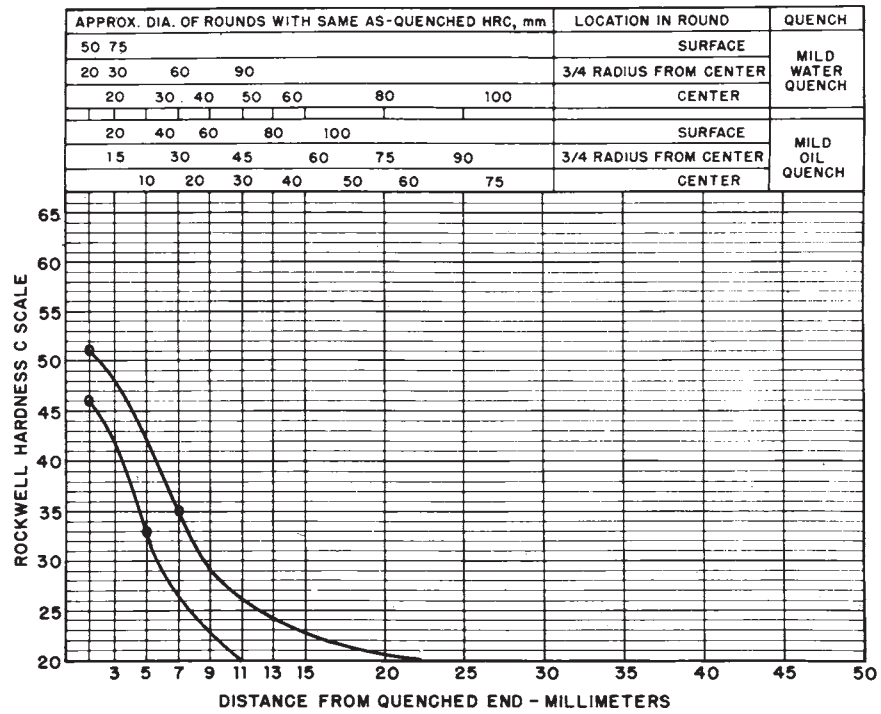


FIG. 5 Limits for Hardenability Band 4027 RH

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HARDENABILITY BAND 4118 RH

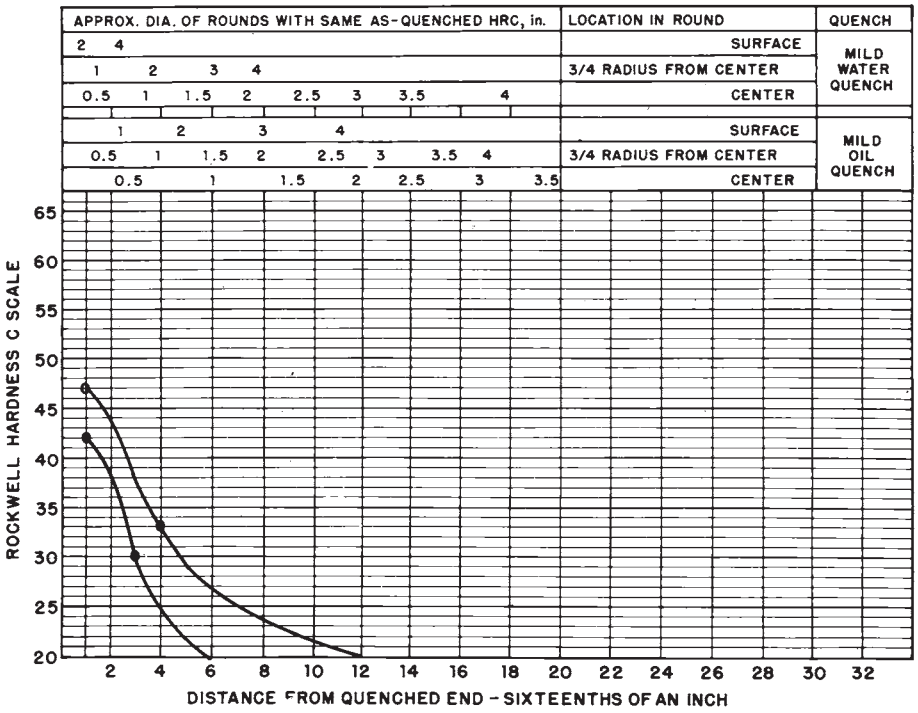
%C	%Mn	%Si	%Ni	%Cr	%Mo	
0.18/0.23	0.70/0.90	0.15/0.35	--	0.40/0.60	0.08/0.15	

HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE SIXTEENTHS OF AN INCH	HRC	
	MAX.	MIN.
1	(47)	(42)
2	44	38
3	38	(30)
4	(33)	25
5	29	22
6	27	20
7	25	--
8	24	--
9	23	--
10	22	--
11	21	--
12	20	--
13	--	--
14		
15		
16		
18		
20		
22		
24		
26		
28		
30		
32		

HEAT TREATING TEMPERATURES

*NORMALIZE	1700	°F
AUSTENITIZE	1700	°F

*For forged or rolled specimens only



HARDNESS LIMITS FOR SPECIFICATION PURPOSES		
"J" DISTANCE MILLIMETERS	HRC	
	MAX.	MIN.
1.5	(47)	(42)
3	44	38
5	37	(29)
7	(31)	24
9	28	21
11	25	20
13	24	--
15	23	--
20	20	--
25	--	--
30		
35		
40		
45		
50		

HEAT TREATING TEMPERATURES

*NORMALIZE	925	°C
AUSTENITIZE	925	°C

*For forged or rolled specimens only

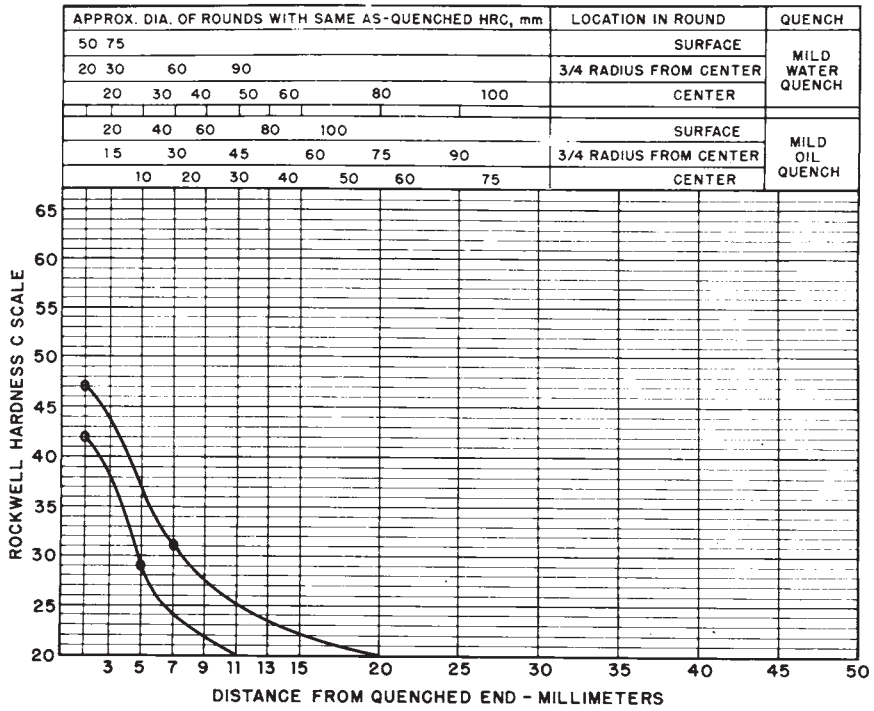


FIG. 6 Limits for Hardenability Band 4118 RH

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